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THE ELECTRONIC CIGARETTE RETAIL ENVIRONMENT IN NEW JERSEY
AND ITS ASSOCIATIONS WITH COMMUNITY DEMOGRAPHICS AND YOUTH
VAPING BEHAVIORS

By

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ABSTRACT OF THE DISSERTATION

The electronic cigarette retail environment in New Jersey and its associations
with community demographics and youth vaping behaviors

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Background: E-cigarette use is on the rise among youth nationally, as well as in New Jersey. Little is known about how e-cigarette availability varies across communities and how exposure to e-cigarette advertising may influence use among youth.

Objectives: This dissertation aims to: 1) Document the relationship between community demographics and the presence of vape shops in New Jersey, 2) characterize the e-cigarette retail environment around 41 New Jersey high schools, and 3) examine associations between e-cigarette promotion at the point-of-sale and vaping behaviors among high school students participating in the 2014 New Jersey Youth Tobacco Survey (NJYTS).

Methods: A combination of geographic information systems (GIS), census tract demographic data, store audits, and youth survey data from the 2014 NJYTS were used to describe community correlates of e-cigarette retail and its associations with vaping behaviors among youth.

Results: E-cigarettes were significantly less likely to be available and advertised in communities with a large proportion of black residents. In predominantly white neighborhoods, e-cigarettes were advertised proportionally more than other tobacco products. Although tobacco use history is the strongest predictor of e-cigarette use among students, the e-cigarette retail environment near schools was independently associated with both ever and current use.

Conclusions: The e-cigarette industry currently faces no federal marketing restrictions. This dissertation documented a high prevalence of point-of-sale promotions in areas where youth spend time and revealed strong associations between the local tobacco retail environment and e-cigarette use. Policies that make e-cigarettes less available and less appealing to youth may slow rates of uptake and ultimately benefit public health.

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CHAPTER 1: INTRODUCTION

Background

Electronic nicotine delivery systems, sometimes called “e-cigarettes,” “vape pens,” or “vaporizers,” are battery-operated devices that heat and vaporize a liquid solution, delivering nicotine to users in a way that mimics the look and feel of conventional cigarette smoking. In this dissertation, the term “e-cigarette” will be used to refer to all types of electronic nicotine delivery systems, including those that look like traditional cigarettes (i.e., “cigalikes”) and those that have open tank systems allowing the user to add their own “e-liquid.” Evidence on the safety of e-cigarettes, including their chemical constituents, toxicity, nicotine delivery, and short-term health effects, varies widely, likely due to the extreme variability in product types, “e-liquid” ingredients, battery voltages, and other factors.¹ A lack of product standards and manufacturing regulations also augments the complexity of safety assessments. Despite the inconclusiveness of e-cigarettes’ health effects, the devices are widely considered a less risky form of nicotine delivery than combustible tobacco products (e.g., cigarettes and cigars), which deliver hundreds of known carcinogens and other harmful chemicals.²

As public health researchers continue to assess the impact of e-cigarettes on population health, key themes emerge. Some of the most discussed and debated points include: e-cigarettes as a method of harm reduction for current smokers, youth experimentation, and the unrestricted marketing of e-cigarettes, including strategies used at the point of sale.

Harm reduction debate

E-cigarettes have been at the center of a harm reduction debate since they entered the U.S. market in 2007. Proponents argue that vaping can help smokers quit cigarettes by delivering a “cleaner” form of nicotine while satisfying the hand-to-mouth psychological addiction that many smokers crave.³ Although no large, clinical trials have examined the efficacy of e-cigarettes for smoking cessation, anecdotally, many former smokers report successfully quitting after switching to a vaping product.⁴⁻⁶ Giovenco and colleagues found that odds of established e-cigarette use were significantly higher among former smokers compared to current smokers.⁷ An additional benefit of e-cigarettes is that they do not produce secondhand smoke, reducing exposure to toxins among non-smokers, such as children living in the homes of smoking parents.³ Although the vapor emitted from e-cigarettes does contain chemical compounds,^{8,9} the magnitude of exposures compared to cigarette smoke is minimal, and at present, presents no apparent risk to human health.¹⁰⁻¹²

The utility of e-cigarettes as a successful harm reduction strategy requires that the potential benefits to individuals and society outweigh the risks. E-cigarette opponents caution that the increasing popularity of vaping products may negate decades of successful public health campaigns to de-normalize smoking behaviors.¹³ Furthermore, many smokers may use e-cigarettes not as a cessation method, but to smoke in places where cigarette use is prohibited (e.g., restaurants, bars, workplaces). In this case, dual use of cigarettes and e-cigarettes may maintain nicotine addiction rather than promote cessation.

Population data from 2013 indicate that between 9.3%¹⁴ and 16.4%⁷ of current smokers have also used an e-cigarette in the past 30 days.

Prevalence of e-cigarette use among youth

Both sides of the e-cigarette harm reduction debate agree that a major concern is the appeal of e-cigarettes to youth. Nicotine exposure during adolescence, a critical period in neural development, has been associated with cognitive and behavioral impairments and lasting structural changes in the brain.¹⁵ Moreover, young people who become addicted to nicotine are more likely to continue smoking throughout adulthood.¹⁶ The Centers for Disease Control and Prevention (CDC) have published several reports on e-cigarette use among middle and high school students using data from the National Youth Tobacco Survey (NYTS). The earliest report found that current e-cigarette use nearly doubled among adolescents between 2011 and 2012, from 0.6% to 1.1% among middle school students, and from 1.5% to 2.8% among high school students. Despite this significant increase, e-cigarettes were, at the time, one of the least commonly used “tobacco” products among youth.¹⁷ Although use of e-cigarettes was relatively low between 2011 and 2013, the 2014 NYTS data revealed that, for the first time, past 30 day use of e-cigarettes surpassed past 30 day use of all other tobacco products, including traditional cigarettes. Approximately 13% of high school students and 4% of middle school students were current e-cigarette users in 2014.¹⁸

Current cigarette smokers comprise the majority of youth who experiment with e-cigarettes; over 80% of ever e-cigarette users report that they currently smoke cigarettes.¹⁹ Among current e-cigarette users in the 2014 Monitoring the Future survey, only 7% had never tried a cigarette (i.e., 93% reported smoking cigarettes at least once).²⁰ Other representative studies, as well as smaller surveys in New York and Connecticut, confirm this relationship between smoking and e-cigarette use.^{21,22}

Some researchers posit that e-cigarette experimentation may serve as a gateway to nicotine addiction, which can potentially lead to use of more risky, combustible tobacco products.²³ Dutra and Glantz, based on the strong association between smoking and e-cigarette use in the NYTS dataset, suggested that “e-cigarette use may encourage conventional cigarette use among adolescents.”²⁴ Another study reported that ever and current users of e-cigarettes who never tried smoking had greater intentions to smoke cigarettes than never e-cigarette users.²⁵ Importantly, as Niaura, Glynn, and Abrams argued in a response to Dutra and Glantz’s paper, an analysis of cross-sectional data is an inappropriate strategy to infer causality, or a “gateway effect.”²⁶ Longitudinal studies are needed to evaluate the claim that e-cigarettes lead to use of riskier tobacco products.

Tobacco product promotion at the point of sale

Demographic and behavioral factors, especially being White, male, in high school, and having a history of tobacco use, predict e-cigarette use among youth,

but tobacco control research over the past few decades acknowledges the importance of the retail environment in influencing use behaviors. This includes both the nature of the point of sale advertising as well as the density of tobacco retailers. After the Master Settlement Agreement restricted billboard advertising and other forms of tobacco marketing, tobacco companies began heavily promoting their products at the point of sale, particularly in convenience stores and gas stations.²⁷⁻³¹ Paynter et al. and Robertson et al., in their systematic reviews on the topic, documented a strong and positive association between youth exposure to advertisements at the point of sale and cigarette smoking.^{32,33} Similar relationships were found between retailer density and tobacco use.³⁴⁻³⁹ The presence of tobacco retailers around schools, in particular, has been shown to predict youth smoking.^{36,38,40}

E-cigarette retail environment

E-cigarette sales have sharply risen since 2007 and the vapor market is now estimated to be a \$3.5 billion dollar industry.⁴¹ Growth has been especially strong in the traditional tobacco retail environment (e.g., convenience stores), likely driven by the tobacco industry's acquisition of existing brands like *Blu*, and the introduction of new brands, like RJ Reynold's *Vuse* and Altria's *MarkTen*.⁴² "Vape shops," independent retailers that exclusively sell vaping products, are opening across the U.S. and offer a wide selection of devices, e-liquids, and accessories.⁴³ Financial analysts estimate that vape shops are the single largest channel for e-cigarette sales, generating \$900 million in 2014.⁴¹

Statement of the problem

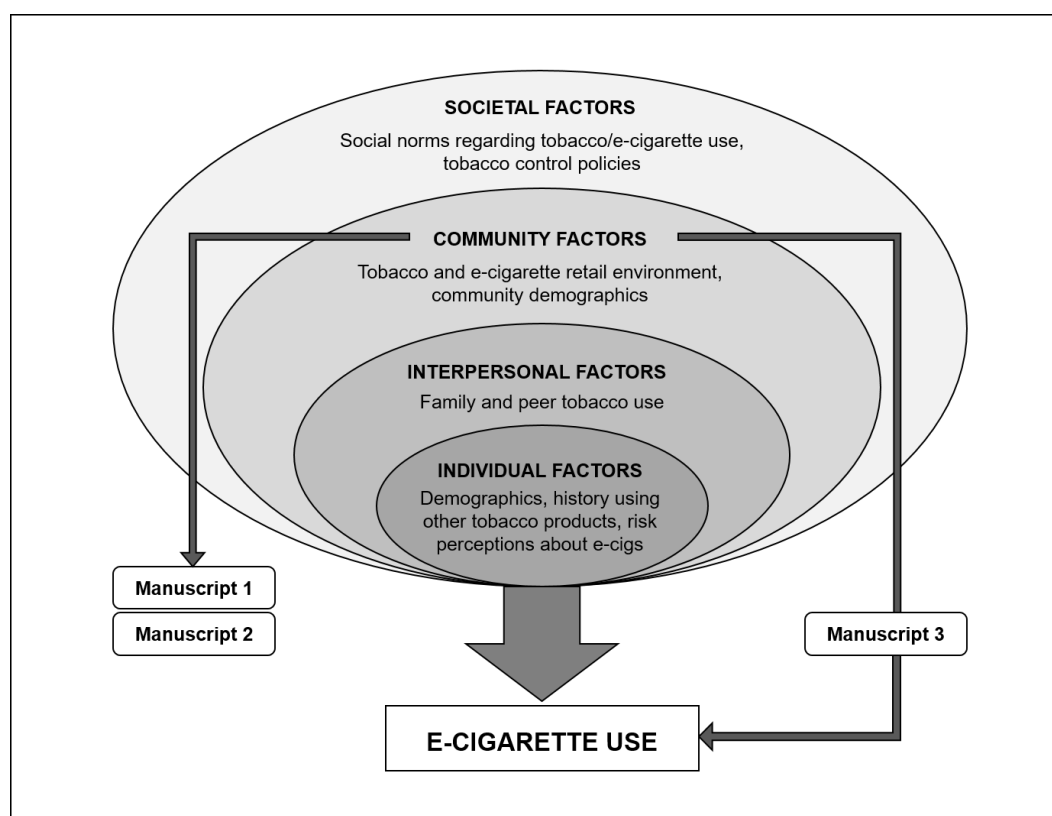
The research proposed in this dissertation is important to the tobacco control community for several reasons. First and foremost, given the relative novelty of e-cigarettes, studies on the e-cigarette retail environment are lacking. Research studies that describe point-of-sale advertising and e-cigarette availability in communities are sorely needed to document industry marketing techniques and to identify which population groups are most heavily exposed to e-cigarette promotion. E-cigarette companies, some of which are owned by tobacco companies, use many of the same marketing approaches that have historically been used to promote cigarettes, but more research is needed to understand how their tactics may differ from the cigarette industry. Second, the link between e-cigarette promotion at the point-of-sale and youth vaping behaviors is entirely unexplored. During a time when e-cigarettes are now the most common “tobacco product” among youth, the type of research in this dissertation is crucial to identify environmental and community-level factors associated with e-cigarette use. Finally, current research on tobacco at the point-of-sale is overwhelmingly focused on cigarettes. Scholarly work that explores how to adapt cigarette-centric methodologies for other tobacco products is critical in today’s diverse tobacco marketplace.

Conceptual framework

The Social-Ecological Model was used as a conceptual framework to guide the project's aims.⁴⁴ This model acknowledges that an individual's health behaviors are shaped by multiple levels of influence, including individual factors such as demographics, attitudes, and risk perceptions. Additionally, influential people in a person's life, such as family and close friends, can promote or reinforce health-related behaviors. Macro-level factors, such as a person's community and the society in which he or she lives, dictate social norms and may enable behaviors to occur. The tobacco control literature has long recognized that both the community and societal factors exert a powerful influence on tobacco use.⁴⁵ Indeed, local and federal policies such as marketing restrictions, age of sale laws, smoke-free air laws, and increased taxation have played instrumental roles in de-normalizing smoking and reducing access to tobacco products in communities.

As illustrated in Figure 1, several interpersonal and individual-level variables have been demonstrated to be associated with e-cigarette use among youth. An individual's history using tobacco products, as well as peer and family use of tobacco products, increase the probability that a young person will try an e-cigarette.^{22,24} Less is known about the influence of e-cigarette availability and promotions at the point-of-sale, but the relationship is hypothesized to mirror the well-documented, positive relationship between cigarette retail and youth smoking behaviors.

Figure 1. Conceptual framework based on the Social-Ecological Model of Health



Project Aims

This dissertation will explore the relationship between the e-cigarette retail environment, community demographics, and youth vaping behaviors in New Jersey using a combination of Geographical Information Systems (GIS) technology, field data collection, and youth surveys. The project consists of three primary aims, each of which will be examined in a respective dissertation chapter. Each chapter will then be submitted to public health journals as a standalone manuscript. Chapters 3 and 4 will characterize the e-cigarette retail environment across communities and near schools in New Jersey, while Chapter 5 will link data collected at the point-of-sale with survey data on e-cigarette

behaviors among youth. The titles, specific aims, and research questions (RQ) for each chapter are provided below:

Chapter 3: The geographic distribution of vape shops and its association with community demographics

Specific Aim 1: Describe the vape shop retail environment in New Jersey.

- RQ 1: How many vape shops are in New Jersey and where are they located?
- RQ 2: Do any geographic patterns exist in the locations of these vape shops?

Specific Aim 2: Describe the types of communities in which vape shops are located.

- RQ 3: What demographic factors are associated with the presence of vape shops at the census tract level?
- RQ 4: How do demographic predictors of vape shops differ from predictors of tobacco retail density?

Chapter 4: Electronic cigarette availability and advertising around high schools

Specific Aim 3: Quantify the availability and marketing of e-cigarettes near New Jersey high schools participating in the New Jersey Youth Tobacco Survey (NJYTS).

- RQ 5: What percentage of sampled schools have at least one e-cigarette retailer within a half-mile, straight line radius?
- RQ 6: What percentage of e-cigarette retailers sell flavored e-cigarettes and e-liquid?
- RQ 7: On average, how many e-cigarette advertisements are visible on the exterior and interior of tobacco retailers?

Specific Aim 4: Describe how e-cigarette availability and advertising near high schools vary across communities.

- RQ 8: How are school enrollment demographics associated with e-cigarette retailer density?
- RQ 9: How are school enrollment demographics associated with the volume of e-cigarette advertisements?

Chapter 5: Association between the tobacco retail environment near schools and electronic cigarette use among youth

Specific Aim 5: Document e-cigarette use among New Jersey high school students.

- RQ 10: What is the prevalence of ever e-cigarette use among New Jersey youth?
- RQ 11: What is the prevalence of current e-cigarette use (i.e., past 30 days) among New Jersey youth?
- RQ 12: Which demographic subgroups have a higher prevalence of e-cigarette use?

Specific Aim 6: Assess the association between the e-cigarette retail environment near schools and odds of e-cigarette use among New Jersey high school students.

- RQ 13: How do the odds of ever and current e-cigarette use differ among students attending schools with varying levels of e-cigarette retailer density?
- RQ 14: How do the odds of ever and current e-cigarette use differ among students attending schools with varying levels of e-cigarette advertising volume?
- RQ 15: How is the proportion of retailers that sell vaping products associated with the odds of ever and current use?

Rationale and Significance

The number of "vape shops" and other e-cigarette retailers is increasing in New Jersey and around the country. Little is known, however, about the types of communities where vape shops are opening. Several New Jersey-focused studies found that *tobacco* retailers are more prevalent in census tracts with lower median household incomes and a high proportion of minority residents, but the state's distribution of *e-cigarette* retailers and vape shops may be strikingly different.⁴⁶⁻⁴⁹ Vaping is widely considered a less hazardous form of nicotine consumption than traditional smoking and may present an opportunity to reduce harm among current smokers who cannot or do not want to quit. If vaping products are less accessible to populations that are most vulnerable to cigarette smoking, the harm reduction benefits of e-cigarettes might be minimized. Conversely, the widespread availability of e-cigarettes may promote product initiation and nicotine addiction among youth or others who might never have used traditional forms of tobacco. Although the relationship between retailer density, point of sale advertising, and *cigarette* smoking among youth is well documented, *vaping* is a relatively new phenomenon that warrants empirical study. The extent to which e-cigarette access and marketing is associated with vaping behaviors among youth is unknown and greatly needed to provide support for regulatory actions and policies restricting product promotion.

New Jersey is an ideal geographic location to study e-cigarette retail. The state has rates of e-cigarette use comparable to national levels and is

racially/ethnically diverse, allowing detailed examination of use behaviors among important subgroups. Furthermore, given the Rutgers School of Public Health's existing relationship with the New Jersey Department of Health, the results of this research may inform future policy/regulatory strategies in the state regarding restrictions on the sale and promotion of e-cigarettes.

Organization of the dissertation

The following chapter (Chapter 2) will provide an in-depth and critical review of the existing literature on tobacco at the point-of-sale. Chapters 3, 4, and 5 will form the basis for three standalone manuscripts that will be submitted to public health and tobacco control journals. These chapters will be formatted as standard research papers, beginning with brief abstracts, followed by Introduction, Methods, Results, and Discussion sections. Chapter 6 will summarize the major findings from each manuscript, identify common themes, discuss public health and policy implications, and propose future research priorities. All references will be presented at the end of the dissertation.

CHAPTER 2: LITERATURE REVIEW

Although the main focus areas in Chapters 3, 4, and 5 all draw from the broader tobacco control literature on product promotion at the point-of-sale, they each address a unique aspect of e-cigarette retail. Chapter 3 focuses on community correlates of retailer density, Chapter 4 is a descriptive study of e-cigarette availability and promotion in stores near schools, and Chapter 5 links the local e-cigarette retail environment with use behaviors among youth. As such, separate literature reviews for each chapter's main theme are presented below.

Community correlates of tobacco retail

Literature on e-cigarette availability and how this differs by neighborhood is scarce. Only two national studies link e-cigarette availability and sales data with community characteristics, and neither includes vape shops in their samples. In 2012, Rose and colleagues conducted store audits of tobacco retailers in a nationally representative sample of communities and documented whether or not stores sold e-cigarettes. They found that approximately one-third of the 4,691 stores in their sample sold e-cigarettes, and that availability was more prevalent in census tracts with a higher median household income, a lower percentage of Black and Hispanic residents, and weak smoke-free air policies (i.e., having a grade of "D" or "F" on the American Lung Association's smoke-free air grade scale).⁵⁰

Using national Nielsen market scanner data, Huang, Tauras, and Chaloupka investigated the price elasticity of e-cigarette demand. They observed

that markets with higher cigarette prices generally had higher sales of e-cigarettes, although this relationship was not statistically significant. Supporting the work of Rose et al., this study also found that sales of disposable e-cigarettes were significantly higher in markets with weak smoke-free air policies. The authors suggest that e-cigarettes may be promoted more heavily in areas where there are more smokers.⁵¹

Given the relative novelty of e-cigarettes in the retail environment, most research documenting community demographic correlates of retailer density has centered on tobacco products, and more specifically, cigarettes. Between 2003 and 2013, ten studies in the United States used GIS techniques to examine associations between retailer density and community demographics. In these studies, the addresses of tobacco retailers were geocoded and linked with census data, usually at the tract level. Most researchers focused on specific geographic areas, including Iowa,^{52,53} New York state,^{54,55} Nebraska,⁵⁶ and New Jersey,⁴⁶⁻⁴⁹ although Rodriguez et al. used data from every census tract in the United States in perhaps the most robust study of tobacco outlet density.⁵⁷

Despite these studies' geographic diversity, differing metrics to calculate density, and varying analytical approaches, three community characteristics consistently predicted high retailer density: low median household income, and high percentages of Black and Hispanic residents. Loomis and colleagues also observed that a higher proportion of youth in a census tract was inversely related to density.⁵⁵ In the only national study on retailer density, Rodriguez et al. noted that urban areas are substantially more likely to have more retailers per 1,000

residents than are rural and suburban tracts, a convergent finding given the tendency of Blacks and Hispanics to live in urban areas.⁵⁷⁻⁵⁹

Tobacco promotion at the point-of-sale

Research assessing e-cigarette advertising via field visits to tobacco retailers is restricted to three small studies. In 2013, Ganz et al. visited all licensed tobacco retailers in Central Harlem, New York City, and determined that 26% of stores had at least one exterior advertisement for e-cigarettes. Nearly half of the stores in the sample sold e-cigarettes, and among those, half sold flavored e-cigarettes.⁶⁰ The remaining two studies focused on e-cigarette advertising and availability surrounding schools and colleges. In a study of two Kentucky counties, 53% of all tobacco retailers also sold e-cigarettes. Furthermore, over two-thirds of the schools in those counties had at least one e-cigarette retailer within a one-mile radius.⁶¹ A longitudinal study of tobacco retailers within a one-mile radius of college campuses in North Carolina and Virginia found that e-cigarette availability and advertising more than doubled between 2012 and 2013. Specifically, e-cigarette availability increased from 25% to 60%, and the presence of interior e-cigarette advertising increased from 13% to 51%.⁶²

Examining trends in tobacco promotion over the last decade may provide insight into current and future e-cigarette marketing strategies in the retail environment. Particularly concerning are tobacco marketing practices in areas where youth are likely to shop and in retailers near schools. In California, Henriksen et al. demonstrated that stores where youth shop frequently had three

times as many advertisements and more shelf space dedicated to the leading cigarette brands than stores less popular among youth.⁶³ In a study of tobacco retailers within a half-mile radius of California schools, the same research team documented greater menthol advertising and lower prices for Newport cigarettes for every percentage increase in Black students.⁴⁰ Other researchers report lower prices of cigarettes⁶⁴ and cigars⁶⁵ in neighborhoods with a higher percentage of youth, and one Massachusetts-based study found that lower income neighborhoods are more likely than higher income neighborhoods to have tobacco advertisements within 1,000 feet of a school.⁶⁶ It is unknown how e-cigarette companies promote their products near schools and places where youth typically shop.

Association between tobacco retail and youth behaviors

Youth smoking

Historically, most studies linking retailer density, point of sale data, and youth tobacco use have focused on cigarette smoking as the primary outcome. In a 30-month longitudinal study of non-smoking adolescents in California, students who reported visiting convenience stores more than twice a week at baseline were significantly more likely to initiate smoking at follow-up compared to students who infrequently visited convenience stores.⁶⁷ Furthermore, self-reported exposure to tobacco advertising at the point-of-sale was associated with cigarette experimentation among California students.^{68,69} In New York, adolescents living in counties with more retail cigarette advertising were more

likely to be current smokers.⁷⁰ This supports Henriksen et al.'s findings that schools in neighborhoods with more tobacco advertisements generally have a higher prevalence of current smoking among students.⁷¹ Slater et al. conducted one of the largest studies linking representative survey data with store audits in close proximity to sampled schools and concluded that a higher volume of point-of-sale tobacco advertisements in a school district was correlated with greater odds of cigarette experimentation.⁷²

Findings on the relationship between retailer density and cigarette use among youth have been mixed. Several studies found crude associations between the two variables, but after controlling for individual and community-level factors, like parental smoking, peer smoking and neighborhood poverty, the relationship disappeared.⁷³⁻⁷⁵ Other research, however, found consistent and positive associations between tobacco retailer density and a variety of smoking behaviors. Four California studies documented significant correlations between high retailer density and ever smoking,^{35,36} past month smoking,^{34,35} and among current smokers, increased consumption.³⁷ Two studies in Illinois observed that, after controlling for potential confounders at the individual and community level, the relationship between retailer density and ever and current smoking persists.^{38,39}

Youth e-cigarette use

Data from the 2014 NYTS indicated that youth with more frequent exposure to tobacco advertisements in the retail environment had greater odds of

e-cigarette experimentation compared to youth who “never” or “rarely” saw tobacco advertisements at stores.⁷⁶ This is the only study to date linking tobacco advertising exposure to e-cigarette use, although it did not specifically assess exposure to *e-cigarette* advertising. Furthermore, exposure to tobacco advertising was measured through self-reports and not store audits.

In the only study predicting initiation of non-cigarette tobacco products using tobacco outlet density as an independent variable, Cantrell et al. linked responses from a national survey of young adults with the density of retailers in the census tract where the respondent lived.⁷⁷ Results differed by age group; retailer density was a strong predictor of non-cigarette combustible product experimentation (e.g., cigars, hookah) for young adults between 18-24 years old. For those between 25-34 years old, increased density was significantly associated with cigarette initiation. No association between retailer density and use of non-combustible tobacco products was found for either age group.⁷⁷ Importantly, “non-combustible tobacco products” included traditional forms of smokeless tobacco, like moist snuff and snus, as well as e-cigarettes, which may have influenced the non-significant findings. Furthermore, the study was restricted to young adults; it is unknown if retailer density differentially impacts youth experimentation with e-cigarettes and other non-cigarette tobacco products.

Summary of the literature

To date, nearly all of the literature on tobacco at the point-of-sale has focused on cigarettes. Cigarette retailer density and advertising volume is higher in communities with lower income levels and higher proportions of racial and ethnic minorities. Cigarette promotion is particularly prevalent in retailers near schools, with some evidence suggesting that the tobacco industry targets neighborhoods where Hispanic and black youth live and go to school. Moreover, increased exposure to cigarettes at the point-of-sale is strongly linked to smoking initiation among youth.

Preliminary evidence indicates that community-level predictors of *e-cigarette* retail may differ from traditional correlates of tobacco retail, though no study has investigated the emerging vape shop channel. At present, e-cigarettes seem to be more available in communities that have proportionally fewer minority residents and higher income levels. Very few studies, however, have assessed the prevalence of e-cigarette availability in stores, with estimates ranging from 45% to 60%. The rapidly-evolving e-cigarette marketplace warrants continued research on e-cigarette promotion in retail settings. Finally, no research has assessed the link between e-cigarette retail in a community and vaping behaviors among youth. The subsequent chapters in this dissertation will fill these important research gaps.

CHAPTER 3: THE GEOGRAPHIC DISTRIBUTION OF VAPE SHOPS AND ITS ASSOCIATION WITH COMMUNITY DEMOGRAPHICS

ABSTRACT

Introduction: Vape shops are opening across the U.S., but little is known about the types of neighborhoods where they are located. This study explores community-level predictors of vape shop locations in New Jersey, U.S.A.

Methods: Vape shops were identified in July 2015 using a validated systematic online search protocol and geocoded using Google Earth Pro. Multivariable logistic regression identified demographic other predictors of vape shop presence at the census tract level.

Results: Tobacco outlet density was consistently associated with higher odds of vape shop presence after adjusting for covariates ($p < 0.05$). However, factors traditionally associated with tobacco retail were *negatively* associated with vapor outlets. Census tracts with a higher proportion of non-Hispanic black residents had significantly lower odds of having a vape shop ($\beta = -0.03$, $p < .001$).

Discussion: Vape shops are commonly located where smokers live, although residents in these census tracts are predominantly white. Current evidence suggests that vaping may be less risky than cigarettes; differential access to less

harmful nicotine delivery systems may exacerbate smoking-related health disparities.

INTRODUCTION

Decades of tobacco control research acknowledge the importance of the retail environment in influencing use behaviors. High tobacco retailer density in neighborhoods, for example, has been associated with ever^{35,36,38} and current^{34,35,39} smoking among youth, and among adults, increased cigarette consumption³⁷ and reduced odds of quitting.⁷⁸ Although the mechanisms through which such relationships operate are multifaceted and not entirely understood, accessibility of tobacco products likely shapes social norms regarding smoking in certain communities. Moreover, the convenience of multiple nearby retailers and repeated exposure to industry marketing at the point of sale likely serve as environmental cues to smoke.⁷⁸ The increasing popularity and availability of electronic nicotine delivery systems (ENDS) necessitates similar research on the ENDS retail environment at the neighborhood level. Sometimes called “e-cigarettes,” “vape pens,” or “vaporizers,” ENDS are battery-operated devices that heat and vaporize a liquid solution, delivering nicotine to users in a way that mimics the look and feel of conventional cigarette smoking. Prevalence of ENDS use in the U.S. is increasing among youth^{18,19} and adults,^{14,79} and in 2015, the vapor market is expected to reach \$3.5 billion in sales.⁴¹ In recent months, the U.K. government released a report concluding that e-cigarettes are substantially less risky than traditional cigarettes.⁸⁰

Given the relative novelty of ENDS in the retail environment, little is known about the types of communities where ENDS availability is highest. Research documenting neighborhood-level correlates of retailer density has centered on

tobacco products, and more specifically, cigarettes. Despite these studies' geographic diversity, differing metrics to calculate density, and varying analytical approaches, three community characteristics consistently predict high tobacco retailer density: low median household income, and high percentages of black and Hispanic residents.^{46-48,53-57} However, in the only study linking ENDS availability with community demographics, Rose and colleagues found that in a national sample of tobacco retailers, e-cigarette availability was more prevalent in census tracts with a higher median household income and a lower percentage of minority residents.⁵⁰ Traditional tobacco retail outlets, like those visited in the aforementioned study, remain major ENDS distribution channels,⁴² but the retail landscape of the vapor market is increasingly diversifying.

"Vape shops," independent retailers that specialize in the sale of ENDS, are opening across the U.S. Although it is difficult to determine the total number of vape shops in the country due to varying definitions of "vape shop" and the lack of a comprehensive retailer database, estimates typically range from 3,500 to 5,000, with some industry experts projecting numbers as high as 35,000.^{43,81,82} Within the \$3.5 billion vapor market, a third of all sales are estimated to occur in vape shops, making it the single largest channel in the category.⁸¹ These stores differ from other types of ENDS retailers in that they offer a wide variety of ENDS devices, including advanced-generation vaping products not currently available in convenience stores or drug stores.⁴³ Most do not sell brands that are owned by tobacco companies, and an adversarial relationship exists between the vape shop industry and Big Tobacco.⁸³ For example, Reynolds American recently

called on the FDA to ban “open-system” vapor products, largely seen as an attack on the burgeoning vaping industry, which specializes in these devices.⁸³ Because vape shops do not require a special operating license in most states, they have been notoriously difficult to locate and are absent in studies assessing the ENDS retail environment.⁸⁴ Despite the increased visibility of vape shops, no research to date has quantitatively described the types of communities in which these retailers are opening.

The observable growth in vape shop openings may indirectly communicate messages to community residents about the products’ popularity and acceptability, and may even influence ENDS use. The demographic profiles of neighborhoods containing vape shops are understudied, and it is unknown whether vape shop presence is related to the proximate tobacco retail environment. The aims of this study were to identify the locations of vape shops in New Jersey, examine the demographic characteristics of the census tracts in which they are located, explore the relationship between vape shop locations and tobacco retailer density, and describe the geographical diffusion of vape shops over time. Based on previous studies of ENDS availability in the traditional tobacco retail environment,⁵⁰ as well as known demographic predictors of e-cigarette use,⁸⁵ we hypothesized that vape shops would be present in areas with a higher percentage of non-Hispanic white residents and higher median income. We also explored other potential community correlates of vape shop presence, including the size of the youth population, median age, percent Hispanic and non-Hispanic black, and educational attainment of the adult population.

METHODS

Vape shop identification and geocoding

Recognizing the general anti-tobacco sentiments of the vape shop industry,⁸³ we defined a “vape shop” as a retailer that sells vaping products and its accessories but does not sell tobacco products, a criterion used to identify vape shops in a previous study.⁸⁴ Thus, smoke shops, convenience stores, drug stores, and mass market retailers that sell tobacco products are not considered vape shops, even though many carry ENDS. Although smoke shops and other types of tobacco stores may have an extensive selection of vaping products, these retailers are licensed to sell tobacco products and so are included in studies that use licensing lists to sample stores. The vape shop is a distinct entity that has been virtually invisible from efforts to describe ENDS availability at the neighborhood level.

Unlike tobacco retailers, vape shops in New Jersey are not required to have a license to sell their products. Consequently, no “master list” of vape shops exists, which necessitates innovative strategies to identify their addresses. However, Yelp, a popular business review website and mobile application, allows users to locate businesses by searching retailer categories paired with geographic locations. After pressure from the Smoke-Free Alternatives Trade Association (SFATA), Yelp added a category for vape shops in 2014, which now represents the most popular way new vape shops advertise their businesses.⁸⁶ Yelp was used to identify vape shops in a recent California-based study,⁸⁷ and

the site has been validated as a promising methodology to identify vape shop locations.⁸⁴ In a study assessing the utility of online search tools to identify vapor stores, 77.6% of Yelp results were determined to be accurate, notably higher than other popular search engines.⁸⁴

In addition to searching the vape shop category in New Jersey using Yelp, we developed a protocol to identify additional vape shops in the state using systematic Internet searches of Google, Google Maps, Facebook, and vape shop directories on several websites dedicated to vaping (e.g., vaporsearchusa.com, vapeabout.com). Search terms included “vape shop,” “vaping lounge,” “vapor store,” and “e-cigarettes.” To confirm that the identified vape shops were open, operating, and did not sell tobacco products, each store was contacted via telephone before being entered into a master database. Shop owners or employees were also asked to provide the month and year that the shop opened. Data collection occurred in June and July 2015. Once the operational status of all vape shops was confirmed, the addresses were batch geocoded using Google Earth Pro and imported as a KML file into ArcGIS (v.10.1). Google Earth Pro was used for geocoding due to its ability to help validate the results through aerial and street view imagery of the building exterior. Google Earth Pro has been used to geocode addresses in other public health studies.⁸⁸

Tobacco retailer density

A list of the licensed tobacco retailers in the state was obtained from the New Jersey Department of Health; these addresses were geocoded using

Google Earth Pro. Three of the most commonly used measures were calculated for each census tract in ArcGIS: retailers per 1,000 residents, retailers per square mile, and retailers per 10km of roadway (road line files obtained from the New Jersey Office of Information Technology, Office of GIS). Census tract was chosen as the geographical unit of analysis to maintain consistency with the majority of studies on tobacco retailer density.^{46-48,53-57}

Demographic data source

The demographic attributes of New Jersey's census tracts, generated using the 2013 American Community Survey (ACS) 5-year estimates, as well as a TIGER/Line® map of the state's census tracts, were downloaded from the U.S. Census Bureau website. Demographic variables included total tract population, proportion of youth (i.e., under 18 years old) and young adults (i.e., 18 to 24 years old), median age, distribution of racial/ethnic groups, educational attainment of the adult population, median household income, and proportion of residents without health insurance. Using the Join tool in ArcGIS, the data tables were linked with their corresponding census tract shapefiles. Non-residential, institutional, or atypical census tracts, such as prisons and military bases, were excluded from analyses (n=21).

Statistical analysis

The Spatial Join tool in ArcGIS identified all census tracts with at least one vape shop located within its administrative boundaries. Mann-Whitney *U* tests

highlighted differences in demographic characteristics and tobacco retail density between census tracts with and without vape shops. Since the main outcome of interest was binary (i.e., presence or absence of a vape shop), logistic regression estimated the odds of a census tract having a vape shop using census demographics and tobacco retailer density measures as the independent variables. Demographic factors empirically shown to predict tobacco retailer density were also included in each model. To examine potential differential associations between vape shop presence and the three measures of tobacco retail density, each was included in separate logistic regression models. Given the tendency of geographically adjacent areas to be more similar than distant ones, the independence assumption of logistic regression may be violated whenever analyzing place-based data. To assess possible clustering of vape shop locations, “spatial autocorrelation” was tested using the join count statistic, a preferred test when the outcome of interest is binary or categorical.^{89,90}

To explore temporal changes in the types of communities where vape shops opened, Spearman rank-order correlation coefficients were calculated to assess the relationship between the number of months since store opening and census tract demographics. The number of months since each vape shop opened was calculated based on the date that the store owner or employee provided during the phone calls and July 2015. A *p*-value of less than 0.05 determined statistical significance for all tests, and SAS (v.9.3, SAS Institute, Inc., Cary, NC) was used for all analyses.

RESULTS

A total of 130 vape shops were identified and successfully geocoded. In total, 125 of the 1,989 census tracts included in the analysis contained at least one vape shop (6.3%). Only 5 tracts contained more than one vape shop. Of the vape shops identified, the earliest reported opening date was May 2011. A total of 38 vape shops opened from 2011 through 2013, 62 opened in 2014, and another 30 opened in the first half of 2015 alone, demonstrating significant growth over time.

The demographic characteristics of census tracts with and without vape shops are shown in Table 1. On average, census tracts containing at least one vape shop had a significantly lower percentage of black residents than those with no vape shops (7.9% versus 15.6%, respectively; $p<.001$). Correspondingly, census tracts with a vape shop had a higher proportion of non-Hispanic white residents (65.6%) compared to census tracts without vape shops (57.4%; $p<.001$). Neighborhoods with vape shops had a smaller youth population than vape shop-free neighborhoods, though this difference is minimal ($p=0.01$). The number of tobacco retailers per 1,000 residents was the only retailer density measure that significantly differed between census tracts where vape shops were present and absent.

The join count statistic indicated no evidence of spatial autocorrelation or clustering ($z=0.05$, $p>0.05$), and thus logistic regression proceeded without geographically-weighted adjustments. Due to a high degree of correlation between percent black residents and percent non-Hispanic white residents ($r=-$

0.71), as well as median income and percent with less than a high school education ($r=-0.71$), the non-Hispanic white and educational attainment variables were excluded from the final regression model to avoid potential effects of multicollinearity. A comparison of model fit statistics determined that median income fit the data best as a categorical variable grouped into quartiles, rather than as a continuous variable.

In each of the three models, percent black, percent Hispanic, and income quartiles significantly predicted the odds of a census tract having at least one vape shop after adjusting for all covariates, including tract population size (Table 2). Percentage of black residents in a census tract was a particularly strong covariate (AOR: 0.96 [0.95-0.98] in Model 1). For every 10 percentage point increase in a census tract's black residents, the odds of a vape shop being present decreased by 33%. The percentage of Hispanic residents demonstrated a similar but smaller effect. Income quartiles were also associated with vape shop presence, such that lower income census tracts had higher odds of having a vape shop compared to the highest income tracts. In all models, tobacco retailer density significantly and positively predicted the odds of vape shop presence. The number of retailers per 1,000 residents exhibited the strongest effect of all density measures. For each additional retailer per 1,000 census tract residents, the odds of having a vape shop increased by 63%.

The negative association between the number of months since each vape shop opened and all three tobacco retailer density measures (Table 3) indicates that stores that opened more recently (i.e., have been open fewer months)

increasingly opened in census tracts with a high density of tobacco retailers.

There was no evidence that store opening dates were associated with residents' race/ethnicity, youth population, or median income.

DISCUSSION

Mirroring national trends, the vaping industry is rapidly expanding across New Jersey, as evidenced by the accelerated growth in vape shop openings since 2011. The strong association between vape shop presence and tobacco retailer density, tested using three of the most common density metrics, suggests that vapor outlets are opening in areas where more smokers live. This is consistent with the literature documenting higher rates of e-cigarette use among current and former smokers,^{7,14,91,92} and may explain why lower income tracts were more likely to have a vape shop compared to those in the highest income quartile; smoking prevalence and tobacco retailer density are inversely related to income levels.⁹³ As hypothesized, the results demonstrated that vape shops were more likely to be located in census tracts with a high proportion of non-Hispanic white residents, and less likely to open in neighborhoods where a large percentage of the population is black. At present, there is no evidence to indicate that vape shops are expanding to more racially diverse areas. Vape shop presence was not associated with a neighborhood's youth population, median age, or educational attainment.

This study has several limitations. We did not capture vape shops that may have opened and then closed before this study was conducted. It is

possible that not all vape shops that were currently operating in New Jersey at the time of this study were identified using our search strategies. Smaller businesses that do not advertise online, for example, may have been overlooked. Since vape shops are emergent businesses vying for customer patronage, however, it is expected that a majority of vape shops will have an online presence. Furthermore, recent vape shop studies using Yelp as a search methodology add to the growing literature validating the site as a legitimate research tool.⁸⁴ Retailers that may sell a wide variety of vaping products were not included in the study if they also sold tobacco products. Although this may introduce potential biases, retailers that do sell tobacco inherently promote use of these products. Anecdotal data from conversations with vape shop owners suggests that many have strong anti-tobacco sentiments, as illustrated by the window art shown in Figure 1. Data collection for this study occurred in July of 2015. Considering the rapid changes in the vapor market, as well as impending FDA e-cigarette deeming regulations, the landscape of vapor retail locations may shift, and the conclusions presented here may differ from future analyses. Also, the extent to which the results of this study in New Jersey are generalizable to other geographic regions is unknown. Finally, the demographic profiles of vape shop locales may not reflect the stores' clientele, some of whom may reside in other neighborhoods. Still, the presence of vapor outlets in a community may indirectly communicate messages about vaping norms and risks to the residents living there.

The long term health effects of vaping are currently unknown, but current research indicates that emissions from ENDS vapor are substantially less risky than cigarette smoke.⁸⁰ If these devices are ultimately found to pose less health risks compared to smoking, and do not lead to increased initiation among nonusers or relapse among former smokers, the implications for individual and public health benefit could be great. ENDS users often report that advanced generation vaping products, like those available in vape shops, deliver nicotine better than first generation models, which could potentially influence cessation outcomes.⁹⁴ If these products are less accessible to smokers living in areas with high minority populations, as this study demonstrates, a potential unintended consequence could be widening of existing health disparities related to smoking cessation, particularly among non-Hispanic blacks.^{95,96} Additional research is needed to explore attitudes toward vaping and reasons for use among various population subgroups, as well as the influence of vape shop presence and e-cigarette availability on the vaping behaviors of community residents.

Table 1. Demographic characteristics of New Jersey census tracts with and without vape shops

	Vape shop present		No vape shop present		p-value ^a
	n=125	mean (sd)	n=1,864	mean (sd)	
Total population		4,860 (1,740)		4,401 (1,800)	<.01
Percent youth (under 18 years)		21.7 (4.8)		22.9 (6.3)	<.01
Percent young adults (18-24 years)		11.6 (5.9)		11.4 (6.8)	0.17
Median age		39.5 (5.4)		39.7 (7.4)	0.98
Percent black, non-Hispanic		7.9 (11.2)		15.6 (23.1)	<.01
Percent Hispanic		16.3 (16.1)		18.2 (20.6)	0.63
Percent white, non-Hispanic		65.6 (24.6)		57.4 (30.9)	0.01
Percent with less than high school education		11.6 (8.1)		12.6 (10.4)	0.79
Median income		35,207 (10,059)		36,142 (13,901)	0.88
Percent without health insurance		13.2 (8.1)		13.1 (9.7)	0.22
Tobacco retailer density (per square mile)		14.3 (29.5)		12.8 (25.7)	0.06
Tobacco retailer density (per 1,000 residents)		1.8 (1.6)		1.2 (1.1)	<.001
Tobacco retailer density (per 10 km roadway)		3.2 (5.2)		2.7 (4.1)	<.01

^aMann-Whitney U tests determined statistically significant differences between group measures of central tendency; bolded values indicate statistically significant findings

Table 2. Adjusted odds of vape shop presence among New Jersey census tracts

	Model 1				Model 2				Model 3			
	β	AOR ^a	95% CI ^b	p-value ^c	β	AOR	95% CI	p-value	β	AOR	95% CI	p-value
Percent youth (under 18 years)	-0.01	0.99	(0.96-1.02)	0.57	0.01	0.99	(0.96-1.03)	0.66	-0.01	0.99	(0.96-1.03)	0.67
Percent black, non-Hispanic	-0.03	0.97	(0.96-0.99)	<.001	-0.04	0.96	(0.95-0.98)	<.001	-0.03	0.97	(0.96-0.99)	<.001
Percent Hispanic	-0.02	0.98	(0.97-1.00)	0.02	-0.01	0.99	(0.97-1.00)	0.03	-0.02	0.98	(0.97-1.00)	0.01
Median income quartiles												
Lowest (<\$26,303)	0.27	2.8	(1.32-5.95)		0.13	2.09	(0.96-4.59)		0.26	2.74	(1.29-5.82)	
Second (\$26,303-\$34,801)	0.26	2.77	(1.53-5.01)	<.01	0.23	2.32	(1.27-4.21)	0.02	0.26	2.74	(1.51-4.95)	<.01
Third (\$34,802-\$43,699)	0.22	2.66	(1.52-4.65)		0.25	2.35	(1.34-4.12)		0.24	2.68	(1.54-4.69)	
Highest (>\$43,699)	1	referent			1	referent			1	referent		
Retailer density (per square mile)	0.01	1.01	(1.00-1.01)	<.01								
Retailer density (per 1,000 residents)					0.49	1.63	(1.41-1.88)	<.001				
Retailer density (per 10 km roadway)									0.08	1.09	(1.04-1.14)	<.001

^aAOR: Adjusted odds ratio – adjusted for all variables in table and total population of census tract (not shown); ^b CI: Confidence interval; ^c Bolded values indicate statistically significant findings

Table 3. Correlation between number of months since vape shop opening date^a and census tract demographics (n=130)

	mean (sd)	ρ^b	p -value
Total population	4,904 (1,754)	0.04	0.65
Percent youth (under 18 years)	21.7 (4.8)	0.01	0.94
Percent young adults (18-24 years)	9.0 (4.8)	-0.04	0.66
Median age	39.5 (5.3)	0.11	0.23
Percent black, non-Hispanic	7.8 (11.1)	-0.17	0.05
Percent Hispanic	16.0 (15.8)	-0.07	0.46
Percent white, non-Hispanic	65.9 (24.5)	0.10	0.26
Percent with less than high school education	11.4 (8.0)	-0.13	0.15
Median income	35,627 (10,173)	0.09	0.33
Tobacco retailer density (per square mile)	14.2 (29.2)	-0.24	0.01
Tobacco retailer density (per 1,000 residents)	1.8 (1.6)	-0.18	0.04
Tobacco retailer density (per 10 km roadway)	3.2 (5.1)	-0.20	0.03

^aTime between store opening date and July 2015, in months; ^b Spearman's rank-order correlation examined monotonic associations between date of store opening and community demographics; bolded values indicate statistical significance

Figure 1. Window art in a New Jersey vape shop



CHAPTER 4: ELECTRONIC CIGARETTE AVAILABILITY AND ADVERTISING AROUND HIGH SCHOOLS

ABSTRACT

Background: E-cigarette companies are increasingly promoting their products at the point of sale, but little is known about e-cigarette availability and advertising in tobacco retailers near schools, and how point of sale marketing may differ across communities.

Methods: Between March and June 2015, researchers visited 194 tobacco retailers within a half-mile of a sample of representative New Jersey high schools. They documented the presence and number of e-cigarette advertisements, as well as product availability, and examined associations with store type and school enrollment demographics. Weighted measures were created to capture e-cigarette promotion as a function of total tobacco product promotion.

Results: Nearly a third (30%) of all tobacco retailers had exterior e-cigarette advertising, however this was significantly more common in gas stations and convenience stores ($p<.001$). E-cigarettes were sold in 58% of stores, and availability was highest in gas stations and drug stores ($p=0.05$). E-cigarette retailer density was significantly correlated with the percentage of students receiving free or reduced lunch ($r_s=0.44$, $p<.01$). E-cigarette advertising was

positively associated with a school's percentage of Hispanic students ($r_s=0.34$, $p=0.03$) and negatively associated with the percentage of non-Hispanic white students ($r_s=-0.34$, $p=0.03$).

Discussion: E-cigarettes are widely available in tobacco retailers near schools, particularly in stores that youth typically visit. Current measures of e-cigarette retail may serve as a proxy for the total tobacco retail environment. More nuanced measures are needed that adjust for the promotion of e-cigarettes relative to other tobacco products. Future research should examine whether e-cigarette retail is associated with use among youth.

BACKGROUND

After the Master Settlement Agreement restricted billboard advertising and other forms of tobacco marketing, cigarette companies began heavily promoting their products at the point of sale, particularly in convenience stores and gas stations.²⁷⁻³¹ In 2012 alone, the tobacco industry spent \$9.2 billion on cigarette advertising and promotion in the retail environment.⁹⁷ Stores where youth frequently visit, such as tobacco retailers near schools, often have disproportionately high levels of tobacco marketing.^{40,63} Retail-based marketing strategies are effective, with numerous studies documenting the strong relationship between exposure to tobacco advertising at the point of sale and susceptibility to smoking, particularly among youth.^{32,33} Electronic cigarettes (e-cigarettes) have recently entered the U.S. marketplace, and it has been projected that their sales may surpass cigarette sales within the next decade.⁴¹ The marked growth in e-cigarette purchases is likely driven in part by increasing advertising expenditures. Between 2011 and 2013, for example, Blu and NJOY advertised more heavily than any other e-cigarette brands and subsequently dominated the market.^{98,99} Although data on e-cigarette advertising in traditional media channels like television, radio, and print are accessible to researchers, information about patterns of e-cigarette marketing at the point of sale is not routinely collected and reported.

Despite the recent emergence of stores specializing in vapor product sales (i.e., “vape shops”), traditional tobacco retailers remain important outlets for e-cigarette retail. E-cigarette sales in the convenience store channel, for

example, more than doubled between 2012 and 2013.⁴² Unlike vape shops, which often exhibit anti-tobacco sentiments and rarely carry e-cigarette brands owned by tobacco companies,^{82,83} traditional tobacco retailers present Big Tobacco with opportunities to leverage existing relationships with store owners in order to market their own vapor products. Indeed, the acquisition and/or development of e-cigarette brands by tobacco companies are clear catalysts for brand growth. After Lorillard acquired Blu e-cigs in 2012, for example, the brand quickly became the market leader.⁴² Vuse, owned by RJ Reynolds, entered the market in 2013 and currently dominates the convenience store channel.⁴¹

Surveillance of the retail environment is an important tool in tobacco control to identify emergent trends and monitor industry initiatives. Store audits can identify promotional trends before sales and marketing data become available to researchers. Furthermore, they can garner support for policies restricting the sale and promotion of tobacco products to youth.¹⁰⁰ To date, research assessing the marketing of e-cigarettes in tobacco retail locations is restricted to a few studies,^{50,60-62} with emerging evidence indicating increasing availability over time.⁶² Little is known about the availability and advertising of e-cigarettes in retailers around schools, and how e-cigarette retailer density and marketing differ by store type and community demographics. Additionally, more nuanced measures of e-cigarette retailer density and marketing are needed that account for the overall tobacco retail environment. In some communities, for example, e-cigarettes advertisements are present, but virtually hidden by a comparatively higher volume of tobacco advertisements. At present, no study

has conceptualized an e-cigarette retail density metric that adjusts for the tobacco retail environment.

The goal of this study was to characterize e-cigarette retail around a representative sample of high schools in New Jersey, a densely populated and ethnically diverse state. We examined the following research questions: (1) what is the availability of vapor products and the presence of e-cigarette advertising?; and (2) are the availability of vapor products and presence of e-cigarette advertising associated with school enrollment demographics? Unadjusted measures of e-cigarette retail and measures that account for the total tobacco environment were compared to examine their impacts on study findings.

METHODS

Retailer selection

The New Jersey Department of Health provided a list of the state's licensed tobacco retailers as of January 2015, which were geocoded using Google Earth Pro and imported into ArcGIS (v.10.1) as a KML file. Google Earth Pro enabled the investigators to verify the accuracy of plotted locations using aerial and street view imagery, and has been used to geocode addresses in other public health research.⁸⁸ The addresses of the high schools participating in the 2014 New Jersey Youth Tobacco Survey (NJYTS)¹⁰¹ were also geocoded using the methods described above. These high schools were randomly selected for participation in the NJYTS with probability proportionate to enrollment size; they represent both urban and suburban communities and have racially and

ethnically diverse student bodies. School enrollment data were downloaded from the New Jersey Department of Education website.¹⁰² A half-mile, straight line buffer was drawn around each high school. Egocentric buffers are commonly used to characterize the tobacco retail environment around schools in the U.S. and typically range from a half-mile to one mile in published studies.^{34,36,38,71} A half-mile was selected for this project because this distance falls within what adolescents perceive to be an easy walking distance.¹⁰³ The Spatial Join tool in ArcGIS identified all retailers falling within the buffer zones. Restaurants, bars, and large supermarkets were eliminated from the final sample of retailers since they do not represent the “traditional” tobacco retail environment where youth typically shop and visit.⁶⁹ Nielsen sales data estimate that most e-cigarette sales in traditional tobacco retailers occur in convenience and drug stores; only 2% occur in the food and mass merchandiser channel.⁴²

Store audits

All sampled stores were visited between March and June 2015. Using Qualtrics survey software on iOS and Android smartphones, two trained research staff collected data on store type, the presence and number of interior and exterior e-cigarette advertisements, and e-cigarette availability. To examine e-cigarette promotion in relation to other tobacco products, the data collection instrument also included measures for cigarette, cigar, and smokeless tobacco advertising. Store type was coded as: convenience store, convenience store with gas, drug store, liquor store, or other. An “advertisement” was defined as an

industry-made sign featuring a tobacco company's logo and/or an image of the product. Only advertisements clearly visible walking past the storefront or standing in front of the cash register were counted. Researchers documented the availability of e-cigarettes, flavored e-cigarettes (not menthol), and "open tank" e-cigarette systems, which are typically sold with bottles of e-liquid that users add to the devices. Each store visit lasted approximately 10 minutes.

Measures of e-cigarette retail

Tobacco retailer density around schools is often calculated as the number of tobacco retailers within a geographic buffer zone.^{34,36,38,71} Although the raw number of nearby retailers that sell e-cigarettes is an important indicator of accessibility, a weighted score that adjusts for e-cigarette availability in the context of the total tobacco retail environment is needed to accurately describe students' exposure to e-cigarettes at the point of sale. For example, consider a school where 1 out of 100 nearby tobacco retailers sells e-cigarettes. This school would receive the same e-cigarette retailer density score as a school with one nearby tobacco retailer that sells e-cigarettes (i.e., 1 e-cigarette retailer within a half-mile radius). Similarly, the unadjusted number of e-cigarette ads around a school can document advertising volume, but a more nuanced measure that considers e-cigarette advertising as a proportion of total tobacco advertising can better describe e-cigarette promotion.

To create a weighted measure of e-cigarette retailer density for each school, the number of e-cigarette retailers was multiplied by the proportion of all

tobacco retailers that sold e-cigarettes. In the example above, the first school would receive a density score of 0.01—one e-cigarette retailer x 1% of tobacco retailers that sold e-cigarettes—while the second school would receive a density score of 1. Weighted measures of advertising volume were calculated in the same way. The total number of e-cigarette ads in the buffer zone was multiplied by the proportion of all tobacco ads that were for e-cigarettes.

Statistical analysis

To assess intercoder reliability between research staff, 10% of sampled stores were simultaneously audited by two researchers. SPSS (v.21) was used to calculate intraclass correlation coefficients (ICC)¹⁰⁴ for each continuous measure, such as number of e-cigarette advertisements; Cohen's kappa statistics¹⁰⁵ assessed agreement on nominal measures, such as e-cigarette availability. Intercoder reliability was excellent across all measures: ICC values and kappa statistics ranged from 0.8 to 1.0 for all continuous and categorical measures on the data collection instrument. Frequency tables and crosstabs described the prevalence of e-cigarette advertising and availability, and chi-square tests determined if these factors significantly differed by store type. Spearman coefficients examined correlations between school enrollment demographics (i.e., racial and ethnic makeup, percent of students receiving reduced or free lunch), tobacco retailer density, e-cigarette retailer density, and volume of tobacco and e-cigarette ads because the data had non-normal

distributions. The unadjusted and weighted e-cigarette retail measures are both presented.

RESULTS

Store characteristics

Of the 41 schools participating in the 2014 New Jersey Youth Tobacco Survey, 27 had at least one tobacco retailer within a half-mile radius and were visited by research staff. The number of proximate retailers per school ranged from 1 to 53 with a mean of 8.2 and a standard deviation of 10.9. Data were successfully collected from 194 stores in the initial sample, yielding a completion rate of 91%. Nineteen retailers were not visited because they were either closed, could not be located, or the owner was not comfortable with research staff auditing the store. The majority of retailers were convenience stores (50%) and convenience stores with gas (15%), followed by liquor stores (12.9%), drug stores (9.3%), and other types of retailers (12.9%), which included dollar stores, cigar shops, and head shops.

E-cigarette availability and advertising

Table 1 describes the presence of e-cigarette ads and the availability of various e-cigarette products. Across all stores, 29.4% and 32.0% had at least one exterior and interior ad, respectively. Although interior advertising did not differ by store type, exterior advertising was significantly more common in convenience stores with gas ($p < .001$). Notably, no drug stores in the sample had

exterior advertising. Nearly all drug stores, however, carried e-cigarettes (88.9%, $p=.05$), compared to an overall prevalence of 57.7%. Availability of “open tank” e-cigarettes that allow users to add their own e-liquid was significantly higher in convenience stores with gas (48.3%) and drug stores (55.6%) than in other store types ($p<.001$). Less than a quarter of all retailers displayed e-cigarettes on the counter near the cash register, with this practice being more common in convenience stores with gas and liquor stores.

School demographics and tobacco/e-cigarette retailer density

As shown in Table 2, correlations between school demographics and unadjusted e-cigarette retail density (i.e., the raw number of e-cigarette retailers) were nearly identical to correlates of tobacco retail density. A school’s percentage of Hispanic students was significantly associated with the number of tobacco and e-cigarette retailers within a half-mile radius, such that availability of both products increased concurrently with increases in a school’s proportion of Hispanic students ($r_s=0.36$, $p=0.02$). A similar but stronger relationship was observed between a school’s percentage of students receiving free or reduced lunch and the availability of tobacco and e-cigarettes ($r_s=0.52$, $p<.001$ and $r_s=0.49$, $p<.01$, respectively). Conversely, an increasing proportion of non-Hispanic white students corresponded with a decrease in the number of nearby tobacco and e-cigarette retailers ($r_s=-0.39$, $p=0.01$ and $r_s=-0.34$, $p=0.03$, respectively).

After weighting the e-cigarette density measure as a function of the number of tobacco retailers, however, the magnitude of the associations weakens, resulting in significance levels that exceed the $p=0.05$ threshold for statistical significance. The percentage of the student body receiving free or reduced lunch remains the only demographic predictor of e-cigarette retail using the adjusted metric ($r_s=0.44$, $p<.01$).

School demographics and tobacco/e-cigarette advertisements

Table 3 describes the associations between school enrollment demographics and the volume of tobacco and e-cigarette advertisements within a half-mile radius. Again, correlations for both the unadjusted number of e-cigarette advertisements and a measure that accounts for the total number of tobacco product advertisements are presented. Overall, correlates of tobacco and e-cigarette advertising were similar to the correlates of retail density presented above. Particularly notable was the strong, positive relationship between the proportion of students receiving free and reduced lunch and the number of ads in stores near schools ($p<.001$). Although significant correlates of e-cigarette marketing remain unchanged across all measures when using the adjusted e-cigarette metric, the strengths of association substantially weaken.

DISCUSSION

E-cigarettes were widely available in tobacco retailers within close proximity to high schools in New Jersey. Nearly 60% of all visited stores offered

the products and 40% sold flavored varieties, including fruit and candy flavors. Open tank e-cigarettes were available in 21% of stores. Tank-like systems are frequently sold with e-liquid bottles that come in a variety of flavors, and some e-cigarette companies even encourage users to follow “recipes” by mixing several e-liquid flavors.¹⁰⁶ The presence and visibility of flavored e-cigarettes near schools is concerning. Recent data from the Population Assessment of Tobacco and Health (PATH) study suggest that youth have a strong preference for flavored e-cigarettes.¹⁰⁷ It is currently unknown which categories of e-cigarettes, or e-cigarette accessories such as e-liquid bottles, appeal most to youth.

The types of e-cigarettes available varied significantly by store type, with tank systems being more likely to be sold in drug stores and convenience stores with gas. It should be noted that all of the drug stores and gas station convenience stores in the sample were larger, chain stores (e.g., Walgreens, Exxon). Since tank systems are typically more expensive than “cigalikes,” it is likely that smaller, independently-owned retailers may not be willing to risk sales losses if consumer demand for the devices is low. E-cigarette advertising is markedly higher in convenience stores and convenience stores with gas compared to other tobacco retail locations. These two retail locations are popular among youth and are associated with tobacco purchasing behaviors. In 2013, for example, 1 out of 5 high school smokers bought their cigarettes from a convenience store or a gas station.¹⁰⁸

A comparison of tobacco retailer density versus a crude, unadjusted measure of e-cigarette retailer density (i.e., the number of tobacco retailers that

sell e-cigarettes) revealed that this simplified measure of e-cigarette availability acts as a proxy for tobacco retail density. In other words, school zones with many tobacco retailers are more likely to have a higher number of e-cigarette retailers. After accounting for the relative availability and marketing of e-cigarettes compared to tobacco products, the strength of association for several correlates substantially weakens. Specifically, the percentages of the student body that are non-Hispanic white or Hispanic are no longer significantly associated with e-cigarette retail at the $p < 0.05$ level. This suggests that in predominantly Hispanic communities, e-cigarettes may be overshadowed by a high volume of tobacco products. Conversely, in largely white communities, e-cigarettes may be promoted at proportionately greater rates.

Interestingly, national estimates of e-cigarette use among youth document the highest rates of current use among non-Hispanic white and Hispanic high school students.^{17,24,109} New Jersey estimates follow similar trends.¹¹⁰ This study, however, found that a school's percentage of non-Hispanic white students was *negatively* associated with e-cigarette advertising. The proportion of Hispanic students enrolled, however, was significantly and strongly related to e-cigarette advertising volume. This suggests that the effect of environmental influences on e-cigarette experimentation and use, such as marketing at the point of sale, may differ between ethnic groups and by neighborhood, although stronger methodological studies that link point of sale data with use behaviors are needed to evaluate these specific associations.

There are several methodological limitations that should be considered when interpreting this study's findings. Although the schools selected for this project were drawn from a random sample and represent various types of communities and geographic settings, the results may not be generalizable to all high schools in the state or nationally. Moreover, the final sample of retailers excluded bars, restaurants, and large grocery stores, and so did not capture all possible retail locations that sold e-cigarettes. Similarly, vape shops and other types of vapor retailers are not included in the state's list of licensed retailers and were not visited by research staff. Though the weighted measures of e-cigarette retailer density and advertising volume are innovative approaches to characterize e-cigarette retail around schools, they are not without limitations. They assume that the retailers selling e-cigarettes are equally as influential as any tobacco retailer in the sample. Conceivably, the e-cigarette retailers may be those frequented most by high school students, or vice versa. In this study, buffer zones around schools were created using a half-mile, straight line radius, which is a common buffer zone used to characterize tobacco retail around schools.^{34,36,38,71} It may not, however, accurately represent students' actual activity spaces within school zones. Future studies should characterize e-cigarette promotions near schools using road network buffers or other sampling techniques. Finally, the neighborhood surrounding a school is not the only environment that can potentially influence a student's perceptions about e-cigarettes and/or e-cigarette use behavior. Other youth access points, like retailers around the home or near parks, are important to consider. It should be

noted, however, that the communities around schools have previously been associated with youth tobacco use^{36,38,71,72} and that students spend a large portion of their day within this geographic area.

Although e-cigarette sales data identify top-selling brands and product attributes, they rarely capture promotional strategies that may be driving sales numbers in different types of retail locations. Store audits provide an opportunity to glean this information in a “real-world” setting. Stores immediately surrounding school zones likely represent retailers that students visit, or at a minimum, those whose advertisements they may see on a regular basis. This study demonstrated that e-cigarette availability and marketing is prevalent around high schools in New Jersey and that e-cigarette retail differs by school enrollment demographics. Future research should examine whether e-cigarette retailer density and marketing volume near schools are associated with e-cigarette use among youth.

Table 1. Presence of e-cigarette advertisements and e-cigarette availability by store type (n=194)

Table 1. Presence of e-cigarette advertisements and e-cigarette availability by store type (n=194)																	
Store type	E-cig advertisements					E-cig availability								E-cig counter display			
	Exterior		p ^a	Interior		p	E-cigs		p	Flavored e-cigs		p	Open tank ^b		p	Sample %	p
	Sample %			Sample %			Sample %			Sample %			Sample %				
Convenience (n=97)	30.9	<.001	34	0.34	50.5	0.05	32	0.06	9.3	<.001	21.7	0.03					
Convenience w/ gas (n=29)	58.6		41.4		62.1		55.2		48.3		37.9						
Drug (n=18)	0		33.3		88.9		61.1		55.6		0						
Liquor (n=25)	12		16		56		48		8		32						
Other ^c (n=25)	28		28		60		40		28		16						
Total	29.4		32		57.7		41.2		21.7		22.7						
*Chi-square tests determined whether e-cigarette advertising and availability differed by store type; ^b “Open tank” systems are e-cigarettes that typically come with bottles of e-liquid that users add to the devices; ^c “Other” stores primarily consisted of dollar stores, tobacco shops, and head shops.																	

^aChi-square tests determined whether e-cigarette advertising and availability differed by store type; ^bOpen tank^c systems are e-cigarettes that typically come with bottles of e-liquid that users add to the devices; ^cOther^d stores primarily consisted of dollar stores, tobacco shops, and head shops.

Table 2. Correlation between school enrollment demographics and e-cigarette retailer density

	Tobacco retailer density ^a		E-cig retailer density ^b		Weighted e-cig retailer density ^c	
	r_s^d	p	r_s	p	r_s	p
School demographics						
% White, NH ^e	-0.39	0.01	-0.34	0.03	-0.27	0.09
% Black, NH	0.13	0.43	0.11	0.49	0.11	0.52
% Hispanic	0.36	0.02	0.36	0.02	0.29	0.06
% Asian, NH	-0.24	0.13	-0.2	0.21	-0.18	0.27
% Receiving free or reduced lunch	0.52	<.001	0.49	<.01	0.44	<.01

^aThe number of tobacco retailers within a half-mile of each school; ^bThe number of tobacco retailers that sell e-cigarettes; ^cThe number of e-cigarette retailers multiplied by the proportion of tobacco retailers that sell e-cigarettes within a half-mile of each school; ^dSpearman coefficients examined correlations between school demographics and retailer density; ^eNH: Non-Hispanic.

Table 3. Correlation between school enrollment demographics and volume of e-cigarette advertisements

Table 3. Correlation between school enrollment demographics and volume of e-cigarette advertisements										
	Tobacco advertisements^a			E-cig advertisements^b			Weighted e-cig advertisements^c			
	Exterior		<i>r_s^d</i>	Interior		<i>r_s</i>	Exterior		<i>r_s</i>	<i>p</i>
	<i>p</i>			<i>p</i>			<i>p</i>			
School demographics										
% White, NH ^e	-0.31	0.05		-0.35	0.02		-0.2	0.2	-0.2	0.3
% Black, NH	0.14	0.38		0.2	0.2		0.04	0.8	0.05	0.8
% Hispanic	0.37	0.02		0.33	0.04		0.39	0	0.34	0
% Asian, NH	-0.23	0.15		-0.3	0.05		-0.1	0.4	-0.1	0.7
% Receiving free or reduced lunch	0.53	<.001		0.58	<.001		0.42	0	0.36	0
									0.53	<.001

^aThe number of tobacco ads within a half-mile of each school; ^bThe number of e-cigarette ads within a half-mile of each school; ^cThe number of e-cigarette ads multiplied by the proportion of all tobacco ads that were for e-cigarettes within a half-mile of each school; ^dSpearman coefficients examined correlations between school demographics and advertising volume; ^eNH: Non-Hispanic.

CHAPTER 5: ASSOCIATION BETWEEN THE TOBACCO RETAIL ENVIRONMENT NEAR SCHOOLS AND ELECTRONIC CIGARETTE USE AMONG YOUTH

ABSTRACT

Background: Electronic cigarettes (e-cigarettes) are now the most popular tobacco product among youth. Little is known about the relationship between exposure to e-cigarette marketing at the point-of-sale and youth e-cigarette use.

Methods: Research staff collected data on e-cigarette availability and promotion in tobacco retailers within a half-mile of schools participating in the New Jersey Youth Tobacco Survey (NJYTS) (n=194). These data were linked with participant responses from the NJYTS and a series of logistic regressions predicted the odds of being an ever and current e-cigarette user.

Results: Nearly a quarter of high school students in New Jersey have tried e-cigarettes (24.1%) and 12.1% are current users. Prevalence is highest among males, non-Hispanic whites, and students who have used other tobacco products. After controlling for covariates and the clustered nature of the data, e-cigarette retailer density around schools was positively associated with ever and current use of e-cigarettes ($p < .05$). E-cigarette advertising volume significantly predicted the odds of being a current e-cigarette user (AOR: 1.03, $p = 0.03$).

Discussion: The promotion of tobacco products in youth-centered neighborhoods communicates messages about social norms and product popularity. This study suggests that the point-of-sale environment around schools may contribute to e-cigarette use among youth. Policy efforts to restrict tobacco promotion at the point-of-sale may play a role in reducing e-cigarette use behaviors.

INTRODUCTION

Electronic cigarettes (e-cigarettes) are now the most popular tobacco product among youth in the United States.¹⁸ In 2014, over 2 million high school students were current e-cigarette users, a significant and substantial increase since 2011.¹⁸ Amid declining rates of nearly all other tobacco products, the high prevalence of e-cigarette use among young people poses a serious public health concern. Nicotine exposure during adolescence, a critical period in neural development, has been associated with cognitive and behavioral impairments and lasting structural changes in the brain.¹⁵ Moreover, young people who become addicted to nicotine are more likely to continue smoking throughout adulthood.¹⁶ The weak state and federal regulations on the manufacturing and marketing of e-cigarettes are thought to facilitate use among youth. Unlike cigarettes, e-cigarettes can be sold in a variety of flavors that appeal to young people¹¹¹ and are advertised on television, radio, and other media channels where cigarette advertising is banned.⁹⁸

Various demographic and behavioral factors, such as being white and having a history of tobacco use, are associated with e-cigarette use among youth,^{22,24,109} but decades of tobacco control research acknowledge the importance of community-level factors in influencing behaviors. Exposure to tobacco marketing at the point-of-sale and tobacco outlet density, in particular, are strongly associated with smoking initiation and current smoking among youth.^{16,32,33,71} Additionally, tobacco retailer density near schools has been

demonstrated to be a significant predictor of cigarette experimentation among students.^{36,38}

Despite the rapidly increasing prevalence of e-cigarette use and a high proportion of adolescents reporting exposure to e-cigarette marketing at the point-of-sale,¹¹² research on the association between e-cigarette retail at the neighborhood level and youth use of the products is extremely limited.⁶⁰ One recent study examined self-reported exposure to tobacco advertising and e-cigarette trial, and documented a positive relationship, though it did not specifically assess exposure to *e-cigarette* advertising.⁷⁶ Cantrell et al. linked responses from a national survey of young adults with the density of tobacco retailers in the respondents' residential census tracts and found no association between retailer density and use of non-combustible tobacco products.⁷⁷ However, the outcome variable included use of *any* non-combustible tobacco product, including moist snuff, snus, and e-cigarettes, which may have influenced the non-significant findings. Furthermore, the availability of e-cigarettes in each tobacco outlet was not considered.

This study uniquely links e-cigarette marketing and availability data collected at the point-of-sale with data on youth e-cigarette use from the 2014 New Jersey Youth Tobacco Survey (NJYTS), a representative survey of high school students in New Jersey. In addition to describing patterns of e-cigarette use, multivariable analyses test the extent to which the e-cigarette retail environment near schools independently predicts experimentation with, and current use of, e-cigarettes among students. The following hypotheses are

tested: 1) the odds of ever and current e-cigarette use will be higher among students at schools with greater *e-cigarette retailer density* within a half-mile radius; and 2) the odds of ever and current e-cigarette use will be higher among students at schools with a greater *volume of e-cigarette advertising* within a half-mile radius. Importantly, e-cigarettes are not sold in all tobacco retailers and in some places, are advertised substantially less than other tobacco products. As such, weighted measures of e-cigarette retail that consider the relative availability and promotion of e-cigarettes to other tobacco products will be compared to traditional point-of-sale metrics to examine the effect of using more nuanced measures.

METHODS

Survey data

The NJYTS is an annual survey of public school students in New Jersey and collects detailed data on tobacco-related behaviors, knowledge, and attitudes. The survey uses a two-stage cluster design to select its sample. Schools are first randomly selected with probability proportionate to enrollment size, such that larger schools have a higher likelihood of selection. Students in each school are then selected using simple random sampling. Weighted results are generalizable to all public school students in the state. Data collection for the 2014 NJYTS occurred between October and December 2014 in 41 New Jersey high schools.

Measures

The two main outcome variables were ever and current e-cigarette use. Ever e-cigarette use was assessed using the question, “*Have you ever used an e-cigarette?*” with response options of “Yes” or “No.” Current e-cigarette use was assessed using the question, “*During the past 30 days, on how many days did you use an e-cigarette?*” Students who responded any number greater than 0 were considered current e-cigarette users.

Demographic correlates included sex, grade level, and race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and non-Hispanic other). The household income of each student was not available, so a school-level variable, percent of the student body receiving free or reduced lunch, was used as a general estimate of a school’s level of economic disadvantage. These data were obtained from the New Jersey Department of Education. Several variables related to tobacco use were also examined. A student was classified as an “ever tobacco user” if he/she reported ever trying cigarettes, cigars/cigarillos, smokeless tobacco (including snus), and/or hookah. A student using any of these products in the past 30 days was considered a current tobacco user. Peer tobacco use was defined as having at least one of four close friends that smokes cigarettes or uses smokeless tobacco. Tobacco use in the home was defined as living with someone who uses any type of tobacco product. To account for the fact that students may visit tobacco retail locations outside of their school zones that would not be captured during our point-of-sale data collection, a survey item that assessed self-reported exposure to tobacco advertising in stores was

included in all analyses. Specifically, the survey item asked: *When you go to a convenience store, supermarket, or gas station, how often do you see ads or promotions for cigarettes and other tobacco products?*

Point-of-sale data collection

The primary independent variables were related to the e-cigarette retail environment surrounding each school in the sample. A complete list of the state's licensed tobacco retailers was obtained from the New Jersey Department of Health. "Vape shops," independent retailers that specialize in the sale of e-cigarettes and their accessories, were also identified using validated online search techniques.^{84,113} Store addresses were geocoded using Google Earth Pro, which enabled the investigators to verify the accuracy of plotted locations using aerial and street view imagery. Google Earth Pro has been used to geocode addresses in other public health research.⁸⁸ The addresses of the 41 schools participating in the 2014 NJTYS were geocoded using the same approach described above. After importing the geocoded data into ArcGIS (v.10.1) as a KML file, a half-mile, egocentric buffer was drawn around each school. The Spatial Join tool identified all tobacco retailers falling within this zone, providing the sampling frame for point-of-sale data collection. Egocentric buffers are commonly used to characterize the tobacco retail environment around schools in the U.S. and typically range from a half-mile to one mile in studies on retailer density.^{34,36,38,71} A half-mile was selected for this project because this distance falls within what adolescents perceive to be an easy walking distance.¹⁰³

Store audits

All sampled stores were visited between March and June 2015. Two trained research staff collected data on e-cigarette availability and the number of e-cigarette advertisements on a store's exterior and interior. To examine e-cigarette promotion in relation to other tobacco products, the data collection instrument also included measures for cigarette, cigar, and smokeless tobacco advertising. An "advertisement" was defined as an industry-made sign featuring a tobacco company's logo and/or an image of the product. Only advertisements clearly visible walking past the storefront or standing in front of the cash register were counted. Each store visit lasted approximately 10 minutes. To assess intercoder reliability between research staff, 10% of sampled stores were simultaneously audited by two researchers. Intraclass correlation coefficients for continuous measures (e.g., number of e-cigarette ads) and Cohen's kappa statistics for categorical measures (e.g., availability of e-cigarettes) were excellent, ranging from 0.8 to 1.0 for all items, so data collection proceeded independently thereafter.^{104,105}

Density measures

A school's e-cigarette retailer density was calculated as the number of tobacco retailers within a half-mile radius that sold e-cigarettes. Although the raw number of nearby retailers that sell e-cigarettes is an important measure of access, this metric ignores that in some neighborhoods, e-cigarettes are sold in a

proportionately greater number of retail locations, an indicator of the product's popularity and visibility. Consider a school where only 10 out of 100 nearby tobacco retailers sell e-cigarettes. Despite the relatively low availability of e-cigarettes, this school would receive the same density score as a school with 10 nearby tobacco retailers, all of which sell e-cigarettes. To better estimate exposure to e-cigarettes at the point of sale, a weighted measure of density that adjusts for the proportion of tobacco retailers that sell e-cigarettes was also used. For each school, the total number of e-cigarette retailers within a half-mile was multiplied by the proportion of all nearby tobacco retailers that sold e-cigarettes. For example, the aforementioned school with 10 e-cigarette retailers out of 100 total tobacco retail locations within a half-mile would receive an unadjusted density score of 10 but a weighted density score of 1 (i.e., 10×0.1).

Advertising volume

Similar to the density measures described above, each school was assigned a value for the total number of e-cigarette advertisements within a half-mile radius, as well as a weighted measure of e-cigarette advertising volume. That is, the total number of e-cigarette ads in the buffer zone was multiplied by the proportion of all tobacco ads that were for e-cigarettes. Data on each school's retail environment collected during store audits was appended to the NJYTS survey data. In other words, each student was assigned the point-of-sale attributes of his/her school as an estimate of exposure to e-cigarette retail.

Statistical analysis

Weighted sample demographics and point prevalence estimates of ever and current e-cigarette use are presented with 95% confidence intervals. Sampling weights accounted for any unequal probabilities of selection, non-response and disproportionate selection of different population groups. All analyses used survey procedures available in SAS (v.9.3) that take into account the complex sampling design to more accurately compute variance and standard error estimates. Bivariable associations between e-cigarette use and various demographic and behavioral factors were tested using the Rao-Scott Chi-Square test.

A series of multivariable logistic regressions using four different measures of a school's proximate e-cigarette retail environment were used to predict the odds of ever and current e-cigarette use among students after controlling for covariates. To account for the clustered nature of the data at the school-level, generalized estimating equations (PROC GENMOD) were fit with binary distributions and logit link functions. School was specified as the subject in the REPEATED statement. Generalized estimating equations are commonly used to estimate the relationship between neighborhood characteristics and individual-level health outcomes when the primary interest is describing changes in the population mean given changes in covariates.¹¹⁴ Adjusted odds ratios (AOR) and 95% confidence intervals are presented for all predictor variables. A *p*-value of less than 0.05 determined statistical significance for all tests.

RESULTS

Student demographics and tobacco use behaviors are presented in Table 1. Most students were non-Hispanic white (49.5%), followed by Hispanic (20.6%), non-Hispanic other (15.8%), and non-Hispanic black (14.0%). Slightly more than 40% of students have ever tried a tobacco product (not including e-cigarettes) and 15.6% are current users of one or more of these tobacco products. A third of students have at least one close friend that smokes cigarettes or uses smokeless tobacco (34.9%) and 39.7% live with a tobacco user. Half of all students report seeing tobacco advertisements in stores “most of the time” or “always” (49.6%).

Almost a quarter of New Jersey high school students have tried using an e-cigarette (24.1%) and 12.1% are current users (Table 2). Ever use is significantly higher among males than females and increases with grade level. Whites have the highest rates of e-cigarette experimentation (27.6%) compared to other racial and ethnic groups. Individual, peer, and family tobacco use are strongly associated with e-cigarette experimentation. Notably, over half of students that have tried another tobacco product have also used an e-cigarette (51.0%). Current e-cigarette use follows identical patterns and is highest among males (14.2%), non-Hispanic whites (14.0%), and those who have a history of tobacco use (26.5%).

In total, 213 tobacco retailers fell within a half-mile radius of the schools in the sample and were visited by research staff. Nineteen retailers were not audited because they were either closed, could not be located, or the owner was

not comfortable with research staff collecting data in the store, yielding a completion rate of 91% (n=194). Notably, no school in the sample had a vape shop in its vicinity. E-cigarettes were available in 57.7% of all retailers, but only 32.0% had any e-cigarette advertising. Of the 41 schools participating in the 2014 NJYTS, 34.1% (n=14) had no tobacco retailers within a half-mile radius and were assigned a value of zero for all retail environment measures. The mean number of e-cigarette retailers near each school was 2.7 (s.d.: 3.9) with a range of 0 to 16. The mean weighted density score was 1.8 (s.d.: 2.5) and ranged from 0 to 9.8. On average, each school had 6.4 (s.d.: 8.4) e-cigarette advertisements within a half-mile (range: 0 to 31) and a weighted e-cigarette advertisement score of 1.4 (s.d.: 2.3, range: 0 to 11.8).

In a series of adjusted regression models, gender, grade level, race, tobacco use history, the percentage of students receiving free/reduced lunch, and self-reported exposure to tobacco advertising in stores were significantly associated with the odds of ever using an e-cigarette after controlling for other covariates (Table 3). Due to extremely high correlation between individual tobacco use, peer tobacco use, and tobacco use in the home, the peer and family tobacco use variables were removed from the final model to minimize multicollinearity. A student's tobacco use history was the strongest predictor of e-cigarette experimentation. The odds of ever e-cigarette use among students who have used other tobacco products were 18 times the odds among students who have never used tobacco ($p<.0001$). Non-Hispanic blacks were significantly less likely to try e-cigarettes than were non-Hispanic whites [AOR: 0.65, 95% CI:

(0.44, 0.96), $p=0.03$]. Furthermore, a school's level of economic disadvantage was negatively associated with e-cigarette trial ($p<.0001$). For every 10-percentage point increase in students receiving free or reduced lunch, the odds of a student at that school ever trying an e-cigarette decreased by approximately 17% ($\beta=-0.02$). Self-reported exposure to tobacco advertisements in stores was positively and consistently associated with e-cigarette initiation, but only one measure of e-cigarette retail around schools, weighted e-cigarette retailer density, was associated with use [AOR: 1.08, 95% CI: (1.01, 1.15), $p=0.04$].

Predictors of current e-cigarette use followed similar trends (Table 4). Specifically, having tried other tobacco products was strongly associated with the odds of being a current e-cigarette user ($p<.0001$ across all models). In these models, however, grade and self-reported exposure to tobacco advertising were not significantly related to product use. Both unadjusted and adjusted measures of e-cigarette retailer density and e-cigarette advertising volume significantly predicted current e-cigarette use. For example, for every additional e-cigarette retailer within a half-mile of a school, the odds of a student at that school being a current e-cigarette user increased by 5% ($p=0.05$). For every 10 additional e-cigarette advertisements, the odds of current e-cig use increased by 28% ($\beta=0.03$, $p=0.03$).

DISCUSSION

Consistent with national trends,¹⁸ e-cigarettes are the most popular tobacco product among youth in New Jersey. Nearly a quarter of high school

students have tried using an e-cigarette and more than one in ten are current users. Demographic and behavioral patterns of use also mirror national youth data. Ever and current e-cigarette users are significantly more likely to be non-Hispanic white, older, and have a history of using other tobacco products.^{18-20,85,115} This study also demonstrated that e-cigarette use is less likely among students in schools that are more economically disadvantaged. There is limited evidence whether socioeconomic status predicts e-cigarette use among youth at a national level, although one study in California documented a similar relationship between poverty and lifetime e-cigarette use.¹¹⁶

The retail environment around schools was positively associated with e-cigarette use among students, although the relationship was considerably stronger for current use than ever use. Both the amount of nearby tobacco retailers that sold e-cigarettes and the number of e-cigarette advertisements within a half-mile of each school significantly increased the odds of a student being a current user. Only the weighted measure of e-cigarette retailer density that accounted for the proportion of stores where e-cigarettes were available was significantly associated with a student trying an e-cigarette. Had retailer density been calculated using only traditional measures that are commonly used in point-of-sale studies (e.g., number of retailers within a given geographic area), no relationship would have been observed between retailer density and trying an e-cigarette. This finding highlights the importance of developing more nuanced measures for studies on non-cigarette tobacco products at the point-of-sale, since some products are promoted disproportionately in certain communities.

Interestingly, self-reported and observed measures of the retail environment did not have the same predictive values in regression models. Self-reported exposure to tobacco advertising was strongly associated with ever e-cigarette use, but not significantly related to current use. One reason for the discrepancy could be that students' perceptions of their own exposure to advertising may not be a valid measure of actual exposure. Alternatively, self-reported measures in this study may have more comprehensively captured exposure to tobacco promotion in all retailers where youth frequently visit, not just retailers near schools. It should be noted, however, that the survey item used to create this measure assessed exposure to *all* tobacco product promotion, so it is not possible to isolate the effect of self-reported exposure to e-cigarette advertising.

This study has important limitations that may hamper the generalizability of the findings and restrict inferences that can be made. First, the store audit data were collected 3 to 5 months after the survey was administered, so the product offerings and marketing tactics documented during the retailer visits may not represent the point-of-sale environment during the months of survey data collection. Second, although the store audits characterized the retail environment surrounding schools, the youth in the sample may not have had exposure to all or any of the retailers that research staff visited. Other youth access points to tobacco, like retailers near the home, community centers, and parks, are undoubtedly important and may shape e-cigarette use behaviors, but were not observed in this study. Third, buffer zones around schools were created using a

half-mile, straight-line radius, which is a common buffer zone used to characterize tobacco retail around schools.^{34,36,38,71} It may not, however, accurately represent students' actual activity spaces within school zones. Future studies should characterize e-cigarette retail near schools using road network buffers or other sampling techniques. Finally, current e-cigarette use was defined as any use in the past 30 days. Given that e-cigarettes are a relatively new tobacco product, this measure may include students who have recently experimented with e-cigarettes. Indeed, research has demonstrated that past 30 day users significantly differ from more established e-cigarette users.⁷ Finally, this study was specific to high school students in New Jersey and may not be generalizable to students nationally or in other states.

The promotion and availability of tobacco products in areas where youth spend a substantial portion of their time, such as school zones, communicates messages about social norms, access, and product popularity. This study revealed a strong link between e-cigarette retail near schools and youth use of the products. The relationship between point-of-sale promotion and current use, in particular, suggests that high levels of advertising and increased product access may contribute to continued use of e-cigarettes. During a time when e-cigarette marketing expenditures are increasing concurrently with youth prevalence rates,¹¹² more research is needed on the influence of industry initiatives on product use among young people. Policy efforts to restrict tobacco promotion at the point-of-sale may ultimately reduce e-cigarette use among youth.

Table 1. Weighted sample demographics and tobacco use behaviors, 2014 New Jersey Youth Tobacco Survey (n=3,909)

	% ^a	95% CI
Gender		
Female	49.5	(47.7, 51.3)
Male	50.5	(48.7, 52.3)
Grade		
9th	26.0	(21.3, 30.7)
10th	25.5	(20.2, 30.8)
11th	24.5	(18.7, 30.2)
12th	24.1	(19.0, 29.1)
Race		
White, NH ^b	49.5	(39.1, 60.0)
Black, NH	14.0	(8.7, 19.3)
Hispanic	20.6	(14.8, 26.5)
Other, NH	15.8	(12.0, 19.7)
Tobacco use history^c		
Ever tried any tobacco product	40.5	(37.0, 44.1)
Currently uses any tobacco product ^d	15.6	(13.0, 18.3)
Peer tobacco use^e		
At least 1 close friend uses tobacco	34.9	(31.3, 38.5)
Tobacco use in home^f		
Lives with a tobacco user	39.7	(35.9, 43.5)
Frequency of seeing tobacco ads in stores		
Most of the time or always	49.6	(46.3, 52.9)
Percent of students receiving free/reduced lunch	34.9	(23.3)

^aFor the percent of students receiving free/reduced lunch, mean and standard deviation presented; ^bNH: Non-Hispanic; ^cHas ever tried cigarettes, cigars, smokeless tobacco, or hookah, ^dUsed any tobacco product at least one day in the past 30 days; ^eIncludes friends who smoke cigarettes or use smokeless tobacco; ^fIncludes use of any tobacco product in home

Table 2. Prevalence of ever and current e-cigarette use by demographic and tobacco-related characteristics, 2014 New Jersey Youth Tobacco Survey (n=3,909)

	Ever e-cig use		p ^b	Current e-cig use ^a		p
	%	95% CI		%	95% CI	
Gender						
Female	21.1	(17.1, 25.1)	<.0001	10.0	(7.2, 12.8)	<.01
Male	27.1	(23.5, 30.7)		14.2	(11.3, 17.1)	
Grade						
9th	16.8	(13.3, 20.3)	<.0001	9.1	(6.1, 12.1)	<.01
10th	20.9	(15.8, 26.1)		10.6	(7.1, 14.0)	
11th	29.8	(24.1, 35.5)		13.8	(9.5, 18.0)	
12th	29.4	(24.0, 34.9)		15.3	(12.1, 18.4)	
Race						
White, NH ^c	27.6	(22.9, 32.2)	<.001	14.0	(11.2, 16.8)	<.0001
Black, NH	17.7	(12.5, 22.9)		8.0	(5.0, 11.1)	
Hispanic	22.3	(18.8, 25.8)		12.4	(9.5, 15.3)	
Other, NH	21.3	(15.9, 26.8)		9.2	(5.9, 12.4)	
Tobacco use history^d						
Ever tried any tobacco product	51	(45.0, 57.0)	<.0001	26.5	(21.3, 31.6)	<.0001
Never tried any tobacco product	5.7	(4.5, 6.9)		2.2	(1.5, 2.8)	
Peer tobacco use^e						
At least 1 close friend uses tobacco	44.1	(38.3, 49.8)	<.0001	27.9	(22.7, 33.1)	<.0001
No close friends use tobacco	13.8	(11.8, 15.9)		3.9	(2.9, 4.8)	
Tobacco use in home^f						
Yes	37.7	(33.0, 42.4)	<.0001	21.8	(17.9, 25.8)	<.0001
No	15.1	(12.3, 17.9)		5.7	(4.2, 7.2)	
Frequency of seeing tobacco ads in stores						
Most of the time or always	28.2	(23.7, 32.7)	<.0001	13.2	(10.1, 16.3)	0.02
Never, rarely, or sometimes	19.6	(16.5, 22.7)		10.5	(8.2, 12.8)	
Total	24.1	(20.5, 27.6)		12.1	(9.6, 14.5)	

^aUsed an e-cigarette on at least one of the past 30 days; ^bRao-Scott Chi Square tested bivariable associations; ^cNH: Non-Hispanic; ^dHas ever tried cigarettes, cigars, smokeless tobacco, or hookah; ^eIncludes friends who smoke cigarettes or use smokeless tobacco; ^fIncludes use of any tobacco product in home

Table 3. Odds of ever using an e-cigarette, 2014 New Jersey Youth Tobacco Survey (n=3,909)

	Model 1			Model 2			Model 3			Model 4		
	AOR	95% CI	p	AOR	95% CI	p	AOR	95% CI	p	AOR	95% CI	p
Gender												
Female	1	Ref		1	Ref		1	Ref		1	Ref	
Male	1.44	(1.22, 1.71)	<.0001	1.44	(1.22, 1.71)	<.0001	1.45	(1.22, 1.72)	<.0001	1.45	(1.22, 1.72)	<.0001
Grade												
9th	1	Ref		1	Ref		1	Ref		1	Ref	
10th	1.12	(0.88, 1.44)	0.35	1.14	(0.89, 1.46)	0.31	1.14	(0.89, 1.47)	0.3	1.14	(0.89, 1.46)	0.32
11th	1.44	(1.13, 1.84)	<.01	1.45	(1.14, 1.84)	<.01	1.41	(1.09, 1.82)	<.01	1.39	(1.07, 1.80)	0.01
12th	1.07	(0.82, 1.41)	0.62	1.08	(0.82, 1.41)	0.59	1.07	(0.82, 1.39)	0.62	1.07	(0.82, 1.39)	0.62
Race												
White, NH ^a	1	Ref		1	Ref		1	Ref		1	Ref	
Black, NH	0.65	(0.44, 0.96)	0.03	0.65	(0.44, 0.96)	0.03	0.65	(0.46, 0.94)	0.02	0.64	(0.45, 0.92)	0.02
Hispanic	0.81	(0.63, 1.04)	0.1	0.82	(0.64, 1.04)	0.11	0.8	(0.63, 1.03)	0.08	0.8	(0.62, 1.03)	0.08
Other, NH	0.84	(0.64, 1.11)	0.22	0.85	(0.64, 1.11)	0.23	0.87	(0.66, 1.15)	0.33	0.86	(0.66, 1.13)	0.28
Tobacco use history^b												
Ever tried any tobacco product	18.01	(14.53, 22.34)	<.0001	18.05	(14.58, 22.33)	<.0001	18.02	(14.56, 22.31)	<.0001	18	(14.54, 22.28)	<.0001
Never tried any tobacco product	1	Ref		1	Ref		1	Ref		1	Ref	
Percent of free/reduced lunch	0.98	(0.98, 0.99)	<.0001	0.98	(0.98, 0.99)	<.0001	0.98	(0.98, 0.99)	<.001	0.99	(0.98, 0.99)	<.0001
Frequency of seeing tobacco ads in stores												
Most of the time or always	1.52	(1.30, 1.78)	<.0001	1.52	(1.30, 1.78)	<.0001	1.54	(1.31, 1.82)	<.0001	1.55	(1.31, 1.83)	<.0001
Never, rarely, or sometimes	1	Ref		1	Ref		1	Ref		1	Ref	
E-cig retailer density^c	1.04	(0.99, 1.10)	0.1									
Weighted e-cig retailer density^d				1.08	(1.01, 1.15)	0.04						
Total e-cig ads^e							1.02	(0.99, 1.04)	0.19			
Weighted e-cig ads^f										1.05	(0.98, 1.11)	0.16

^aNH: Non-Hispanic; ^bHas ever tried cigarettes, cigars, smokeless tobacco, or hookah; ^cNumber of tobacco retailers that sell e-cigarettes within a half-mile of school; ^dNumber of e-cigarette retailers multiplied by the proportion of tobacco retailers that sell e-cigarettes within a half-mile of school; ^eTotal number of e-cigarette advertisements within a half-mile of school; ^fNumber of total e-cigarette advertisements multiplied by the proportion of all tobacco advertisements that were for e-cigarettes within a half-mile of school

Table 4. Odds of currently using e-cigarettes^a, 2014 New Jersey Youth Tobacco Survey (n=3,909)

	Model 1			Model 2			Model 3			Model 4		
	AOR	95% CI	p	AOR	95% CI	p	AOR	95% CI	p	AOR	95% CI	p
Gender												
Female	1	Ref		1	Ref		1	Ref		1	Ref	
Male	1.44	(1.12, 1.85)	0.01	1.43	(1.11, 1.84)	0.01	1.42	(1.11, 1.83)	0.01	1.42	(1.12, 1.85)	0.01
Grade												
9th	1	Ref		1	Ref		1	Ref		1	Ref	
10th	1.03	(0.73, 1.47)	0.85	1.05	(0.74, 1.49)	0.79	1.05	(0.74, 1.49)	0.8	1.04	(0.73, 1.48)	0.83
11th	0.98	(0.68, 1.43)	0.93	0.98	(0.68, 1.42)	0.92	0.94	(0.65, 1.35)	0.73	0.91	(0.63, 1.31)	0.61
12th	0.94	(0.71, 1.23)	0.64	0.94	(0.72, 1.24)	0.67	0.92	(0.69, 1.21)	0.54	0.92	(0.69, 1.22)	0.57
Race												
White, NH ^b	1	Ref		1	Ref		1	Ref		1	Ref	
Black, NH	0.68	(0.48, 0.97)	0.03	0.68	(0.48, 0.97)	0.04	0.69	(0.49, 0.98)	0.04	0.67	(0.47, 0.95)	0.03
Hispanic	0.93	(0.69, 1.26)	0.64	0.95	(0.71, 1.27)	0.95	0.93	(0.71, 1.28)	0.75	0.94	(0.70, 1.27)	0.7
Other, NH	0.79	(0.58, 1.08)	0.14	0.79	(0.58, 1.08)	0.14	0.8	(0.58, 1.10)	0.17	0.79	(0.57, 1.08)	0.14
Tobacco use history^c												
Ever tried any tobacco product	16.22	(11.68, 22.54)	<0.001	16.2	(11.67, 22.49)	<0.001	16.18	(11.65, 22.49)	<0.001	16.2	(11.65, 22.54)	<0.001
Never tried any tobacco product	1	Ref		1	Ref		1	Ref		1	Ref	
Percent of free/reduced lunch	0.98	(0.97, 0.99)	<0.001	0.98	(0.98, 0.99)	<0.001	0.98	(0.97, 0.99)	<0.001	0.99	(0.98, 0.99)	<0.001
Frequency of seeing tobacco ads in stores												
Most of the time or always	1.14	(0.90, 1.45)	0.29	1.14	(0.90, 1.44)	0.29	1.14	(0.90, 1.46)	0.28	1.15	(0.90, 1.46)	0.27
Never, rarely, or sometimes	1	Ref		1	Ref		1	Ref		1	Ref	
E-cig retailer density^d	1.05	(1.00, 1.10)	0.05	1.08	(1.01, 1.16)	0.04						
Weighted e-cig retailer density^e												
Total e-cig ads^f							1.03	(1.00, 1.05)	0.03			
Weighted e-cig ads^g										1.07	(1.01, 1.13)	0.01

^aUsed an e-cigarette on at least 1 of the past 30 days; ^bNH Non-Hispanic; ^cHas ever tried cigarettes, cigars, smokeless tobacco, or hookah; ^dNumber of tobacco retailers that sell e-cigarettes within half-mile of school; ^eNumber of e-cigarette retailers multiplied by the proportion of tobacco retailers that sell e-cigarettes within half-mile of school; ^fTotal number of e-cigarette advertisements within half-mile of school; ^gNumber of total e-cigarette advertisements multiplied by the proportion of all tobacco advertisements that were for e-cigarettes within half-mile of school

CHAPTER 6: SUMMARY

A summary of the dissertation findings and how they relate to the published literature is presented separately for each chapter. This is followed by a section that identifies common themes across the chapters. The dissertation concludes with a brief discussion of the project's strengths and limitations, public health and tobacco control policy implications, and a concluding paragraph that makes broader recommendations for future areas of study.

Summary of main findings

Amid declining cigarette consumption in the United States, use of e-cigarettes has increased dramatically in recent years among both youth and adults.^{2,14,17,18,117} Although e-cigarettes are considerably safer than combustible forms of tobacco and may help some smokers quit,^{2-5,118} public health experts generally agree that any nicotine use among youth is problematic.^{119,120} Tobacco use history is a strong predictor of e-cigarette experimentation,^{14,19,24,91,121} but at present, it is unknown how the vapor retail environment varies across communities and how it is associated with the e-cigarette use behaviors of community residents, particularly youth. Using GIS techniques, store audits, and youth survey data, this dissertation examined e-cigarette retail in New Jersey and its relationship with e-cigarette use among high school students. Major findings from each of the three chapters are summarized below. Each chapter summary begins with a restatement of the research questions posed in Chapter 1.

Chapter 3: The geographic distribution of vape shops and its association with community demographics

- RQ 1: How many vape shops are in New Jersey and where are they located?
- RQ 2: Do any geographic patterns exist in the locations of these vape shops?
- RQ 3: What demographic factors are associated with the presence of vape shops at the census tract level?
- RQ 4: How do demographic predictors of vape shops differ from predictors of tobacco retail density?

New Jersey vape shops were identified using a systematic online search protocol and their addresses were geocoded. Statistical testing determined demographic predictors of vape shop presence at the census tract level. The state's vape shop industry experienced rapid growth since the first store opened in 2011. The number of shops more than tripled since 2013, from 38 to 130 as of June 2015. Vape shops appear to be opening in communities where smokers live. The odds of a census tract having a vape shop increased as a function of the tract's tobacco retailer density, after adjusting for population size. However, demographic characteristics typically associated with tobacco retail^{46-49,52-57} were *negatively* related to vape shop density. For example, the odds of vape shop presence decreased as a tract's proportion of black residents increased [AOR:

0.97 (0.96-0.99), $p < .001$]. Similarly, a tract's proportion of Hispanic residents was negatively associated with the presence of a vape shop ($p = 0.01$). These relationships held even after controlling for median income level and population size. Although no published studies have examined the geographic distribution of vape shops, the findings from Chapter 3 are consistent with the one existing study on e-cigarette availability which found that e-cigarettes were more common in communities with a higher median income and a greater proportion of white residents.⁵⁰

The overarching theme of this dissertation is access to e-cigarettes among youth, but the results from Chapter 3 have implications that extend beyond youth use of the products. At present, there is no evidence that vape shops are more likely to open in communities with a higher proportion of youth or young adults, but they are significantly more likely to open in neighborhoods with a higher tobacco retail density. In light of recent evidence suggesting that many former smokers have used e-cigarettes to quit cigarettes,¹¹⁸ the availability of advanced vaping products in vape shops – retailers that typically embrace “anti-tobacco” sentiments – may encourage product switching among community residents. If less risky products are relatively unavailable in non-white communities, existing health disparities may worsen as a result of continued combustible product use among historically disadvantaged groups.

Chapter 4: Electronic cigarette availability and advertising around high schools

- RQ 5: What percentage of sampled schools have at least one e-cigarette retailer within a half-mile, straight line radius?
- RQ 6: What percentage of e-cigarette retailers sell flavored e-cigarettes and e-liquid?
- RQ 7: On average, how many e-cigarette advertisements are visible on the exterior and interior of tobacco retailers?
- RQ 8: How are school enrollment demographics associated with e-cigarette retailer density?
- RQ 9: How are school enrollment demographics associated with the volume of e-cigarette advertisements?

All tobacco retailers within a half-mile of a random sample of New Jersey high schools were visited between March and June 2015. Research staff collected data on e-cigarette availability and advertising, and analyses described how e-cigarette promotion varied by the enrollment demographics in each school. Over half of stores sold e-cigarettes and a third of all stores displayed at least one e-cigarette advertisement. These estimates are within the range of prior studies on e-cigarette promotion at the point-of-sale.⁶⁰⁻⁶² Exterior advertising and the availability of “open tank” e-cigarettes, which allow users to add and mix their own e-liquid, were significantly more common in convenience stores compared to other types of tobacco retailers. This is concerning since research indicates that

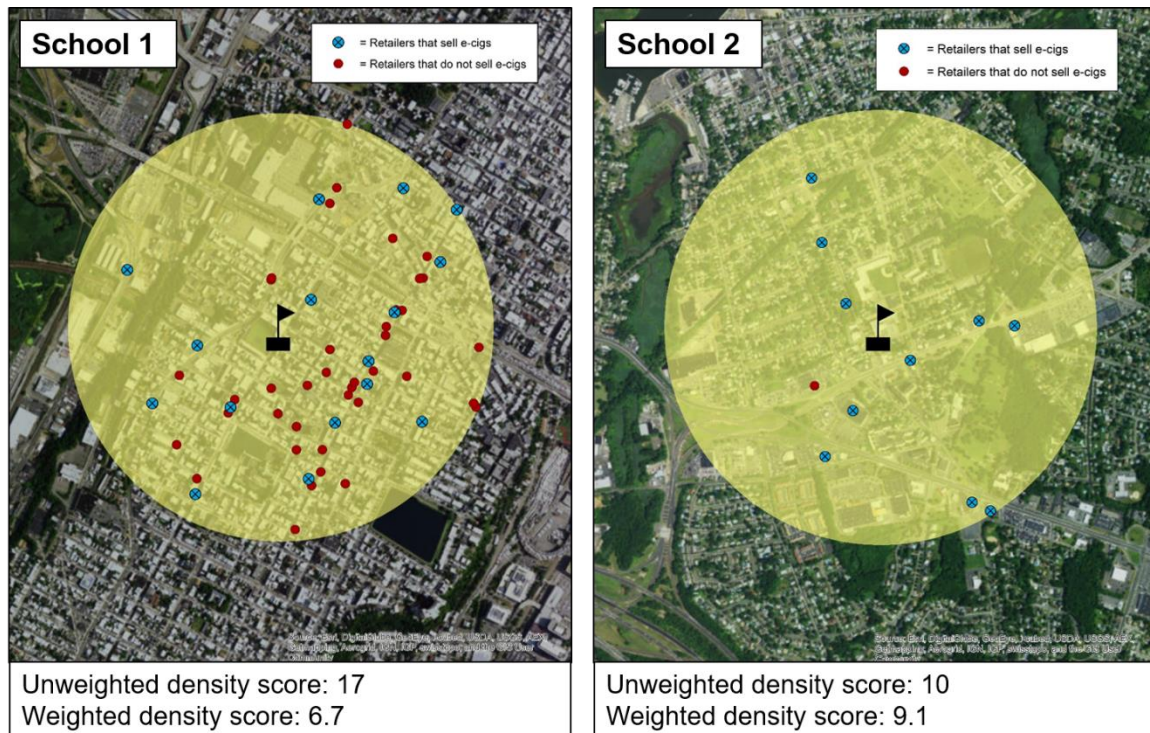
convenience stores are highly frequented by youth and serve as important tobacco access points.¹⁰⁸

Unadjusted measures of e-cigarette retailer density (i.e., the raw number of tobacco retailers within a half-mile of each school that sold e-cigarettes) and e-cigarette advertising volume (i.e., the raw number of e-cigarette advertisements within a half-mile of each school) were significantly correlated with the racial and ethnic makeup of the study body. Specifically, e-cigarette retailer density was positively associated with the percentage of Hispanic students ($r_s=0.36$, $p=0.02$) and negatively associated with the percentage of white students ($r_s=-0.34$, $p=0.03$). E-cigarette advertising volume followed similar patterns. This finding was unexpected since e-cigarette use is highest among white youth.^{17,18,24,109}

Although not an original aim of the manuscript, this study identified important limitations of applying traditional tobacco retailer density measures to e-cigarette retail. In an exploratory analysis, the tests of association described above were repeated using the density of all tobacco retailers within a half-mile of each school (i.e., whether or not they sold e-cigarettes). The correlation coefficients were nearly identical between the two tests. Logically, a school that has an extremely high number of tobacco retailers in its buffer zone will inherently have a sizable number of e-cigarette retailers. Indeed, this is the principle behind using standardized rates in epidemiology. Areas with extremely large population sizes are typically more likely to yield a higher number of disease cases. Adjustment and standardization is necessary to draw fair comparisons between areas of different population sizes.

Consider a school in the sample that has 43 tobacco retailers within a half-mile, 17 of which sell e-cigarettes. This school would receive an unadjusted density score of 17. Another school with 11 proximate tobacco retailers, 10 of which sell e-cigarettes, would receive a lower score of 10. In School 1, e-cigarette availability (and hence, visibility) is generally low compared to School 2, where these products are virtually omnipresent. Although the raw number of nearby retailers that sell e-cigarettes is an important measure of access, this metric ignores that in some neighborhoods, e-cigarettes are sold in a proportionately greater number of retail locations. I created a system of weighting to adjust for the relative promotion of e-cigarettes compared to other tobacco products to more accurately characterize retail exposure. For each school, the number of e-cigarette retailers was multiplied by the proportion of all tobacco retailers that sold e-cigarettes. After adjustment, School 1 would receive a weighted density score of 6.7 (i.e., $17 \times 17/43$) and School 2 would receive a weighted density score of 9.1 (i.e., $10 \times 10/11$). This adjustment minimizes the impact of schools whose nearby retail environments predominantly promote tobacco products other than e-cigarettes (Figure 1).

Figure 1. Illustration of unweighted vs. weighted e-cigarette retailer density scores



The new, adjusted measures of e-cigarette density and advertising yielded different conclusions than the unweighted measures when the analyses in Manuscript 2 were repeated. Specifically, the negative relationship between a school's proportion of white students and e-cigarette retail was no longer significant at the $p < 0.05$ level. The strong, positive correlation between Hispanic students and e-cigarette retail substantially weakened. This indicates that e-cigarettes may be promoted at proportionately higher rates near predominantly white schools. This study is supported by epidemiological data showing that white students are more likely than students of other races to use e-cigarettes.^{17,18,24,109}

Chapter 5: Association between the tobacco retail environment near schools and electronic cigarette use among youth

- RQ 10: What is the prevalence of ever e-cigarette use among New Jersey youth?
- RQ 11: What is the prevalence of current e-cigarette use (i.e., past 30 days) among New Jersey youth?
- RQ 12: Which demographic subgroups have a higher prevalence of e-cigarette use?
- RQ 13: How do the odds of ever and current e-cigarette use differ among students attending schools with varying levels of e-cigarette retailer density?
- RQ 14: How do the odds of ever and current e-cigarette use differ among students attending schools with varying levels of e-cigarette advertising volume?
- RQ 15: How is the proportion of retailers that sell vaping products associated with the odds of ever and current use?

Survey data from the 2014 New Jersey Youth Tobacco Survey (NJYTS) were analyzed to describe e-cigarette use behaviors among New Jersey high school students. Data on e-cigarette promotion at the point-of-sale around each high school in the sample were merged with participant responses from those schools. Analyses documented the extent to which the proximate e-cigarette

retail environment was associated with ever and current use of the products. Almost a quarter of New Jersey high school students have tried using an e-cigarette and 12.1% are current users, making e-cigarettes the most popular tobacco product among youth in the state. The prevalence of current use in New Jersey is on par with the national rate of 13.4%.¹⁸ In both bivariable analyses and adjusted logistic regression models, being male, non-Hispanic white, and having a history of tobacco product use were strongly associated with ever and current e-cigarette use. Previous tobacco use was the strongest predictor of e-cigarette use, consistent with nearly all population-level studies.^{7,14,19,22,24,91,122} The odds of trying an e-cigarette among those who have ever used another tobacco product were 18 times the odds among students who have never used tobacco [AOR: 18.05, (14.58, 22.33), $p<.0001$]. Attending a school with a high level of economic disadvantage, operationalized as the percentage of students receiving free or reduced lunch, was negatively associated with e-cigarette use.

Only an adjusted measure of e-cigarette retailer density near schools (using the weighting system described in Manuscript 2) was associated with ever e-cigarette use [AOR: 1.08, (1.01, 1.15), $p=0.04$], though self-reported exposure to tobacco advertising in stores was also a significant predictor of experimentation ($p<.0001$). All measures of e-cigarette retail within a half-mile of schools (i.e., unweighted and weighted retailer density and advertising volume) were significantly associated with the odds of being a current user ($p<.0001$). The weighted measure of e-cigarette retailer density, an indicator of availability and promotion relative to other tobacco products, strongly predicted odds of current

use [AOR: 1.08, (1.01, 1.16), $p=0.04$]. This study was the first to link store audit data on e-cigarettes with youth use behaviors, but the finding that retail exposure is associated with tobacco product use is consistent with the existing literature on cigarette retail and youth smoking.

Common themes

All three manuscripts demonstrated that e-cigarettes have become increasingly popular in New Jersey in recent years. Manuscript 1 highlighted the rapid growth in vape shop openings, Manuscript 2 documented a slightly higher prevalence of e-cigarette availability and advertising than previous point-of-sale studies,^{50,60-62} and Manuscript 3 found that rates of e-cigarette use among youth are on par with the increasing rates observed nationally.^{17,18,123} The intense marketing of e-cigarettes in youth-focused neighborhoods during a time when youth use of the products is on the rise is troubling.

E-cigarettes are known to appeal to smokers^{14,19,24,91,121} and this relationship is supported by the results of Manuscript 1 and Manuscript 3. That vape shops are opening in areas where tobacco retail is high suggests that the vaping industry is vying for the patronage of tobacco users, who are recognized consumers of e-cigarettes and may use the products during cigarette quit attempts.^{5,118} Even among youth, previous tobacco use was the strongest predictor of e-cigarette experimentation and current use in Manuscript 3. Despite this consistent relationship across studies, however, nearly 6% of New Jersey high school students who have never used tobacco have tried an e-cigarette.

Moreover, the e-cigarette retail environment near schools was predictive of e-cigarette use even after controlling for tobacco use, indicating that vapor products may have some appeal to youth who may not have been at risk for tobacco use.

National data show that e-cigarette use is largely a behavior of white Americans; prevalence is significantly lower among racial and ethnic minorities, particularly black Americans.^{7,85,92} Findings from this dissertation confirm this relationship and further suggest that the e-cigarette retail environment may play a role in differences in uptake. Manuscript 1 and Manuscript 2 demonstrated that vapor retail outlets and promotion of e-cigarettes were significantly more common in predominantly white communities. Manuscript 3 revealed an important link between exposure to e-cigarette marketing near schools and e-cigarette use among youth, who are also more likely to be white.

Strengths and limitations

The three studies in this dissertation were the first to describe the types of communities where vape shops are opening and document associations between e-cigarettes at the point-of-sale and youth vaping behaviors. To date, nearly all studies on the tobacco retail environment focus on cigarettes, so the research presented here fills important gaps in the tobacco control literature. Perhaps most importantly, this project demonstrated that more nuanced metrics are needed to describe non-cigarette tobacco product promotion at the point-of-sale. Unlike cigarettes, which are available in virtually every tobacco retailer,

products like e-cigarettes are promoted and available at different rates between communities. Adjustments that take into consideration the promotion of e-cigarettes in the context of the diverse tobacco marketplace are necessary to more accurately describe exposure to tobacco product marketing. This dissertation proposes a novel approach to address this issue.

Despite the importance and timeliness of each manuscript, they are not without methodological limitations. All of the studies were specific to New Jersey so the results may not be generalizable to other geographic regions. It should be noted, however, that New Jersey is one of the most diverse states in the U.S., making it an ideal location to study tobacco product use among demographic subgroups. Each manuscript was cross-sectional in nature, a substantial limitation given the dynamic e-cigarette marketplace. With FDA set to assert its deeming regulations on electronic nicotine delivery systems, the market is expected to change substantially in the next few years, so results from Manuscripts 1 and 2 may not hold in the near future. The data's cross-sectionality is a particular concern in Manuscript 3. Although the study identified predictors of ever and current e-cigarette use, we cannot make any claims about causality or future tobacco use trajectories (e.g., whether studies continue to use e-cigarettes or other tobacco products, or stop using tobacco products altogether).

Due to the unavailability of student addresses, Manuscripts 2 and 3 focused only on the school neighborhood. School zones are important environments that can shape health behaviors, but they are not the only places

where youth may be exposed to e-cigarette and tobacco marketing. Furthermore, each school zone was defined as a half-mile, egocentric buffer around the school building. This is a commonly-used metric in tobacco control point-of-sale studies,^{34,36,38,71} but it may not accurately represent students' activity spaces within their school neighborhoods. Finally, the traditional tobacco retail environment is known to influence tobacco use behaviors, but it is not the only channel for e-cigarette sales. Online vendors and other retail locations not explored in this dissertation may be equally as influential.

Implications for policy-making and public health

At this point in time, the e-cigarette industry faces no federal manufacturing or marketing restrictions. As a result, e-cigarette companies offer a wide variety of products (e.g., flavored e-liquids, open tank systems) and use advertising strategies that are banned for cigarettes (e.g., self-service counter displays, television advertisements, event sponsorships).^{98,99,124} In New Jersey, there are no licensing requirements for vendors that sell vapor products. Policymakers' hesitancy to pass legislation may be due in part to a lack of research regarding the safety of e-cigarettes as well as the influence of e-cigarette marketing on use behaviors. Studies on the availability and promotion of these products at the point-of-sale are necessary to inform policy and lead to scientifically-driven legislation. The three manuscripts in this dissertation, which highlight the rapid growth in vape shop openings, the high prevalence of e-cigarette advertising near schools, and the link between the retail environment

and youth e-cigarette use, provide support for regulations that would make e-cigarettes less available and less appealing to youth.

It is worth noting, however, that e-cigarettes are widely regarded as a less risky product than combusted tobacco. As such, they may benefit individuals who are unable or unwilling to quit smoking. Although most public health professionals agree that youth should not use any form of nicotine, harm reduction among adult smokers may substantially reduce the morbidity and mortality caused by cigarettes. This dissertation provides evidence that e-cigarette retail differs across communities, such that the products are less available and less promoted in predominantly black neighborhoods. Rates of combustible tobacco use (i.e., cigarettes and cigars) are highest among blacks in the United States, who also experience smoking-related health disparities.¹²⁵ If reduced risk products are less accessible to populations that would potentially benefit from their use, existing health disparities may worsen. This concept is explored in-depth in Manuscript 1. In summary, marketing restrictions that reduce e-cigarette access and appeal to youth are necessary, but regulations should not be so severe that they destroy the market entirely.

Future research directions

Continued surveillance of youth and adult tobacco behaviors are essential to monitor the potential impact of e-cigarettes on public health. Although there is scant evidence that e-cigarette use is high among those who have never used tobacco, this behavior may change as the e-cigarette market continues to evolve

and as the public's risk perceptions about e-cigarettes change. Longitudinal surveillance studies, such as FDA and NIH's Population Assessment of Tobacco and Health (PATH) study, will be especially useful to investigate whether e-cigarettes are contributing to successful quitting among smokers, or if they have a "gateway effect," leading youth to experiment with riskier tobacco products. Special attention should be paid to differential rates of e-cigarette uptake between sociodemographic groups and the potential influence on smoking-related health disparities.

In addition to behavioral surveillance, researchers should continue to follow trends in e-cigarette retail, such as product characteristics driving sales growth and the types of devices that are available at the point-of-sale and in other retail locations. At this point in time, e-cigarettes are considered less risky than combustible tobacco, but product offerings will change in the coming years and the new generation of electronic nicotine delivery systems may have a different risk profile than the e-cigarettes that are currently marketed. In order to accurately assess the safety of e-cigarettes in the years to come, public health researchers and exposure scientists will need to collaborate to identify *what* people are using, *how* they are using it, and its associated level of risk.

Finally, the kind of research presented in this dissertation should be expanded, not only geographically, but methodologically. As technology advances, we are able to better characterize individuals' interactions with their community and environment through tools like personal global positioning systems (GPS) and ecological momentary assessment (EMA). Incorporating

these technologies into studies on tobacco at the point-of-sale will enable us to draw stronger conclusions about the influence of tobacco marketing on use behaviors, not just for youth, but for all community members exposed to the tobacco industry's messages.

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APPENDICES

Appendix 1. Protocol to identify vape shops

Search terms: *vape, vaping, vapor, vape shop, vapor shop, vape store, vapor store, vaping store, vape lounge, vapor lounge, vaping lounge*

1. Yelp

- Zoom to the northernmost part of the state
- Enter terms into search bar
- In Map View, click “Redo Search In This Area”
- Collect name, address, phone number, website from the store’s page
- Move down and across the state and repeat the steps above until all areas of the state have been searched

2. Google Maps

- Zoom to the northernmost part of the state
- Enter terms into search bar and click “Search”
- Collect name, address, phone number, website from the store’s page
- Move down and across the state and repeat the steps above until all areas of the state have been searched

3. Google search

- Enter the terms into the search bar, followed by “in New Jersey”
- Scan the first 20 pages for each search term and follow the links for all results that appear to be websites of vaping retailers
- Collect name, address, phone number, website from the store’s page

4. Search engines on websites dedicated to vaping

- Enter “New Jersey” as your location in the vape shop directory feature on the following websites:
 - vapestores.com
 - vapingstores.com
 - vaporsearchusa.com
 - vapeabout.com
 - guidetovaping.com
- Employ the same approach used to search for vape shops on Google

5. Facebook

- Enter the terms into the search bar at the top of the page, followed by “New Jersey”
- Scan the tabs that say “pages” and “places”
- Collect name, address, phone number, website from all store pages that appear

Appendix 2. Telephone script to confirm status as vape shop

The following script is a general guide to follow when calling the vape shops identified using the search protocol. The major goals of the phone call are to:

- Confirm that the phone number is working and assigned to the vape shop
- Verify that the shop is open and operating
- Record the month and year that the shop opened
- Ensure that the shop does not sell tobacco products

After the phone call, enter the appropriate information, including the date of the phone call, into the vape shop database.

Caller: Hi – Is this [*name of vape shop*]? I'm calling to ask about your hours of operation. When is your store open during the week?

Vape shop staff: [*provides answer*]

Caller: Thank you. I found your address listed as [*address*] online. Is that the correct location?

Vape shop staff: [*provides answer*]

Caller: I've probably driven past there before, but I don't remember seeing your shop. When did your store open?

Vape shop staff: [*provides answer*]

Caller: Congratulations on opening up. Do you by any chance also sell tobacco products, like hookah or cigarettes or cigars, or do you only sell vaping products?

Vape shop staff: [*provides answer*]

Caller: Thank you so much for your help.