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Neighborhood racial, ethnic, and income disparities in accessibility to multiple tobacco retailers: Mecklenburg County, North Carolina, 2015

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1. Introduction

Tobacco use remains the leading cause of preventable death in the United States (U.S.), causing more than 480,000 deaths annually (2014 Surgeon General's Report). Smoking is attributable to 8 of 10 COPD-related deaths (2014 Surgeon General's Report), and tobacco use contributes to 88% of lung cancers, the leading cause of cancer death for men and women (Siegel et al., 2015). It is estimated that there are 375,000 tobacco retailers in the U.S., or 27 tobacco retailers per every McDonalds restaurant (Point-of-Sale Report to the Nation, 2015). Exposure to tobacco retailers is not equitable across neighborhoods, with numerous studies documenting a greater concentration of tobacco retailers in neighborhoods with higher percentages of Black, Hispanic, and lower income individuals (Fakunle et al., 2010; Rodriguez et al., 2013; Andrew Hyland et al., 2003; Lee et al., 2017). The best available measures for place-based exposure to tobacco retail outlets are *density* and *proximity*, which are imperfect proxies for the *availability* and *accessibility* of tobacco products, respectively (Table 1).

Availability is a geographic construct that represents the actual supply of tobacco products (indicated by the number of tobacco retailers in a geographic area). However, **accessibility** indicates how easily a person residing in a geographic area can obtain the supply of tobacco products through a retailer. A person could live in a neighborhood that has a high count of tobacco retailers (high availability measured through *density*); however, this person may live far from these tobacco retailers (low accessibility measured through *proximity* to a tobacco retailer). We propose a new measure, *multi-retailer proximity,* which measures an individual's accessibility to not just one retail supply of tobacco products, but to multiple. In this way, it is a hybrid measure that can tell someone about *both* the potential availability of a supply, and how easily someone can get to this supply.

Tobacco retailer density is measured in several ways; most common measures include number of tobacco retailers per land area, per population, and per roadway (Mayers et al., 2012). In contrast, much of the literature assessing residential proximity only measures the distance from a sample of residences to the nearest *one* tobacco retailer (Frick and Castro, 2013; Young-Wolff et al., 2014; West et al., 2010; Henriksen et al., 2008; Cantrell et al., 2015). However, an ecological momentary assessment found that adult smokers have contact with an average of 2.7 tobacco retailers a day, (Kirchner et al., 2013) and studies on proximity to alcohol outlets typically measure average proximity to 5–9 retailers (Guide for Measuring Alcohol Outlet Density, 2017). Given that young adults (Shareck et al., 2016) and adults generally (Kirchner et al., 2013) are exposed to more than one tobacco retailer on a daily basis and do not always shop at the nearest retailer (Cannuscio et al., 2013), the traditional proximity measure to the single closest tobacco retailer may not fully capture actual variation in retailer accessibility or any association to tobacco use behaviors. Rather, a measure of *multi-retailer proximity* may be preferred.

Living close to or in places with a high number of retailers may decrease travel costs to obtain tobacco products (Schneider et al., 2005; Chaiton et al., 2018; Yu et al., 2010) and increase exposure to tobacco product marketing (Luke et al., 2017; Lee et al., 2015; Loomis et al., 2012), of which the tobacco industry spends more than $1 million an hour on in the retail environment (Federal Trade Commission Cigarette Report for 2015, 2017). In places with higher tobacco retailer density, individuals have higher cigarette smoking intentions (Cantrell et al., 2016), higher rates of smoking, initiation, or maintenance, (Cantrell et al., 2016; Kirchner et al., 2017; McCarthy et al., 2009; Pearce et al., 2009, 2016; Reitzel et al., 2011; Schleicher et al., 2016) and reduced smoking cessation (Reitzel et al., 2011; Halonen et al., 2014). Living near just a single tobacco retailer is associated with smoking more cigarettes per day (Chuang et al., 2005) and decreased smoking abstinence and cessation (Reitzel et al., 2011; Jaana et al., 2014). Furthermore, residential proximity to the nearest tobacco retailer is associated with decreased smoking abstinence (Lorraine et al., 2011). Lesser known is whether multi-retailer proximity impacts tobacco use behaviors and if there is a dose–response relationship between living

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Table 1
Summary of common measures of tobacco retailer exposure.

Measure	Description	Example	Considerations
Density	Measures the concentration, or **availability,** of retail tobacco supply in a geographic area.	In a 2012 nationally representative sample of tobacco retailers, there was an average density of 1.3 tobacco outlets per 1000 persons. Unadjusted models indicated that as proportion of Black residents in a census tract increased, tobacco retailer density also significantly increased (Lee et al., 2017).	Must define meaningful geographic area (e.g., census block, census tract). Neighborhood and thus measure is typically constrained by geographic administrative boundaries. May be sensitive to changes in population distribution in a neighborhood. While kernel density estimation may account for some of these limitations, advanced spatial methodological skills and sensitive model assumptions must be made (Carlos et al., 2010; Shi, 2010).
Proximity	Measures how easily one can obtain a retail tobacco product supply, or **accessibility.** Indicated by distance from a point of interest (i.e. residential address, school) to a tobacco retailer.	In a sample of adult daily smokers, participants living less than 500 meters from the closest tobacco retailer were significantly less likely to maintain smoking abstinence 6 months after a quit attempt (Reitzel et al., 2011).	Must define and have access to meaningful point of interest. Measure of distance between point of interest and nearest retailer may span geographic administrative boundaries, such as census blocks, tract, counties, etc. Must decide how to best measure proximity (e.g., Euclidean or 'as the crow flies' versus a roadway).

close to a certain number of retailers and tobacco use behaviors. A study in Canada found that individuals living within 250 meters of more than one tobacco retailer had a significantly lower odds of smoking abstinence and decreased time to smoking their first cigarette (Chaiton et al., 2014).

While several ecological studies have documented neighborhood demographic disparities in tobacco retailer density, (Peterson et al., 2010; Fakunle et al., 2010; Rodriguez et al., 2013; Andrew Hyland et al., 2003; Lee et al., 2017) we extend the literature by conducting the first study to examine whether there are associations of neighborhood-level race, ethnicity, and income with residential *multi-retailer proximity*. We capture multi-retailer proximity by spatially measuring the average road network distance from each residence to the nearest one, five, and ten tobacco retailers in a large U.S. urban area: Mecklenburg County, North Carolina (NC). By using a measure of multi-retailer proximity, we may inherently capture the residential availability of tobacco product supply *and* how accessible this supply is (based on distance) from each residence.

2. Materials and methods

2.1. Data sources

2.1.1. Tobacco retailer list

Neither the state of NC nor the federal government requires a tobacco retailer licensing system to monitor locations where tobacco products can be legally sold. In the absence of valid and reliable tobacco retailer licensing lists, several research studies have used data from the most recent 2012 U.S. Economic Census to determine what store types are likely to be tobacco retailers (Rodriguez et al., 2013; D'Angelo et al., 2014). The Economic Census reports the percent of retail tobacco sales by store type, and 10 store types (e.g., gasoline stations, convenience stores, supermarkets, beer/wine/liquor stores) made up approximately 99% of 2012 retail tobacco product sales. These 10 retail store types also made up 99% of retail alcohol product sales, indicating that there is much overlap between alcohol retailer and tobacco retailer store types. NC does have a state-wide list of alcohol retailers, which is used by the U.S. Food and Drug Administration (FDA) for retail tobacco compliance check inspections and by the NC Alcohol Law Enforcement Agency (ALE) for compliance checks of youth tobacco access policies. For these reasons, we started with the statewide ALE list, described elsewhere, (Myers et al., 2015) as our baseline sampling frame of tobacco retailers

Between 2012 and 2015, this list was updated quarterly by local and state public health practitioners as part of regular state health department operations. Staff visited retailers on the list and verified whether tobacco products were sold; additionally, staff would add tobacco retailers that were confirmed to sell tobacco products but may not have been on the original ALE list. Using this information from our community partners, we created a list of tobacco retailers that were verified in 2015. Finally, tobacco retailers in nearby neighboring counties were included in analyses to account for the possibility that people living close to the border of Mecklenburg County may also shop at or be exposed to tobacco retailers outside of these administrative county lines.

2.1.2. Residential addresses locations

Mecklenburg County is home to Charlotte, the 17th largest city in the U.S. (Charlotte Observer, 2014) with an estimated metropolitan population of nearly 2.5 million people (American Community Survey, 2015). We retrieved all 2015 geocoded residential and non-residential addresses in Mecklenburg County (N = 506,065) from the county's spatial analysis website (Open Mapping Mecklenburg County GIS, 2016). For each residential and non-residential address, we retrieved a geocoded latitude and longitude, or spatial point location. Then, residential addresses were identified by designated building-use codes. Designated building-use codes for residential addresses included single family residential, duplex/triplex, garden apartment, townhouse, townhouse apartment, condo, commercial condo, condo high rise, high-rise apartment, manufactured home, mobile home, and single-family resorts. Residences in multi-unit buildings (e.g., duplex/triplex, townhouse, apartments) were included as individual addresses. We removed non-residential addresses, which resulted in a total of 437,334 possible residential addresses in Mecklenburg County.

2.1.3. Sociodemographic variables

All neighborhood (i.e. census tract) sociodemographic population estimates were downloaded from the 2011–2015 5-Year American Community Survey (ACS) (American Community Survey, 2015). The 5-Year ACS represents a rolling average of population estimates between 2011 and 2015. While 1-year 2015 ACS estimates are available for public download, the Census Bureau recommends using 5-Year estimates when using small (i.e. census tract or smaller) geographic areas due to reliability and data availability issues (American Community Survey, 2015). Census tracts are administrative boundaries that vary in size and population (1200–8000 residents) and are most often used in neighborhoods and health research (Matthews and Yang, 2013; Diez-Roux, 2008; Arcaya et al., 2016). Tract-level demographic variables included percent non-Hispanic race (i.e. White, Black, Asian/Hawaiian

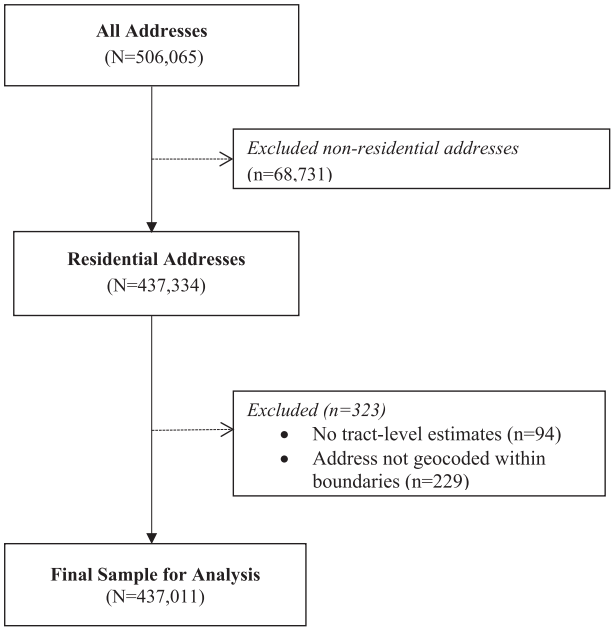

Fig. 1. Residential address sample identification in Mecklenburg County, North Carolina (2015).

or Other Pacific Islander [Asian/HPI]), percent Hispanic or Latino ethnicity, and median household income. Because there may be threshold effects, quintiles of each neighborhood demographic variable were created where for example, quintile 1 (Q1) represents the lowest 20% neighborhood median household income and quintile 5 (Q5) represents the highest 20% neighborhood median household income. Population density (total population per square mile of land) was also retrieved from the ACS and used as a control variable in the models described below.

2.2. Analysis

After mapping the geopoint location of residential addresses in ArcGIS 10.5, we then spatially joined neighborhood demographic quintile estimates to each residential address. To protect confidentiality, some ACS estimates are not available in geographic areas with a small total population, or those with a small population by demographic characteristics (three census tracts). In total, we were able to spatially join 437,011 residential addresses to neighborhood demographic characteristics, or 99.9% of all residences (Fig. 1).

2.2.1. Multi-retailer proximity

Using ArcGIS 10.5 and ESRI StreetMap Premium (a road network data source), we used the OD Cost Matrix spatial analysis tool to calculate the shortest road network distance from *each* residential address to the nearest one, five, and ten tobacco retailers. We did not force the spatial analysis tool to follow road rules (i.e. one-way streets, private roads, turn restrictions, illegal u-turns) as some individuals may walk or cycle on streets. Sensitivity analyses on a random sample of 10% of census tracts indicated a minimum Pearson's correlation of 0.996 when comparing distances calculated with and without road restrictions.

As other studies have demonstrated, measuring the distance from one point to another using a street network is preferable, as it may more accurately demonstrate likely travel patterns compared to measuring Euclidian distances, or a straight-line distance from one point to another (Oliver et al., 2007; Duncan et al., 2014). Fig. 2 conceptualizes how we measured road-network proximity to the nearest one tobacco retailer (Residence A) and average multi-retailer proximity to several tobacco retailers (Residence B). Notably, by measuring multi-retailer proximity (vs. density alone), we are able to include potential exposure to tobacco retailers outside of a residence's census tract in calculations. Multi-retailer proximity to the nearest five and ten tobacco retailers were averaged for each residential address. For descriptive statistics, we averaged the distances from each residential address to the nearest one, five, and ten tobacco retailers by quintile of each neighborhood demographic variable.

2.2.2. Statistical modeling

Though our sample represents a census of residential addresses within Mecklenburg County, to increase statistical generalizability of associations to other similar counties, we tested associations of sociodemographic characteristics with residential multi-retailer proximity. To aid in interpretability, we fit linear random intercept multilevel models that included each sociodemographic variable separately, and we keep our estimates unstandardized. All models were fit using SAS 9.4 and controlled for tract population density (Eq. (1)).

$$\text{Proximity}_{ij} = \beta 0 + \beta 1 PopulationDensity_j + ...\beta_k Sociodemographics_j + r_{ij} + u_{0j} \quad (1)$$

The statistical model includes an additional random effect term, u_{0j}, which varies according to a normal distribution for each census tract. The ICC for distance to the nearest one tobacco retailer was 0.57, indicating that 57% of the variance in individual distance to the nearest retailer is attributable to between census tract differences. The random effect term accounts for the nesting of residences (i) within census tracts (j) so that estimates and standard errors are not biased due to individual observations being correlated within a neighborhood. Finally, we also fit a multivariable linear random intercept multilevel model that included all sociodemographic variables (except for quintile percent White).

3. Results

3.1. Multi-retailer proximity descriptives

In Mecklenburg County, there are 230 census tracts with population estimates. The average tract-level sociodemographic characteristics were as follows: percent White (48.5, SD = 28.3), percent Black (31.7, SD = 24.3), percent Asian/HPI (5.0, SD = 5.5), percent Hispanic or Latino ethnicity (12.2, SD = 11.5), median household income ($62,454, SD = $30,880). For all residences (N = 437,011), the average distance to the nearest one, five, and ten retailers were 0.91 (SD = 0.71), 1.23 (SD = 0.80), and 1.68 (SD = 0.94) miles, respectively.

As seen in Fig. 3, individuals living in neighborhoods with the lowest proportion (Q1) of White people were on average 0.60 miles away from a single retailer while those living in neighborhoods with the highest proportion (Q5) of White people were on average 1.11 miles away from a single tobacco retailer. Those living in neighborhoods with the highest proportion of all other races/ethnicity were less than a mile away from a single retailer (Q5 Black = 0.65 miles; Q5 Hispanic = 0.74 miles; Q5 Asian/HPI = 0.86 miles). In general, as neighborhood quintile of White residents increases, so did multi-retailer proximity. In contrast, as neighborhood quintile of Black residents increases, multi-retailer proximity decreased, or individuals in these neighborhoods lived closer to multiple tobacco retailers. A similar trend is observed for neighborhood quintile of Hispanic or Latino ethnicity. No obvious upward or downward trends were observed as quintile of Asian/HPI increased.

We also observed strong positive trends between neighborhood median household income and multi-retailer proximity. While those living in the lowest income neighborhoods (Q1 = $15,382–33,873) were less than half a mile away from a single tobacco retailer, those in the highest income areas were over a mile away. By measuring multi-retailer proximity, we also find that those living in the lowest income neighborhoods were on average closer to 10 tobacco retailers (0.88 miles) than people in the three higher income neighborhood quintiles

Fig. 2. Example of calculating road-network proximity to the nearest one tobacco retailer (Residence A) and average multi-retailer proximity to the nearest ten tobacco retailers (Residence B).

were to just a single tobacco retailer (Q3 = 0.94 miles; Q4 = 1.07 miles; Q5 = 1.25 miles).

3.2. Random intercept multilevel models

Next, we fit mixed effects regression models that accounted for the nesting of residences within census tracts.

3.2.1. Univariate models

Compared to the highest income neighborhoods (Q5), lower income neighborhoods (Q1–Q4) were significantly closer to tobacco retailers (Table 2). This effect is amplified for those in the lowest income neighborhood (Q1). Compared to those living in the highest income areas, those living in the lowest income neighborhood were on average 0.67 miles (SE = 0.09, $p < 0.001$) closer to a single tobacco retailer; additionally, they were 0.83 (SE = 0.11) and 1.08 (SE = 0.13) miles closer to five and ten tobacco retailers ($p < 0.001$). We confirm our descriptive results that neighborhoods with a higher proportion (Q1–Q4) of White residents were farther from tobacco retailers compared to those living in neighborhoods with the lowest proportion of White residents (Q1). Compared to those living in neighborhoods with the lowest proportion of Black people, we found that only those living in neighborhoods with the highest proportion of Black people (Q5 = 51.8–94.1%) were significantly closer to not just one (B = -0.43, SE = 0.10), but also five (B = -0.50, SE = 0.11) and ten (B = -0.68, SE = 0.14) tobacco retailers, representing about just a 10-minute walk. Finally, residences in Q2 (3.5–5.8%) of Hispanic or Latino residents were slightly farther away from multiple tobacco retailers compared to those living in Q1 (0–3.4%). No significant trends were documented for quintile Asian/HPI.

3.2.2. Multivariable models

We also fit a single multivariable model that included all area demographic variables, except for quintile percent White (as this would include nearly 100% of the population). Consistent with the univariate models, we found that residents living in all lower income neighborhoods (Q1–Q4) lived significantly closer to one, five, and ten tobacco retailers compared to those living in the highest income neighborhoods (Table 2). This disparity was stronger than those in univariate models. Interestingly, some models also indicated that quintiles with a greater proportion of Black residents (compared to lowest) were *farther* away from tobacco retailers. We investigated this further and found that correlations between quintile percent Black and quintile median household income were high (Cramer's V = 0.40) (Kim, 2017). Therefore, the quintile income and percent Black effects are not truly isolated from one another, and caution should be taken when trying to interpret estimates, and any causal associations, in isolation of one other.

4. Discussion

Consistent with previous literature, our study replicates racial, ethnic, and income disparities in retailer density of tobacco retailers. As we present a census of data and due to the correlation of sociodemographics indicated earlier, we focus our discussion on the univariate models. We found that those living in lower income and more minority neighborhoods may have even greater accessibility to and risk of tobacco retailer exposure than previously documented.

While tobacco retailer density measures give information about the availability of tobacco retailers within an area, they do not traditionally consider whether people live close to or can easily access tobacco retail outlets. Existing studies that assess proximity to tobacco retailers typically only measure distance to the nearest *single* retailer, (Cantrell et al., 2015; Frick and Castro, 2013; Henriksen et al., 2008; West et al., 2010; Young-Wolff et al., 2014) even though adult smokers have contact with multiple tobacco retailers a day, with up to an average of 13 contacts in one study (Kirchner et al., 2013). Some researchers have called for the importance of assessing accessibility to multiple retailers in an effort to better assess potential accessibility (Apparicio et al., 2008; Chaiton et al., 2014; Duncan et al., 2014; Shareck et al., 2016). For example,

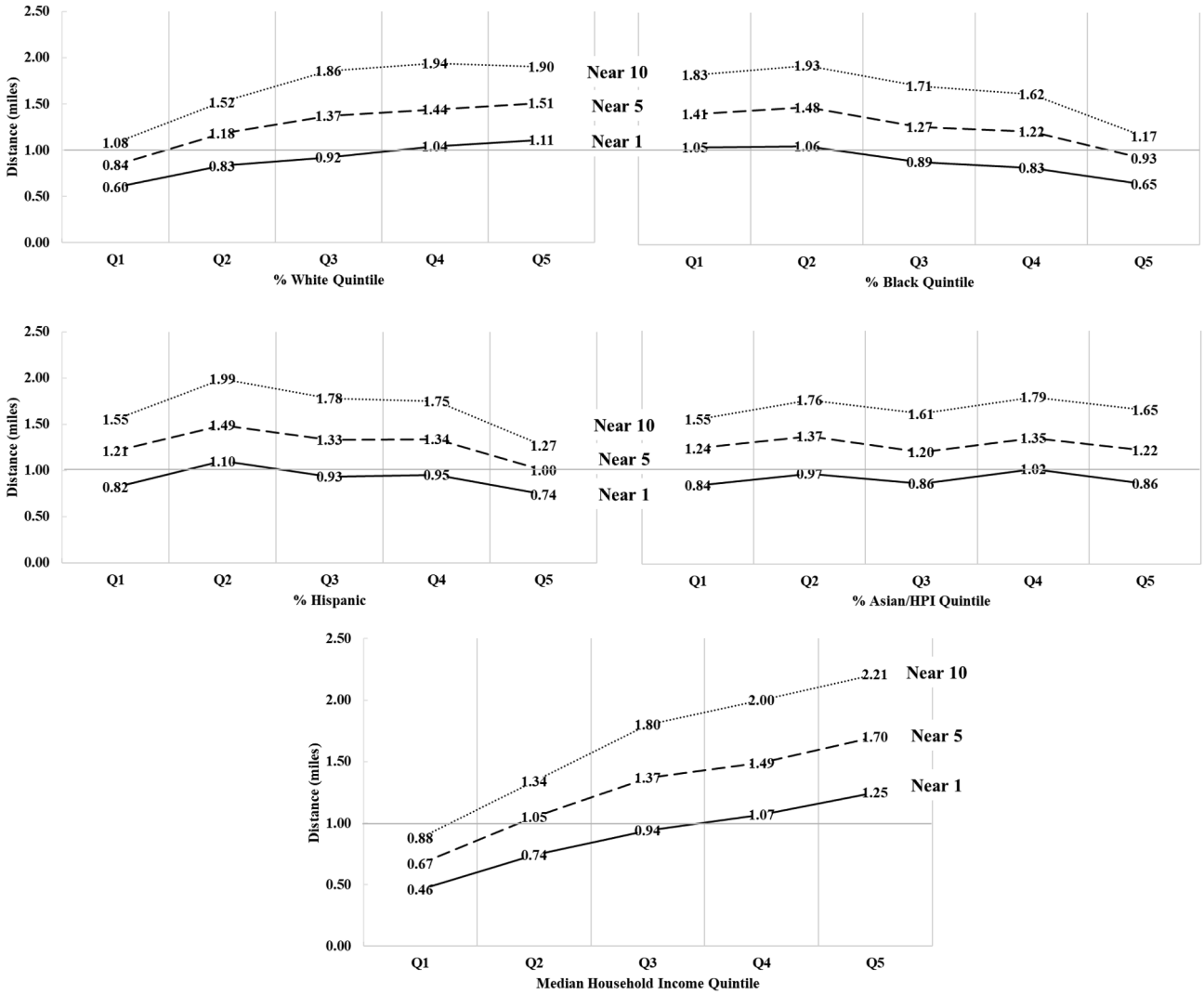

Fig. 3. Average multi-retailer proximity (miles) by census tract demographic quintile, Mecklenburg County, North Carolina, 2015 (N = 437,011).

one study found that as smokers came into contact with more retailers in a day, they had a lower odds of quitting, (Kirchner et al., 2013) suggesting that only assessing the closest retailer to one's residence may not be the strongest correlate of tobacco use behaviors. Preferred retailers may be beyond the nearest option, rather they may be retailers with the easiest shopping experience, those that carry the preferred tobacco products, have the fastest check-out lines, or those that are in a more convenient or safer location.

In our study, we found that proximity to the nearest tobacco retailer decreased as the neighborhood proportion of Black and Hispanic or Latino residents increased, which is similar to other studies assessing the density of tobacco retail outlets (Lee et al., 2017; Peterson et al., 2011; Novak et al., 2006). However, we also found this trend to be true for multi-retailer proximity. Univariate mixed effects models assessing neighborhood proportion of Black residents indicated that only neighborhoods with the highest proportion of Black residents (compared to lowest) were significantly closer to multiple tobacco retailers, indicating that those living in these neighborhoods may have a disparate increased accessibility to tobacco retailers. In contrast, we found that as the neighborhood proportion of White residents increased, average distance to tobacco retailers also significantly increased. By measuring multi-retailer proximity, we also documented that residences in the lowest neighborhood quintile of percent White were as close to *ten* tobacco retailers (1.08 miles) as those in the highest neighborhood quintile of percent White were to just a *single* retailer (1.11 miles). Given that White adults (15.0%) have higher smoking prevalence than both Black (14.6%) and Hispanic (9.8%) adults, (Centers for Disease Control & Prevention, 2018) these disparate findings indicate that the higher documented availability and accessibility of tobacco retailers may perhaps actually be supplier-driven (i.e. tobacco retailers are disproportionately locating in neighborhoods with a greater proportion of Black or Hispanic or Latino residents), rather than demand-driven.

We also observed large disparities in multi-retailer proximity by median household income. Residences in neighborhoods in the lowest income quintile were on average closer to ten retailers (0.88 miles) than those residing in the highest income quintile were to just a single retailer (1.25 miles). Mixed effects models indicated that those in the lowest income neighborhoods were over a mile closer to ten retailers compared to those in the highest income areas. This was the greatest disparity in multi-retailer proximity observed in our study and is consistent with other literature that has documented socioeconomic disparities in tobacco retailer density (Lee et al., 2017; Peterson et al., 2011; Novak et al., 2006; Chaiton et al., 2013). Given that low socioeconomic persons have higher smoking rates, less success at quitting smoking, and disproportionately worse smoking-related disease and outcomes (Garrett et al., 2015), greater attention to how accessibility to *multiple* tobacco retailers in lower income neighborhoods may impact tobacco use behaviors and related health outcomes is warranted.

A 2012 national study found that tobacco retailers have an average of 29.5 tobacco marketing materials, such as branded displays or signs,

Table 2
Associations of census tract demographic quintiles with multi-retailer proximity, Mecklenburg County, North Carolina, 2015 (N = 437,011).

	Univariate Models						Multivariable Models					
	Near 1		Near 5		Near 10		Near 1		Near 5		Near 10	
	B (SE)		B (SE)		B (SE)		B (SE)		B (SE)		B (SE)	
Median household income												
Q1 ($15,382–33,873)	−0.67 (0.09)	***	−0.83 (0.11)	***	−1.08 (0.13)	***	−0.83 (0.13)	***	−1.10 (0.16)	***	−1.41 (0.19)	***
Q2 (33,874–49,588)	−0.48 (0.09)	***	−0.59 (0.11)	***	−0.80 (0.13)	***	−0.71 (0.12)	***	−0.92 (0.14)	***	−1.22 (0.17)	***
Q3 (49,589–67,336)	−0.37 (0.09)	***	−0.39 (0.11)	***	−0.48 (0.13)	***	−0.53 (0.10)	***	−0.66 (0.12)	***	−0.84 (0.15)	***
Q4 (67,337–85,918)	−0.19 (0.09)	***	−0.19 (0.11)		−0.17 (0.13)		−0.29 (0.10)	**	−0.37 (0.11)	**	−0.43 (0.14)	**
Q5 (85,919-$190,104) *ref*	–		–		–		–		–		–	
White												
Q1 (0.9%-19.4) *ref*	–		–		–							
Q2 (19.5–36.9)	0.16 (0.10)		0.24 (0.12)	*	0.33 (0.14)	*						
Q3 (37.0–59.3)	0.20 (0.10)	*	0.35 (0.12)	**	0.57 (0.14)	***						
Q4 (59.4–80.4)	0.38 (0.10)	***	0.47 (0.12)	***	0.70 (0.14)	***						
Q5 (80.5–96.1%)	0.38 (0.10)	***	0.48 (0.12)	***	0.60 (0.14)	***						
Black												
Q1 (0.5%-7.0) *ref*	–		–		–		–		–		–	
Q2 (7.1–19.8)	0.00 (0.10)		0.06 (0.11)		0.07 (0.14)		0.12 (0.09)		0.24 (0.11)	*	0.30 (0.14)	*
Q3 (19.9–36.9)	−0.15 (0.10)		−0.11 (0.11)		−0.08 (0.14)		0.18 (0.11)		0.35 (0.13)	**	0.54 (0.16)	***
Q4 (37.0–51.7)	−0.11 (0.10)		−0.02 (0.11)		0.00 (0.14)		0.24 (0.11)	*	0.46 (0.13)	***	0.65 (0.16)	***
Q5 (51.8–94.1%)	−0.43 (0.10)	***	−0.50 (0.11)	***	−0.68 (0.14)	***	0.13 (0.13)		0.24 (0.15)		0.32 (0.18)	
Asian/HPI												
Q1 (0.0%-1.2) *ref*	–		–		–		–		–		–	
Q2 (1.3–2.7)	0.09 (0.10)		0.1 (0.12)		0.18 (0.15)		0.02 (0.09)		−0.02 (0.11)		0.01 (0.13)	
Q3 (2.8–4.4)	0.11 (0.10)		0.08 (0.12)		0.19 (0.15)		−0.01 (0.09)		−0.10 (0.11)		−0.06 (0.13)	
Q4 (4.5–7.5)	0.21 (0.10)	*	0.15 (0.12)		0.27 (0.15)		0.11 (0.09)		0.01 (0.11)		0.08 (0.13)	
Q5 (7.6–48.6%)	0.14 (0.10)		0.13 (0.12)		0.28 (0.15)		0.03 (0.09)		−0.03 (0.11)		0.05 (0.13)	
Hispanic or Latino												
Q1 (0.0%-3.4) *ref*	–		–		–							
Q2 (3.5–5.8)	0.23 (0.10)	*	0.25 (0.12)	*	0.39 (0.15)	**	0.16 (0.09)		0.15 (0.10)		0.25 (0.12)	*
Q3 (5.9–10.7)	0.07 (0.10)		0.10 (0.12)		0.22 (0.15)		0.07 (0.09)		0.09 (0.11)		0.17 (0.13)	
Q4 (10.8–20.8)	0.11 (0.10)		0.14 (0.12)		0.21 (0.15)		0.23 (0.09)	*	0.26 (0.11)	*	0.35 (0.13)	**
Q5 (20.9–61.9%)	0.03 (0.10)		−0.01 (0.12)		−0.04 (0.15)		0.24 (0.10)	*	0.21 (0.12)		0.22 (0.14)	

Note: All models control for census tract population density and account for the nesting of individuals within census tracts through a random intercept. Multivariable models include all variables, except for quintile percent White. *p < 0.05, **p < 0.01, ***p < 0.001.

and 75% of retailers had at least one tobacco product price promotion (Ribisl et al., 2017). Tobacco industry documents show that the industry has used marketing to influence tobacco use behaviors (Ling and Glantz, 2002) and this marketing has been targeted in neighborhoods with more racial and ethnic minorities (Yerger et al., 2007; Lee et al., 2015). Furthermore, exterior or store-front marketing has been documented in more minority and lower income neighborhoods (Lee et al., 2015; Laws et al., 2002). People living in close proximity to a high number of tobacco retailers may also see a high amount of tobacco marketing, even if they are not entering the store. Furthermore, residents living near multiple tobacco retailers may also observe more people purchasing and using tobacco products, thereby normalizing and cueing tobacco use behaviors. These cues to smoke could increase cravings and undermine quit attempts, encouraging relapse behavior among smokers (Reitzel et al., 2011).

Future research is needed to document whether an increasing number of tobacco retailers near a residence (and even other anchor points, such as a school or work locations) influences tobacco use behaviors. It seems plausible that there may be a dose–response relationship in which being close to several tobacco retailers may have a differential impact on tobacco use behaviors than just being close to a single retailer. Studies that have not found significant associations when measuring proximity to the nearest single retailer may consider extending traditional proximity measures to include other retailers that are near an anchor point. If certain groups are disproportionately closer to a higher number of tobacco retailers than other groups, this could have implications for explaining some observed tobacco-related health disparities. Studies that have only calculated distance to the nearest one retailer may be potentially underestimating these differences.

Finally, given the associations of tobacco retailer exposure (both density and proximity) on tobacco use behaviors, our study demonstrates the importance of tobacco control policies that can decrease the multi-retailer proximity of tobacco retailers in residential areas, especially in neighborhoods with more minority and lower income residents. A North Carolina simulation study found that a policy that creates a 500-foot retailer proximity restriction, or that tobacco retailers cannot be within 500 feet of each other, could reduce tobacco retailer density by 22.1% (Myers et al., 2015). An additional study conducted in Missouri and New York found that prohibiting tobacco retailers from operating within 1000 feet of schools could also reduce neighborhood income and racial disparities in tobacco retailer density (Ribisl et al., 2017). For example, researchers found that prior to a ban, retailer density per 1000 population was 1.28 in the lowest income neighborhoods and 0.84 in the highest income neighborhoods. However, after a ban was implemented, retailer density dropped to 0.36 and 0.45 in the lowest and highest income areas, respectively, and similar trends were observed by proportion of African Americans in a neighborhood (Ribisl et al., 2017). Retailer reduction policies such as these may limit or decrease both the density, multi-retailer proximity, and clustering of tobacco retailers close to residences, and may have a pro-equity effect for those located in more vulnerable neighborhoods. As previously noted, not all states require tobacco retailer licensing, and establishing a licensing system is a strong first step toward being able to design and implement retailer reduction strategies (Tobacco Retailer Licensing Playbook, 2018; Ackerman et al., 2017). Licensing allows governments to regulate who can sell tobacco while also being able to limit the number and locations of tobacco retailers (Tobacco Retailer Licensing Playbook, 2018) which could decrease multi-retailer proximity.

Some limitations of this study should be noted. Geocoded addresses

were provided by the Mecklenburg County government, and there is the possibility that there were positional errors, leading to inaccurate multi-retailer proximity calculations. While we used the best available data to create a tobacco retailer list with local community partners, it is plausible that our list omitted some tobacco retailers that were either not on the original ALE list and/or were not ground-truthed during regular state health department operations. However, we have no reason to believe that this would be systematic and thus, for the purposes of demonstrating the use of multi-retailer proximity to measure area disparities, we believe these data were still valid and that our results are not biased. While our study sample is limited to residences in Mecklenburg County, a strength of this study is that we are using a census of residential addresses, so the associations documented represent the true population in Mecklenburg. We also conducted inferential statistics, which may increase statistical generalizability of findings to similar counties; however, we caution readers when interpreting the results of the multivariable model as marginal effects, as there is high correlation between sociodemographics in our study area (and likely others). While our statistical models account for correlations of individuals *within* census tracts, there may be spatial autocorrelation of individuals *between* census tracts. Recent studies have discussed the potential need to fit models that account for both within- and between-tract correlations; however, there is no gold standard model at this time to account for these correlations, or agreement if this is statistically necessary or efficient (Chaix et al., 2005; Xu, 2014; Park and Kim, 2014). These studies do indicate that fixed effects are consistent whether accounting for within-, between-, or both correlations, but standard errors may be underestimated in some model types (Chaix et al., 2005; Xu, 2014; Park and Kim, 2014). For purposes of demonstrating how to calculate multi-retailer proximity, we did not weight the distance of each tobacco retailer to a residence (i.e. those retailers that are closer to an individual may be weighted more heavily); future studies may want to consider incorporating this into distance calculations. Finally, while we operationalized neighborhoods as census tracts, other neighborhood definitions may also be appropriate (eg, census blocks) (Duncan et al., 2014)

5. Conclusions

Our study demonstrates that there are racial, ethnic, and income disparities in multi-retailer proximity to tobacco retailers. By measuring road network proximity to more than one retailer, we propose a promising measure that may better assess potential accessibility to *multiple* retail supplies of tobacco products. Furthermore, this methodology may be applicable to other fields and studies, such as measuring multi-retailer proximity to food and alcohol retailers.

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Conflict of Interest

AE Myers, LF Isgett and KM Ribisl receive royalties from the dissemination of Counter Tools' software applications, including the North Carolina Store Mapper tool, which was used to retrieve a list of tobacco retail outlets for this study. KM Ribisl serves as an expert consultant in litigation against tobacco companies.

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References

Ackerman, A., Etow, A., Bartel, S., Ribisl, K.M., 2017. Reducing the density and number of tobacco retailers: policy solutions and legal issues. Nicotine Tob. Res. 19 (2), 133–140. https://doi.org/10.1093/ntr/ntw124.

Andrew Hyland, M.J.T., Michael Cummings, K., Bauer, Joseph, Alford, Terry, Wieczorek, William F., 2003. Tobacco outlet density and demographics in Erie County, New York. Am. J. Public Health 93 (7).

Apparicio, P., Abdelmajid, M., Riva, M., Shearmur, R., 2008. Comparing alternative approaches to measuring the geographical accessibility of urban health services: distance types and aggregation-error issues. Int. J. Health Geogr. 7, 7. https://doi.org/10.1186/1476-072X-7-7.

Arcaya, M.C., Tucker-Seeley, R.D., Kim, R., Schnake-Mahl, A., So, M., Subramanian, S.V., 2016. Research on neighborhood effects on health in the United States: a systematic review of study characteristics. Soc. Sci. Med. 168, 16–29. https://doi.org/10.1016/j.socscimed.2016.08.047.

American Community Survey, 2015. Washington, DC: United States Census Bureau. Retrieved from: https://www.census.gov/programs-surveys/acs/guidance/estimates.html. Accessed January 5, 2018.

Cannuscio, C.C., Tappe, K., Hillier, A., Buttenheim, A., Karpyn, A., Glanz, K., 2013. Urban food environments and residents' shopping behaviors. Am. J. Prev. Med. 45 (5), 606–614. https://doi.org/10.1016/j.amepre.2013.06.021.

Cantrell, J., Anesetti-Rothermel, A., Pearson, J.L., Xiao, H., Vallone, D., Kirchner, T.R., 2015. The impact of the tobacco retail outlet environment on adult cessation and differences by neighborhood poverty. Addiction 110 (1), 152–161. https://doi.org/10.1111/add.12718.

Cantrell, J., Pearson, J.L., Anesetti-Rothermel, A., Xiao, H., Kirchner, T.R., Vallone, D., 2016. Tobacco retail outlet density and young adult tobacco initiation. Nicotine Tob. Res. 18 (2), 130–137. https://doi.org/10.1093/ntr/ntv036.

Chaiton, M.O., Mecredy, G.C., Cohen, J.E., Tilson, M.L., 2013. Tobacco retail outlets and vulnerable populations in Ontario, Canada. Int. J. Environ. Res. Public Health 10 (12), 7299–7309. https://doi.org/10.3390/ijerph10127299.

Chaiton, M., Mecredy, G., Rehm, J., Samokhvalov, A.V., 2014. Tobacco retail availability and smoking behaviours among patients seeking treatment at a nicotine dependence treatment clinic. Tob. Induc. Dis. 12 (19), 1–5. http://www.tobaccoinduceddiseases.com/content/12/1/19.

Carlos, H.A., Shi, X., Sargent, J., Tanski, S., Berke, E.M., 2010. Density estimation and adaptive bandwidths: a primer for public health practitioners. Int. J. Health Geogr. 9. https://doi.org/10.1186/1476-072X-9-39.

Chaiton, M.O., Mecredy, G., Cohen, J., 2018. Tobacco retail availability and risk of relapse among smokers who make a quit attempt: a population-based cohort study. Tob. Control 27 (2), 163–169. https://doi.org/10.1136/tobaccocontrol-2016-053490.

Charlotte is now the 17th largest US city and growing faster than Austin, 2014. Charlotte Observer; Charlotte, NC. Retrieved from https://www.charlotteobserver.com/charlottefive/c5-around-town/article236136178.html#storylink=cpy.

Chaix, B., Merlo, J., Chauvin, P., 2005. Comparison of a spatial approach with the multilevel approach for investigating place effects on health: the example of healthcare utilisation in France. J. Epidemiol. Community Health 59 (6), 517–526. https://doi.org/10.1136/jech.2004.025478.

Chuang, Y.C., Cubbin, C., Ahn, D., Winkleby, M.A., 2005. Effects of neighbourhood socioeconomic status and convenience store concentration on individual level smoking. J Epidemiol. Community Health 59 (7), 568–573. https://doi.org/10.1136/jech.2004.029041.

D'Angelo, H., Fleischhacker, S., Rose, S.W., Ribisl, K.M., 2014. Field validation of secondary data sources for enumerating retail tobacco outlets in a state without tobacco outlet licensing. Health Place 28, 38–44. https://doi.org/10.1016/j.healthplace.2014.03.006.

Diez-Roux, A.V., 2008. Neighborhoods and health: where are we and were do we go from here? Revue d'Épidémiologie et de Santé Publique. 55 (1), 13–21. https://doi.org/10.1016/j.respe.2006.12.003.

Duncan, D.T., Kawachi, I., Subramanian, S.V., Aldstadt, J., Melly, S.J., Williams, D.R., 2014. Examination of how neighborhood definition influences measurements of youths' access to tobacco retailers: a methodological note on spatial misclassification. Am. J. Epidemiol. 179, 373–381. https://doi.org/10.1093/aje/kwt251.

Fakunle, D., Morton, C.M., Peterson, N.A., 2010. The importance of income in the link between tobacco outlet density and demographics at the tract level of analysis in New Jersey. J. Ethn. Subst. Abuse. 9 (4), 249–259. https://doi.org/10.1080/15332640.2010.522890.

Current cigarette smoking among U.S. Adults aged 18 years and older. Atlanta, GA: Centers for Disease Control & Prevention; 2018. Retrieved from: https://www.cdc.gov/tobacco/campaign/tips/resources/data/cigarette-smoking-in-united-states.html. Accessed December 1, 2019.

Federal trade commission cigarette report for 2015. Washington, DC: Federal Trade Commission; 2017. Retrieved from: https://www.ftc.gov/system/files/documents/reports/federal-trade-commission-cigarette-report-2015-federal-trade-commission-smokeless-tobacco-report/2015_cigarette_report.pdf. Accessed March 2, 2018.

Frick, M., Castro, M.C., 2013. Tobacco retail clustering around schools in New York City: examining “place” and “space” Health Place 19, 15–24. https://doi.org/10.1016/j.healthplace.2012.09.011.
Guide for measuring alcohol outlet density. Atlanta, GA: Centers for Disease Control and Prevention; 2017 Accessed August 6, 2017.
Garrett, B.E., Dube, S.R., Babb, S., McAfee, T., 2015. Addressing the Social Determinants of Health to Reduce Tobacco-Related Disparities. Nicotine Tob. Res. 17 (8), 892–897. https://doi.org/10.1093/ntr/ntu266.
Halonen, J.I., Kivimaki, M., Kouvonen, A., et al., 2014. Proximity to a tobacco store and smoking cessation: a cohort study. Tob. Control 23 (2), 146–151. https://doi.org/10.1136/tobaccocontrol-2012-050726.
Henriksen, L., Feighery, E.C., Schleicher, N.C., Cowling, D.W., Kline, R.S., Fortmann, S.P., 2008. Is adolescent smoking related to the density and proximity of tobacco outlets and retail cigarette advertising near schools? Prev. Med. 47, 210–214. https://doi.org/10.1016/j.ypmed.2008.04.008.
Jaana, I., Halonen, M.K., Kouvonen, Anne, Pentti, Jaana, Ichiro Kawachi, S.V., Subramanian, J.V., 2014. Proximity to a tobacco store and smoking cessation: a cohort study. Tob. Control 23 (2), 146–151. https://doi.org/10.1136/tobaccocontrol-2012-050726.
Kim, H.Y., 2017. Statistical notes for clinical researchers: Chi-squared test and Fisher’s exact test. Restor. Dent. Endod. 42 (2), 152–155. https://doi.org/10.5395/rde.2017.42.2.152.
Kirchner, T.R., Cantrell, J., Anesetti-Rothermel, A., Ganz, O., Vallone, D.M., Abrams, D.B., 2013. Geospatial exposure to point-of-sale tobacco: real-time craving and smoking-cessation outcomes. Am. J. Prev. Med. 45 (4), 379–385. https://doi.org/10.1016/j.amepre.2013.05.016.
Kirchner, T.R., Anesetti-Rothermel, A., Bennett, M., et al., 2017. Tobacco outlet density and converted versus native non-daily cigarette use in a national US sample. Tob. Control. 26 (1), 85–91. https://doi.org/10.1136/tobaccocontrol-2015-052487.
Laws, M.B., Whitman, J., Bowser, D.M., Krech, L., 2002. Tobacco availability and point of sale marketing in demographically contrasting districts of Massachusetts. Tob. Control 11 (Suppl II), ii71–ii73. https://doi.org/10.1136/tc.11.suppl_2.ii71.
Lee, J.G.L., Henriksen, L., Rose, S.W., Moreland-Russell, S., Ribisl, K.M., 2015. A systematic review of neighborhood disparities in point-of-sale tobacco marketing. Am. J. Public Health 105, e8–e18. https://doi.org/10.2105/AJPH.2015.302777.
Lee, J.L., Henriksen, L., Rose, S.W., Moreland-Russell, S., Ribisl, K.M., 2015. A systematic review of neighborhood disparities in point-of-sale tobacco marketing. Am. J. Public Health 105 (9), e8–e18. https://doi.org/10.2105/ajph.2015.302777.
Lee, J.G., Sun, D.L., Schleicher, N.M., Ribisl, K.M., Luke, D.A., Henriksen, L., 2017. Inequalities in tobacco outlet density by race, ethnicity and socioeconomic status, 2012, USA: results from the ASPiRE Study. J. Epidemiol. Community. Health 71 (5), 487–492. https://doi.org/10.1136/jech-2016-208475.
Ling, Pamela M., Glantz, Stanton A., 2002. Why and How the Tobacco Industry Sells Cigarettes to Young Adults: Evidence From Industry Documents. Am. J. Public Health 92 (6), 908–916. https://doi.org/10.2105/ajph.92.6.908.
Loomis, B.R., Kim, A.E., Busey, A.H., Farrelly, M.C., Willett, J.G., Juster, H.R., 2012. The density of tobacco retailers and its association with attitudes toward smoking, exposure to point-of-sale tobacco advertising, cigarette purchasing, and smoking among New York youth. Prev. Med. 55 (5), 468–474. https://doi.org/10.1016/j.ypmed.2012.08.014.
Lorraine, R., Reitzel, E.K.C., Li, Yisheng, Cao, Yumei, Mater, Richard Dela, Mazas, Carlos A., Ludmila Cofta-Woerpel, P.M.C., Wetter, David W., 2011. The effect of tobacco outlet density and proximity on smoking cessation. Am. J. Public Health 101 (2), 315–320. https://doi.org/10.2105/AJPH.2010.191676.
Luke, D.A., Hammond, R.A., Combs, T., et al., 2017. Tobacco town: computational modeling of policy options to reduce tobacco retailer density. Am. J. Public Health 107 (5), 740–746. https://doi.org/10.2105/AJPH.2017.303685.
Matthews, S.A., Yang, T.C., 2013. Spatial polygamy and contextual exposures (SPACEs): promoting activity space approaches in research on place and health. Am. Behav. Sci. 57 (8), 1057–1081. https://doi.org/10.1177/0002764213487345.
Mayers, R.S., Wiggins, L.L., Fulghum, F.H., Peterson, N.A., 2012. Tobacco outlet density and demographics: a geographically weighted regression analysis. Prev. Sci. 13 (5), 462–471. https://doi.org/10.1007/s11121-011-0273-y.
McCarthy, W.J., Mistry, R., Lu, Y., Patel, M., Zheng, H., Dietsch, B., 2009. Density of tobacco retailers near schools: effects on tobacco use among students. Am. J. Public Health 99 (11), 2006–2013. https://doi.org/10.2105/AJPH.2008.145128).
Myers, A.E., Hall, M.G., Isgett, L.F., Ribisl, K.M., 2015. A comparison of three policy approaches for tobacco retailer reduction. Prev. Med. 74, 67–73. https://doi.org/10.1016/j.ypmed.2015.01.025.
Novak, S.P., Reardon, S.F., Raudenbush, S.W., Buka, S.L., 2006. Retail tobacco outlet density and youth cigarette smoking: a propensity-modeling approach. Am. J. Public Health 96, 670–676. https://doi.org/10.2105/AJPH.2004.061622.
Oliver, L.N., Schuurman, N., Hall, A.W., 2007. Comparing circular and network buffers to examine the influence of land use on walking for leisure and errands. Int. J. Health Geogr. 6, 41. https://doi.org/10.1186/1476-072X-6-41.
Open mapping Mecklenburg County GIS. Charlotte, NC: City of Charlotte and Mecklenburg County; 2016. Retrieved from: http://maps.co.mecklenburg.nc.us/openmapping/data.html.
Park, Y.M., Kim, Y., 2014. A spatially filtered multilevel model to account for spatial dependency: application to self-rated health status in South Korea. Int. J. Health Geogr. 13 (1), 6. https://doi.org/10.1186/1476-072X-13-6.
Pearce, J., Hiscock, R., Moon, G., Barnett, R., 2009. The neighbourhood effects of geographical access to tobacco retailers on individual smoking behaviour. J. Epidemiol. Community Health 63 (1), 69–77. https://doi.org/10.1136/jech.2007.070656.
Pearce, J., Rind, E., Shortt, N., Tisch, C., Mitchell, R., 2016. Tobacco retail environments and social inequalities in individual-level smoking and cessation among Scottish adults. Nicotine Tob. Res. 18 (2), 138–146. https://doi.org/10.1093/ntr/ntv089.
Peterson, N.A., Yu, D., Morton, C.M., Reid, R.J., Sheffer, M.A., Schneider, J.E., 2010. Tobacco outlet density and demographics at the tract level of analysis in New Jersey: a statewide analysis. Drugs Educ. Prev. Policy 18 (1), 47–52. https://doi.org/10.3109/09687630903514891.
Peterson, N.A., Yu, D., Morton, C.M., Reid, R.J., Ma, Sheffer, Schneider, J.E., 2011. Tobacco outlet density and demographics at the tract level of analysis in New Jersey: a statewide analysis. Drugs Educ. Prev. Policy 18, 47–52. https://doi.org/10.3109/09687630903514891.
Reitzel, L.R., Cromley, E.K., Li, Y., et al., 2011. The effect of tobacco outlet density and proximity on smoking cessation. Am. J. Public Health 101 (2), 315–320. https://doi.org/10.2105/ajph.2010.191676.
Ribisl, K.M., D'Angelo, H., Feld, A.L., et al., 2017. Disparities in tobacco marketing and product availability at the point of sale: results of a national study. Prev. Med. 105, 381–388. https://doi.org/10.1016/j.ypmed.2017.04.010.
Ribisl, K.M., Luke, D.A., Bohannon, D.L., Sorg, A.A., Moreland-Russell, S., 2017. Reducing disparities in tobacco retailer density by banning tobacco product sales near schools. Nicotine Tob. Res. 19 (2), 239–244. https://doi.org/10.1093/ntr/ntw185.
Rodriguez, D., Carlos, H.A., Adachi-Mejia, A.M., Berke, E.M., Sargent, J.D., 2013. Predictors of tobacco outlet density nationwide: a geographic analysis. Tob. Control. 22 (5), 349–355. https://doi.org/10.1136/tobaccocontrol-2011-050120.
Schleicher, N.C., Johnson, T.O., Fortmann, S.P., Henriksen, L., 2016. Tobacco outlet density near home and school: Associations with smoking and norms among US teens. Prev. Med. 91, 287–293. https://doi.org/10.1016/j.ypmed.2016.08.027.
Schneider, J.E., Reid, R.J., Peterson, N.A., Lowe, J.B., Hughey, J., 2005. Tobacco outlet density and demographics at the tract level of analysis in Iowa: implications for environmentally based prevention initiatives. Prev. Sci. 6 (4), 319–325. https://doi.org/10.1007/s11121-005-0016-z.
Shareck, M., Kestens, Y., Vallee, J., Datta, G., Frohlich, K.L., 2016. The added value of accounting for activity space when examining the association between tobacco retailer availability and smoking among young adults. Tob. Control 25 (4), 406–412. https://doi.org/10.1136/tobaccocontrol-2014-052194.
Shi, X., 2010. Selection of bandwidth type and adjustment side in kernel density estimation over inhomogeneous backgrounds. Int. J. Geogr. Inf. Sci. 24 (5), 643–660. https://doi.org/10.1080/13658810902950625.
Siegel, R.L., Jacobs, E.J., Newton, C.C., et al., 2015. Deaths due to cigarette smoking for 12 smoking-related cancers in the United States. JAMA Intern. Med. 175 (9), 1574–1576. https://doi.org/10.1001/jamainternmed.2015.2398.
Point-of-sale report to the nation: the tobacco retail and policy landscape. St. Louis, MO: Center for Public Health Systems Science at the Brown School at Washington University in St. Louis and the National Cancer Institute, State and Community Tobacco Control Research Initative; 2015. Retrieved from: https://cphss.wustl.edu/items/point-of-sale-report-to-the-nation-the-tobacco-retail/.
The health consequences of smoking—50 years of progress: a report of the surgeon general. Atlanta, GA: United States Department of Health and Human Services; 2014. Retrieved from: https://www.hhs.gov/surgeongeneral/reports-and-publications/tobacco/index.html. Accessed January 2, 2014.
Tobacco Retailer Licensing Playbook. Oakland, CA: ChangeLab Solutions; 2015. Retrieved from: https://www.changelabsolutions.org/sites/default/files/TRL_Playbook_FINAL_20150511.pdf. Accessed July 11, 2018.
West, J.H., Blumberg, E.J., Kelley, N.J., et al., 2010. Does proximity to retailers influence alcohol and tobacco use among Latino adolescents? J. Immigr. Minor. Health 12, 626–633. https://doi.org/10.1007/s10903-009-9303-2.
Xu, H., 2014. Comparing spatial and multilevel regression models for binary outcomes in neighborhood studies. Sociol. Methodol. 44 (1), 229–272. https://doi.org/10.1177/0081175013490188.
Yerger, V.B., Przewoznik, J., Malone, R.E., 2007. Racialized Geography, Corporate Activity, and Health Disparities: Tobacco Industry Targeting of Inner Cities. J. Health Care Poor Underserved 18 (4), 10–38. https://doi.org/10.1353/hpu.2007.0120.
Young-Wolff, K.C., Henriksen, L., Delucchi, K., Prochaska, J.J., 2014. Tobacco retailer proximity and density and nicotine dependence among smokers with serious mental illness. Am. J. Public Health 104, 1454–1463. https://doi.org/10.2105/AJPH.2014.301917.
Yu, D., Peterson, N.A., Sheffer, M.A., Reid, R.J., Schnieder, J.E., 2010. Tobacco outlet density and demographics: analysing the relationships with a spatial regression approach. Public Health 124 (7), 412–416. https://doi.org/10.1016/j.puhe.2010.03.024.