



## Vape shop identification, density and place characteristics in six metropolitan areas across the US

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### ABSTRACT

Vaping is increasingly prevalent and controversial. Vape shops and convenience stores are common but distinct sources of vaping products, and where they locate may reflect likely target markets. This study examined the density and neighborhood demographics of vape shops and convenience stores in six metropolitan statistical areas (MSAs): Atlanta, Boston, Minneapolis, Oklahoma City, San Diego, Seattle. We identified 459 vape shops using Yelp and Google application programming interfaces and 10,777 convenience stores using ReferenceUSA and Dun & Bradstreet. Retailers were geocoded to census tracts ( $n = 4,442$ ), and logistic regressions were conducted using as predictors percent non-White, percent youth (5–17 years or 5–20 years), and median household income from the American Community Survey, 2013–2017. Per 10,000 young adults, vape shop density ranged from 0.6 (Boston, San Diego) to 1.7 (Oklahoma City), and convenience store density ranged from 12.6 (San Diego) to 26.3 (Oklahoma City). Logistic regressions indicated that vape shops more likely resided in tracts with lower percentages of youth in Boston, but higher percentages of youth in Atlanta, as well as with lower incomes in Boston and Seattle. Convenience stores more likely resided in tracts with lower percentages of non-Whites in Atlanta and Boston; lower incomes in Atlanta, Boston, San Diego, and Seattle; and higher percentages of youth in Atlanta, Boston, and Minneapolis. These common retail sources of vaping products differentially locate in relation to neighborhood sociodemographics across MSAs. Findings suggest that, in some MSAs, vape shops and convenience stores may target youth and lower income populations.

### 1. Introduction

Vaping products have emerged globally and in the US market, with use and awareness increasing (Cantrell et al., 2018; Wang et al., 2018). Vape shops are unique retailers that exclusively sell vaping products and have also rapidly expanded (Lee et al., 2018). Estimates regarding distribution channels of vaping products in the US are difficult to obtain, and where available, focus mainly on products distributed through major vaping product companies and brands rather than products more commonly sold in vape shops. Thus, these numbers likely reflect

overestimations of distribution via convenience stores (30% of product sales), online sales (25%) and other mainstream channels rather than vape shops (20%) (Stimson, 2014).

The exact number of US vape shops is unknown. The Food and Drug Administration's (FDA's) vape shop registry is limited to manufacturers (i.e., any entity that manufactures, fabricates, assembles, processes, or labels vaping products (Food and Drug Administration, 2019)), 14 states do not have tobacco retailer licensing that consider vape shops as tobacco retailers, and some state licensing lists do not distinguish vape shops from other tobacco retailers (Public Health Law Center, 2019).

*Abbreviations:* MSA, metropolitan statistical area; FDA, Food and Drug Administration; VAPES, Vape shop Advertising, Place characteristics and Effects Surveillance

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However, estimates indicate rapid increases in US vape shops over the last few years (e.g., nearly threefold increase to 9,945 from 2013 to 2015) (Dai et al., 2017). Nonetheless, they are vastly outnumbered by convenience stores. Estimates of convenience stores that sell vaping products range from 73% to 86% (Ribisl et al., 2017; Schleicher et al., 2017).

Vaping is a controversial and urgent public health issue. While vaping products may deliver fewer harmful chemicals than traditional cigarettes and potentially support cessation efforts, (Grana et al., 2014; Kalkhoran and Glantz, 2016; Malas et al., 2016) vaping products may contain chemicals that may increase risks of addiction and disease (e.g., cardiovascular, lung, pulmonary, cancer) (Grana et al., 2014; The National Academies of Sciences Engineering and Medicine, 2018). In light of reports of vaping-related lung illnesses across the US (Centers for Disease Control, 2019), a better understanding of influences on vaping is critical. From a socioecological perspective (McLeroy et al., 1988), behavior – including vaping – is influenced by multilevel factors, from individual consumer characteristics to environmental factors (e.g., retail availability, marketing) to broader macro-level factors (e.g., tobacco-related legislation).

The retail environment for vaping products is a key factor in influencing product use, particularly among youth. Such retail and related marketing aim to expand markets, attract new users, promote continued use, and shape perceptions of products and their use (Lovato et al., 2011; Paynter and Edwards, 2009). This is particularly crucial for newer products because the ways consumers are first exposed to products is highly influential on short-term sales or gains (Sethuraman et al., 2011).

Vape shops are unique tobacco retail settings, given the diversity of the products they sell and the promotional strategies used. Whereas convenience stores typically sell select closed-systems (i.e., devices with e-liquid already included), vape shops sell diverse devices, including closed systems, open systems (i.e., devices in which consumers add e-liquids), herbal/dry chamber vaporizers, and wet/dry vaporizers (Lee and Kim, 2015), as well as various accessories and e-liquid flavors (Lee and Kim, 2015; Sussman et al., 2014). Vape shops also promote experimenting and socializing at tasting bars (Lee and Kim, 2014; Kong et al., 2017), market via social media (Cheney et al., 2015), and use advertising messaging to influence how and why consumers vape (3; Berg, 2016; Getachew et al., 2018), (e.g., perceptions of product safety or use for cessation (Kong et al., 2017; Berg, 2016; Getachew et al., 2018; Berg et al., 2014)).

Where vape shops locate may be an indicator of their target markets (Berg, 2018). Prior research suggests that physical availability of retailers increases exposure to environmental cues that promote use, reduces search costs to obtain tobacco, and deters quit attempts (Berg, 2018; Yu et al., 2010; Chuang et al., 2005; Henriksen et al., 2008, 2010). However, limited published research has examined where vape shops locate or impact of access on use (Dai et al., 2017; Giovenco et al., 2016; Bostean et al., 2018; Robitaille et al., 2019). There is evidence indicating targeting of young adults, particularly of college campuses (Robitaille et al., 2019; Dai and Hao, 2017). Moreover, consistent with literature regarding the impact of exposure to tobacco retailers and retail marketing (Yu et al., 2010; Chuang et al., 2005; Henriksen et al., 2008, 2010), recent research has found that adolescent vaping is related to greater exposure to vape retailers and advertising (Giovenco et al., 2016). Additionally, research on traditional tobacco retailers indicates high density of retailers in vulnerable neighborhoods, such as low-income or racial/ethnic minorities (Yu et al., 2010; Chuang et al., 2005; Henriksen et al., 2008, 2010); the research regarding place characteristics of vape shops have shown mixed results regarding associations with such target populations (Dai et al., 2017; Giovenco et al., 2016). This may be due to methodological issues. For example, valid methods for creating a census of vape shops in order to plot their locations are limited. Using online sources to capture names and addresses of possible vape shops is one methodological approach (Kim et al., 2016; Lee

et al., 2016). However, one analysis indicated that online sources overestimate the number of vape shops by misclassifying smoke/tobacco shops and head shops that sell vaping products as well as other tobacco products as vape shops (Giovenco, 2018). Another plausible cause for inconsistent findings across studies is that vape shops situate within communities differently across cities or states. (Dai et al., 2017) However, limited research has covered multiple regions across the US with distinct tobacco control environments and social norms.

Related to this latter point, the broader tobacco control environment including policies, such as cigarette taxation and smoke-free air policies, as well as other tobacco control and prevention strategies (Centers for Disease Control and Prevention, 2012), may influence vaping behavior and the related retail environment. Particularly relevant to the vaping industry, in 2016, FDA finalized a rule extending its regulatory authority to cover all tobacco products including vaping products. While FDA regulates several aspects of the tobacco industry relevant to retail and marketing (US Food and Administration, 2019), FDA does not oversee zoning laws that would regulate where vape shops (or other tobacco retailers) can locate, which typically prohibit such retail proximity to child-friendly areas (e.g., schools, playgrounds). This leaves states and local jurisdictions to implement such policies.

Leveraging a socioecological perspective (McLeroy et al., 1988), the current study aimed to contribute to the research regarding retail environment for vaping product. Specifically, we examined the density and neighborhood demography (e.g., characterized by age, race/ethnicity, household income) of vape shops (that sell no other tobacco products beside vaping products) relative to convenience stores (which predominately sell vaping and other tobacco products). Based on the aforementioned literature, it was hypothesized that vape shops and convenience stores would similarly target neighborhoods with young people; however, the conflicting findings regarding whether vape shops target racial/ethnic minorities and low-income populations preclude the formation of specific hypotheses but rather justify exploration across MSAs. Using a combination of data sources and telephone protocol to identify vape shops in six metropolitan statistical areas (MSAs) from six states with varying tobacco control contexts, this study addresses some limitations of prior research (i.e., lack of verification of webscraped data, limited geographic/contextual variability) (Dai et al., 2017; Giovenco et al., 2016). The comparison of vape shops to convenience stores yield data whether and how vape shop locations differ from the retail locations where most tobacco products are commonly purchased (American Heart Association, 2012).

## 2. Material & methods

### 2.1. Study settings

The Vape shop Adsvertising, Place characteristics and Effects Surveillance (VAPES) study examines the vape shop retail environment and its impact on vaping and tobacco use among young adults aged 18–34, as defined by the US Census Bureau (United States Census Bureau, 2018). A metropolitan statistical area (MSA) is a geographical unit centered on one or more large cities, defined by the US Office of Management and Budget and used by the Census Bureau. The VAPES study focuses on six MSAs: Atlanta-Sandy Springs-Roswell (Georgia); Boston-Cambridge-Newton (Massachusetts); Minneapolis-St. Paul-Bloomington (Minnesota); Oklahoma City (Oklahoma); San Diego-Carlsbad (California); and Seattle-Tacoma-Bellevue (Washington). These MSAs were selected for representation across US regions, and they vary in terms of state tobacco control policies (Public Health Law Center, 2019; American Lung Association, 2018). For example, across all categories (tobacco prevention, smoke-free air, cessation access, tobacco taxation, Tobacco 21), California earned all A-grades but one, Massachusetts and Minnesota earned at least two A grades, and Washington, Oklahoma and Georgia earned predominately D and/or F

grades. A similar gradient also applies to vaping. At the time of assessment, California and Minnesota taxed vaping products; California, Minnesota, and Washington required licenses for retail sales of vaping products (Public Health Law Center, 2019). In addition, California and Washington had retail markets for recreational marijuana.

## 2.2. Retail location data

### 2.2.1. Vape shops

Adapting procedures from previous research (Sussman et al., 2014; Bostean et al., 2018; Kim et al., 2016; Lee et al., 2016), we searched “vaporizer store” on Google Maps and “vape shops” on Yelp to identify stores tagged by retailers or customers as vape shops in the six states. The files (downloaded November–December 2017) were de-duplicated, cases with missing street addresses were removed, and key variables were created with common formats and content to increase record matching via code. Each list of likely vape shops were then merged using street address and zip code to link common records from the two online sources, using IBM SPSS Statistics for Windows, v.25 (IBM; Armonk, NY). This merged file was further reviewed to identify additional duplications and matched stores that did not link due to variations in street addresses between the two sources. Among the likely vape shops in six MSAs ( $n = 1,093$ ), 26.3% ( $n = 287$ ) were unique to Google Maps and 35.8% ( $n = 391$ ) were unique to Yelp.

As in previous research (Giovenco et al., 2019), we used a telephone protocol to determine whether the stores: 1) sold vape products and 2) also sold other conventional tobacco products (e.g., cigarillos). Study staff phone verified 894 stores (81.8% completion rate). Although alternative phone numbers were explored, reasons for incomplete phone verification ( $n = 199$ ; 18.2%) were no answer, poor connection, answering machines with uncertain owners (individual vs. shop), and refusal at beginning (Fig. 1a). Among completed phone verifications ( $n = 894$ ), ineligible cases ( $n = 132$ , 14.8%) included those that did not sell vape products ( $n = 20$ , 2.2%) or were permanently closed, duplicate entries, or not retail storefronts ( $n = 112$ , 12.6%). Addresses of the merged file of vape shops were geocoded to latitude/longitude and aggregated to census tracts and MSA, using ArcGIS v10.4.1 (ESRI; Redland, CA; mapping rate = 100%).

### 2.2.2. Convenience stores

Data were derived from ReferenceUSA (December 2018) and Dun & Bradstreet (November 2018) for stores with Standard Industrial Classification codes that correspond to convenience stores (RefUSA: 541103, 554101, 554102, 554103; Dun & Bradstreet: 541102, 55410000, 55419901, 55419903, 55419904) (Han et al., 2012). As for vape shops, we similarly removed duplicates then merged the lists based on street address, zip code, and state to link records, using R statistical software v3.5.3 (R Foundation for Statistical Software; Vienna, Austria). Duplicate records were further eliminated using Google OpenRefine and then by hand review. Among the 10,777 total convenience stores in the six MSAs, 32.7% ( $n = 3,524$ ) were unique to Dun & Bradstreet, and 24.4% ( $n = 2,630$ ) were unique to ReferenceUSA. Similar to vape shops, addresses of the merged file of convenience stores were geocoded to latitude/longitude (mapping rate = 98.4%) and aggregated to tract and MSA.

## 2.3. Neighborhood characteristics

Demographics for all 4,525 census tracts were obtained from five-year estimates from the American Community Survey (2013–2017) in order to characterize total population: race/ethnicity (% of residents who were Black, Non-Hispanic; Asian/Pacific Islander, non-Hispanic; Hispanic; Other/Alaskan Native/American Indian/multiple races; White, non-Hispanic), age (% youth ages 5–17 years or ages 5–20 years in Tobacco 21 states, % ages 18–34), and median household income. Race/ethnicity was operationalized as percent non-White (including

Hispanic; i.e., % non-White =  $100 - \% \text{ non-Hispanic White}$ ) due to high variability across MSAs and low prevalence of each non-White racial/ethnic group in one or more of the MSAs (e.g., 4.7% Black in San Diego, 5.4% Black in Seattle, 3.0% Asian/Pacific Islander in Oklahoma City, 5.3% Asian/Pacific Islander in Atlanta).

## 2.4. Analysis

The analytic sample of 4307 census tracts excluded tracts without residents ( $n = 16$ ) and tracts with less than 50% of the land area intersecting the MSA ( $n = 206$ ), including 4 tracts with zero population and less than 50% of the tract within the MSA in Washington. These exclusion criteria did not affect any tracts with a vape shop and excluded 19 tracts with at least one convenience store.

We computed two measures of density for the 4307 census tracts across MSAs, separately for phone-verified vape shops and convenience stores: 1) stores per 10,000 young adults (ages 18–34), which is the focal age group for this study (Shortt et al., 2015; Hahn et al., 2015), and 2) stores per 10 roadway miles, which is a measure of accessibility (Gruenewald et al., 2006; Romley et al., 2007). These measures were calculated using ArcGIS v10.4.1. Notably, 3,906 tracts (90.7%) contained no vape shops, and among the 402 tracts (9.3%) with any vape shops, all but 49 (12.4%) contained only one. Given the sparse distribution of vape shops, our primary analysis examined which population demographics were associated with presence of any vape shops in census tracts (0 = none, 1 = any) (Giovenco et al., 2016; Bostean et al., 2018).

Separately for each MSA, logistic regression models assessed relationships between presence of vape shops and tract-level characteristics. Parallel models for convenience stores were estimated to explore if the relationships between neighborhood characteristics and vape shop density differed across store types. Because of varying relationships between predictors and outcomes across MSAs, we ran parallel models for each. One model would have required dummy coding MSAs and running a generalized linear mixed model interacting all census-based predictors with five MSAs. This approach would have yielded an over-parametrized model with inadequate power to detect varying relationships across MSAs. To accommodate non-linear relationships between tract-level demographics and retailer presence, the demographic variables were quartiled within MSA, with the lowest (quartile 1) as the reference category. All analyses were performed using IBM SPSS Statistics for Windows, v.25 (IBM; Armonk, NY).

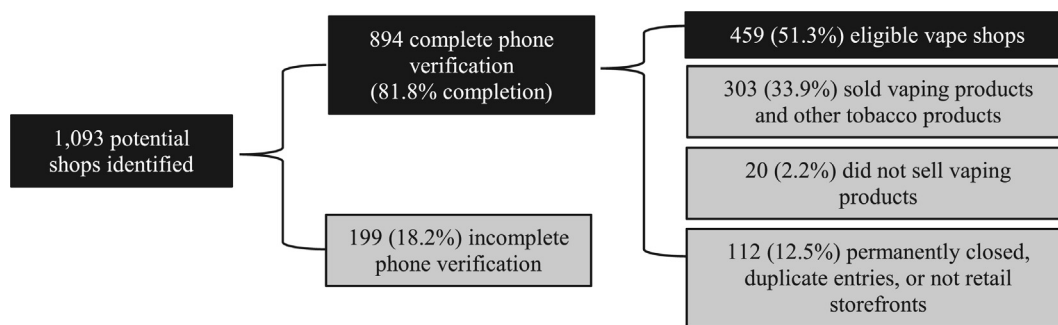
## 3. Results

Results from the phone verifications indicated that, of 894 locations that retailers or customers tagged as vape shops on Yelp or as vaporizer stores on Google, 51.3% were shops that did not sell other tobacco products (Fig. 1a). The proportion of these vape shops ranged from 38.1% in the San Diego MSA to 71.3% in the Oklahoma City MSA (mean = 52.3%, SD = 11.7; Fig. 1b).

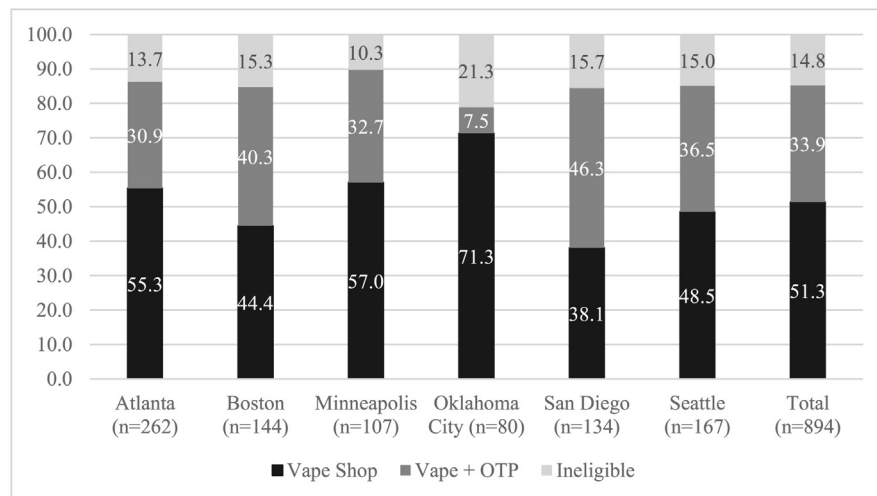
### 3.1. Density/location of vape shops and convenience stores

Table 1 characterizes the number of census tracts and population size of each MSA, as well as population demographics derived from tract-level estimates. Across the MSAs, there were 23 times as many convenience stores as vape shops (minimum = 16 vape shops in San Diego MSA, maximum = 41 in Boston MSA) (computed from Table 1). Within the MSAs, the average roadway distance between vape shops was 2.7 miles (SD = 3.1, minimum = 1.8 miles in the Seattle MSA, maximum = 3.6 miles in the Minneapolis MSA). By comparison, the average roadway distance between convenience stores was 0.5 miles (SD = 0.1, minimum = 0.3 miles in Boston MSA, maximum = 0.7 miles in Oklahoma City MSA).

On average, vape shop density per 10,000 young adults (ages



a. Vape Shop Identification Flowchart



b. Percent of stores that were vape shops, by MSA: Phone verifications in Months, 2017

Fig. 1. Vape Shop Identification Flowchart and Outcomes by MSA. a. Vape Shop Identification Flowchart. b. Percent of stores that were vape shops, by MSA: Phone verifications in Months, 2017.

18–34) was 1.0 (SD = 0.4, minimum = 0.6 in Boston and San Diego MSAs, maximum = 1.7 in Oklahoma City MSA). Vape shop density per 10 roadway miles was 0.03 (SD = 0.01, minimum = 0.02 in Minneapolis and San Diego MSAs, maximum = 0.03 in other MSAs). By contrast, convenience store density per 10,000 young adults was 20.1 (SD = 6.0, minimum = 12.6 in San Diego MSA, maximum = 26.3 in Oklahoma City MSA). On average, convenience store density per 10 roadway miles was 0.7 (SD = 0.3, minimum = 0.4 in Minneapolis MSA, maximum = 1.2 in Boston MSA).

3.2. Correlates of vape shop and convenience store presence

Logistic regressions identified correlates of the presence of at least one retailer (vape shop and convenience store separately) in a census tract, separately, for MSAs in Tobacco 21 states (Table 2) and in other states (Table 3). Predictors of tract-level demographics for the presence of vape shops across MSAs were idiosyncratic. Percent of non-White residents was associated with lower odds of vape shop location in the Seattle MSA (quartile 3 only). There were lower odds of vape shops in tracts with the highest percentage of youth in the Boston MSA, but higher odds of vape shops in tracts with higher percentage of youth in the Atlanta MSA (quartiles 2 and 3). Finally, there were lower odds of vape shops being located in tracts with the highest quartile of median household income in the Boston MSA and in tracts with higher median household income (quartiles 3 and 4) in the Seattle MSA. None of the three tract-level characteristics were associated with the presence of convenience stores in the Oklahoma City MSA.

There were lower odds of having convenience stores and vape shops

in tracts with higher income in Boston and Seattle MSAs. In the Atlanta MSA only, there was lower likelihood of both store types in the highest quartile of non-White residents, but a higher likelihood in tracts with higher proportions of youth (quartiles 2 and 3). Correlates that were unique to convenience stores were: lower odds in tracts with higher median household income in the San Diego and Atlanta MSAs; higher odds of convenience stores in tracts with higher percent of youth (quartile 2 only) in the Boston and Minneapolis MSAs; and lower odds of convenience stores in tracts with the highest proportion of non-White residents in the Boston MSA. Again, no tract-level characteristics were associated with the presence of convenience stores in the Oklahoma City MSA.

4. Discussion

The present study extended prior work by including six MSAs with distinct tobacco control contexts and by adding rigor to the data used to plot vape shop locations (Dai et al., 2017; Giovenco et al., 2016). This study confirms that online sources overestimate the number of vape shops and to a varying degree across six MSAs in the US. Across the MSAs, 51.3% of the stores on Yelp and Google that were identified as vape shops/vaporizer stores were vape shops that did not sell conventional tobacco products. This finding is similar to the overall proportion of vape shops (44.4% “true positives”) in New York City, as confirmed from telephone/visits reported by Giovenco (2018). As for New York City Boroughs (Giovenco, 2018), there was almost a two-fold difference in the proportion of stores that were vape shops across MSAs. The highest proportion was in the Oklahoma City MSA, where the city

**Table 1**  
Descriptive statistics by metropolitan statistical area.

	Atlanta-Sandy Springs-Roswell (Georgia)	Boston-Cambridge-Newton (Massachusetts)*	Minneapolis-St. Paul-Bloomington (Minnesota)	Oklahoma City (Oklahoma)	San Diego-Carlsbad (California)*	Seattle-Tacoma-Bellevue (Washington)*
<b>Census Tracts</b>	n = 948	n = 895	n = 766	n = 362	n = 625	n = 711
<b>Population Size</b>	5,700,990	4,289,006	3,397,781	1,353,504	3,281,075	3,700,465
<b>Demographics, M (SD)</b>						
<b>Median household income</b>	\$66,506 (31,097)	\$86,894 (37,185)	\$75,233 (28,094)	\$54,964 (24,122)	\$75,424 (30,655)	\$82,207 (30,867)
<b>Youth</b>						
5–17 years old	17.9% (5.3)	14.6% (5.7)	16.7% (5.3)	17.2% (5.8)	15.1% (5.6)	15.5% (4.9)
5–20 years old (T21 MSAs only)	–	19.0% (7.7)	–	–	19.4% (6.8)	18.9% (6.0)
<b>Race/ethnicity</b>						
Asian/Pacific Islander, non-Hispanic	5.3% (7.4)	8.1% (8.7)	6.6% (8.0)	3.0% (4.2)	10.8% (11.6)	13.1% (10.3)
Black, non-Hispanic	33.9% (30.0)	8.7% (14.8)	9.2% (11.6)	12.5% (17.5)	4.7% (5.5)	5.4% (6.4)
Hispanic	10.3% (12.1)	12.3% (16.8)	6.3% (6.9)	14.2% (17.4)	33.2% (23.4)	9.7% (7.5)
Other/multiple races, non-Hispanic	2.5% (1.7)	3.0% (2.7)	3.8% (2.9)	8.7% (3.3)	3.8% (2.4)	6.3% (3.2)
White, non-Hispanic	47.9% (29.6)	67.9% (25.7)	74.1% (20.7)	61.6% (21.7)	47.5% (25.1)	65.6% (17.5)
Non-white	52.1% (29.6)	32.1% (25.7)	25.9% (20.7)	38.4% (21.7)	52.5% (25.1)	34.4% (17.5)
<b>MSA-level Retail Attributes</b>						
<b>Vape shops</b>						
Count	145	64	61	57	51	81
Density per 10,000 residents age 18–34 years	1.1	0.6	0.8	1.7	0.6	0.9
Density per 10 roadway miles	0.03	0.03	0.02	0.03	0.02	0.03
Avg roadway distance to nearest competitor (mi)	3.0 (3.1)	3.0 (3.1)	3.6 (3.7)	2.5 (4.2)	2.0 (2.5)	1.8 (1.9)
% of tracts with at least one vape shop	12.7%	6.5%	7.2%	15.2%	7.4%	9.6%
<b>Convenience stores</b>						
Count	3392	2619	1328	899	1121	1382
Density per 10,000 residents age 18–34 years	25.6	24.1	16.7	26.3	12.6	15.0
Density per 10 roadway miles	0.8	1.2	0.4	0.5	0.5	0.5
Avg roadway distance to nearest competitor (mi)	0.5 (0.7)	0.3 (0.4)	0.6 (1.0)	0.7 (1.3)	0.4 (0.8)	0.5 (0.9)
% of tracts with at least one convenience store	86.7%	87.7%	76.2%	84.8%	68.8%	74.8%

Note: All entries are mean (standard deviation) unless otherwise noted. \* T21 states.

**Table 2**  
Correlates of tracts with at least one vape shop or convenience store among MSAs in States with Tobacco 21 (December 2017).

	Boston-Cambridge-Newton (Massachusetts) n = 890 census tracts			San Diego-Carlsbad (California) n = 620 census tracts			Seattle-Tacoma-Bellevue (Washington) n = 711 census tracts					
	Convenience stores			Vape shops			Convenience stores			Vape shops		
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
<b>Constant</b>	0.21		16.00		0.09		4.05		0.16		9.03	
<b>Neighborhood characteristics</b>												
<b>% Non-White</b>												
Quartile 2	0.95	(0.44, 2.07)	1.02	(0.54, 1.93)	1.56	(0.57, 4.23)	1.61	(0.95, 2.72)	1.21	(0.45, 3.28)	0.71	(0.44, 1.14)
Quartile 3	0.73	(0.33, 1.59)	0.57	(0.30, 1.07)	1.44	(0.50, 4.18)	1.01	(0.58, 1.74)	2.75	(1.11, 6.79)	1.09	(0.66, 1.80)
Quartile 4	0.47	(0.18, 1.20)	0.39	(0.17, 0.89)	1.22	(0.36, 4.10)	0.72	(0.39, 1.35)	1.82	(0.70, 4.74)	0.89	(0.51, 1.57)
<b>% Youth (5–20 years)</b>												
Quartile 2	0.64	(0.32, 1.27)	2.73	(1.35, 5.52)	0.84	(0.35, 2.00)	0.76	(0.46, 1.26)	0.94	(0.47, 1.91)	0.82	(0.49, 1.36)
Quartile 3	0.56	(0.27, 1.18)	1.53	(0.82, 2.85)	0.64	(0.25, 1.63)	0.86	(0.51, 1.46)	0.58	(0.27, 1.25)	0.81	(0.49, 1.35)
Quartile 4	0.34	(0.13, 0.91)	0.80	(0.45, 1.43)	0.85	(0.33, 2.21)	1.04	(0.59, 1.86)	0.77	(0.37, 1.58)	0.70	(0.42, 1.15)
<b>Median household income</b>												
Quartile 2	1.18	(0.54, 2.58)	0.70	(0.33, 1.47)	1.04	(0.46, 2.38)	0.91	(0.52, 1.59)	0.53	(0.28, 1.01)	0.66	(0.36, 1.21)
Quartile 3	0.44	(0.17, 1.12)	0.57	(0.25, 1.30)	0.75	(0.29, 1.90)	0.54	(0.30, 0.96)	0.14	(0.05, 0.37)	0.27	(0.15, 0.48)
Quartile 4	0.22	(0.07, 0.71)	0.29	(0.13, 0.65)	0.37	(0.11, 1.20)	0.29	(0.16, 0.53)	0.27	(0.12, 0.63)	0.29	(0.16, 0.53)

Quartile classification computed within MSA based on ACS 5-yr tract estimates (2013–2017). Adjusted odds ratios for presence of one or more vape shops, or one or more convenience stores in census tract. **Bolded** values indicate statistically significant findings (p < 0.05).

**Table 3**  
Correlates of tracts with at least one vape shop or convenience store among MSAs in states without tobacco 21 (December 2017).

	Atlanta-Sandy Springs-Roswell (Georgia) n = 946			Minneapolis-St. Paul-Bloomington (Minnesota) n = 763			Oklahoma City (Oklahoma) n = 361					
	Convenience stores			Vape shops			Convenience stores			Vape shops		
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
<b>Constant</b>	0.09		12.98		0.10		2.77		0.32		5.29	
<b>Neighborhood characteristics</b>												
<b>% Non-White</b>												
Quartile 2	<b>2.17</b>	<b>(1.23, 3.83)</b>	1.62	(0.95, 2.75)	0.96	(0.46, 2.03)	0.87	(0.53, 1.41)	1.19	(0.52, 2.71)	0.64	(0.29, 1.39)
Quartile 3	<b>2.32</b>	<b>(1.29, 4.18)</b>	1.17	(0.63, 2.18)	0.94	(0.42, 2.09)	0.91	(0.53, 1.55)	1.20	(0.51, 2.81)	1.15	(0.46, 2.87)
Quartile 4	<b>0.28</b>	<b>(0.11, 0.68)</b>	<b>0.47</b>	<b>(0.23, 0.98)</b>	0.38	(0.13, 1.14)	0.76	(0.41, 1.44)	0.45	(0.14, 1.39)	1.20	(0.40, 3.65)
<b>% Youth (5–17 years)</b>												
Quartile 2	<b>2.22</b>	<b>(1.23, 3.98)</b>	<b>2.01</b>	<b>(1.13, 3.58)</b>	1.68	(0.78, 3.64)	<b>1.98</b>	<b>(1.19, 3.29)</b>	1.46	(0.66, 3.19)	1.96	(0.79, 4.85)
Quartile 3	<b>2.03</b>	<b>(1.11, 3.71)</b>	<b>1.96</b>	<b>(1.13, 3.40)</b>	0.87	(0.36, 2.14)	1.40	(0.86, 2.27)	0.70	(0.29, 1.70)	0.98	(0.44, 2.18)
Quartile 4	1.78	(0.96, 3.31)	1.36	(0.81, 2.26)	1.36	(0.56, 3.31)	1.29	(0.78, 2.14)	0.78	(0.31, 1.98)	1.01	(0.42, 2.38)
<b>Median household income</b>												
Quartile 2	0.80	(0.44, 1.46)	<b>0.75</b>	<b>(0.36, 1.54)</b>	0.77	(0.31, 1.87)	1.08	(0.63, 1.86)	0.60	(0.23, 1.56)	1.18	(0.44, 3.17)
Quartile 3	0.58	(0.31, 1.09)	<b>0.27</b>	<b>(0.13, 0.56)</b>	0.68	(0.26, 1.79)	1.30	(0.70, 2.41)	0.51	(0.19, 1.39)	0.84	(0.30, 2.36)
Quartile 4	0.54	(0.27, 1.09)	<b>0.14</b>	<b>(0.06, 0.31)</b>	0.69	(0.25, 1.95)	0.71	(0.38, 1.36)	0.47	(0.16, 1.37)	0.96	(0.32, 2.87)

Quartile classification computed within MSA based on ACS 5-yr tract estimates (2013–2017). Adjusted odds ratios for presence of one or more vape shops, or one or more convenience stores in census tract. **Bolded** values indicated statistically significant finding (p < 0.05).

center was featured in a 2014 *New York Times* story about the rise of vape shops (Richtel, 2014) and where the past-month vaping prevalence is highest (McPhillips, 2019). Although California was among the five states with highest density of vape shops in 2016 (Groskopf, 2016), the lowest proportion of vape shops in the San Diego MSA may reflect a declining prevalence of past-month vaping among California adults from 2016 to 2017 (McPhillips, 2019).

In addition, there were 23 times as many convenience stores as vape shops across the MSAs. Similar to vape shops, the Oklahoma City MSA had the greatest density of convenience stores per 10,000 young adults, with the lowest densities in the Boston and San Diego MSAs. These results coincide with prior findings indicating that vape shop presence is more common in census tracts with higher densities of other tobacco retailers (Giovenco et al., 2016; Bostean et al., 2018).

In the current study, census tract characteristics that were associated with the presence of at least one vape shop were somewhat idiosyncratic to MSA. For example, vape shops were more likely to reside in tracts with lower percentages of youth in Boston, but higher percentages of youth in Atlanta. Higher neighborhood household income was associated with lower odds of a vape shop locating in census tracts in the Boston and Seattle MSAs, with inconsistent results for each quartile. No tract-level characteristics were associated with vape shop location in the Minneapolis and Oklahoma City MSAs. Prior research on vape shop locations in the US found that greater vape shop density was associated with the presence of larger percentages of Hispanic and Asian residents in urban and nonurban areas, people aged 18–29 and 30–44 years old in urban areas, and people with less than a college degree in urban areas (Dai et al., 2017). However, no associations were found between vape shop density and poverty level or percent Blacks (Dai et al., 2017). Other studies suggest a negative relationship between percent of Blacks and vape shop location (Giovenco et al., 2016, 2019; Bostean et al., 2018).

Taken together, the limited common correlates of vape shop and convenience stores locations suggest that vape shops and convenience stores may share some common neighborhood characteristics in some but not all markets (Giovenco et al., 2019). Prior research interviewing vape shop owners (Cheney et al., 2015, 2016) has shown that owners attempt to attract different groups of users, including young adults and long-term smokers. Current analysis adds new insight regarding the distribution of vape shops, particularly with regard to whether location may be a way of targeting vulnerable communities (e.g., low income, low education, or racial minorities) in ways tobacco companies have traditionally targeted them (U.S. Department of Health and Human Services, 2012, 1998).

## 5. Study strengths and limitations

This study advances the literature by addressing some limitations of prior research (i.e., lack of verification of webscraped data, limited geographic/contextual variability) (Dai et al., 2017; Giovenco et al., 2016). Specifically, this study used a combination of data sources and telephone protocol to identify vape shops in six MSAs from six states with varying tobacco control contexts. However, this study has some limitations in that it was based on two search terms and two online sources, which may have limited the sampling frame for telephone verifications of likely vape shops. Census tract as a definition of neighborhood has inherent limitations and there may be factors other than population demographics that are associated with vape shop density, such as the distribution of other vendors that sell e-cigarettes (i.e., convenience stores, pharmacies, smoke shops) and marijuana (in some states). In addition, this study did not model individual racial/ethnic categories, which makes it difficult to compare with results from previous studies in New York City, Orange County, New Jersey and the US. Generalizability of the current study findings to other MSAs in the six study states and to other states is also limited.

## 6. Conclusion

Surveillance of vape shop retail environment over time and across contexts is critical, particularly given different regulatory environments across states and localities, as well as pending FDA regulation. Indeed, regulations of flavored tobacco and/or all vaping products might increase or decrease vape shop density, depending on whether the goals of comprehensive restriction are weakened by exemptions for significant tobacco retailers. Results indicated some correlations between vape shop and convenience store densities and that, in some cases, these tobacco retailers may locate near vulnerable populations. Location choices could be a part of a marketing strategy to target specific consumer markets. This study provides evidence to inform initiatives aimed at federal, state and local regulations on vape shops as well as a licensing requirement to implement and enforce regulation.

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## Author contributions

Berg, Schleicher, and Henriksen conceptualized and oversaw the execution of these analyses. Schleicher, Henriksen, and Johnson led data analyses. Berg, Schleicher, and Henriksen led the writing of the manuscript. Barker, Getachew, Weber, Park, Patterson, Dorvil, Fairman, and Meyers contributed to data collection and manuscript preparation. Berg finalized the manuscript, and all authors reviewed and approved the final manuscript submitted.

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## Ethical approvals

Institutional Review Board approvals were not required for this manuscript, as no human subjects were involved in this manuscript.

## Declaration of interests

The authors declare no conflicts of interests.

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