Spatial Disparities in School Proximity to Tobacco/Vape Outlets

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ABSTRACT

Objective: We sought to determine school and community characteristics associated with proximity to tobacco and ENDS storefronts within a 0.5-kilometer radius in California.

Methods: A list of licensed tobacco retailers was obtained from the California Department of Tax and Fee Administration; retailer names and addresses were used to scrape Yelp in order to determine sub-categorization of business as a vape or tobacco shop. US Census Bureau data was used to assess characteristics at the census tract level, and the California Department of Education provided school characteristics. Logistic regression with backward selection was used to assess for associations.

Results: The final regression model included six community variables which were all negatively associated with retailer proximity (percent male, percent age 5-10, percent age 15-20, percent age 25-30, percent age 55-60, and percent age 60-65) as well as four school characteristics which were all positively associated (percent female students, percent Hispanic students, percent White students, percent eligible for free and reduced priced meals [FRPM]).

Conclusions: Variation in demographics reflected most of the risk associated with school proximity to tobacco retailers. FRPM was associated with storefront proximity indicating that schools with lower socioeconomic status may be at higher exposure to tobacco retailing.

Key Words: tobacco; vaping; e-cigarettes; disparities; school

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INTRODUCTION

In 2020, 19.6% of U.S. high school and 4.7% of middle school students reported past 30-day use of electronic nicotine delivery systems (ENDS), also known as e-cigarettes, the most of any tobacco product type.[1] Currently, e-cigarettes are the most common form of tobacco product used among high school and middle school students and have held this position since 2014.[1,2] These data points have raised concerns among public health professionals and policymakers about an ongoing "vaping" epidemic among youth and adolescents, particularly concerning given the potential short and long-term health harms associated with nicotine exposure for different stages of adolescent development.[3]

Specifically, vaping among underage youth is a pervasive public health challenge that requires further exploration of the tobacco and ENDS product risk environment. According to Monitoring the

Future, the proportion of middle and high school students vaping nicotine doubled between 2017 and 2019.[4] Past 30-day use of vaping in 2019 was 25% among 12th graders, 20% among 10th graders, and 9% among 8th graders.[5] These statistics indicate an increasing proportion of teenagers who vape through middle and high school years, as well a higher overall risk for associated health harms and adverse events derived from vaping, such as e-cigarette or vaping product use associated injury (EVALI), nicotine poisoning, or non-nicotine-related adverse events such as burns and heavy metal poisoning.[5]

The changing tobacco and ENDS retail environment may also influence uptake of these addictive and dangerous products due to illegal access (e.g., underage purchasing, fake identification, ability to source from friends and family, etc.), but also due to exposure to tobacco marketing and advertising from different tobacco retail outlets (TROs) categories. The typology of licensed tobacco retailers is extensive, including non-specialized retailers such as gas stations and grocery stores, but also including physical storefronts who specialize in the sale of tobacco and/or vaping products.[6] Increasing use of e-cigarettes among youth and adolescents has also been paralled by an increasing number of specialty vape, shops (i.e., retailers that specialize in promotion and sale of different ENDS), which may pose unique challenges to prevention efforts due to their role in normalizing use, interacting directly with vaping user communities, using new forms of marketing, and differential marketing and presence in neighborhoods.[7] Access to vape products through specialized retailers can also introduce increased risk for vaping-related adverse events, as stores may offer an enhanced array of flavorings, adulterated e-juices, customized mods, and/or e-cigarette component parts that may lead to overconsumption.

Though selling nicotine-containing products to minors violates federal law, evidence suggests that brick and mortar retailers are the dominant means by which underage youth acquire nicotine products. For example, a 2018 survey of 1,000 underage youth (aged 12-17 years) found that 74% obtained their JUUL flavor pods from physical retail locations, with 52% obtaining this product through social means (i.e. friends/family) and 6% through online transaction.[8] This underlines the potential risk of youth proximity to TROs, such as within a certain distance of schools. In fact, previous studies suggest that the location of TROs effects youth tobacco use patterns, especially the density of TROs around homes but also schools.[9-15]

Existing empirical evidence on the effects of vape shop location on adolescent e-cigarette use is limited but suggests that there may be positive relationship between location and use.[16-18] Predictors of vape shop location, however, vary considerably by area and methodology. One study in New Jersey found that vape shops are located where tobacco retail is high but where few racial minorities reside,[17] whereas others have found that vapes shops are located in areas with larger proportion of minority populations.[19-21] Variability in predictors of vape shop location may reflect the unique demographic and business dynamics of a specific community and suggests the need for location-specific analyses.

Previous literature suggests that physical distance between schools and tobacco outlets is inversely associated with initiation and frequency of cigarette smoking.[22,23] Several of these studies have also tested associations between retailer location and area-level demographic characteristics, including race/ethnicity,[24] age,[6] and education.[25] The concentration of TROs among communities exhibiting specific demographic characteristics may aggravate existing tobacco-related health disparities and usage patterns mediated by access and availability to tobacco and ENDS products.[26,27] Building on this prior research, this study aims to ascertain the proportion of middle and high schools located in California with licensed tobacco or vape retailers within a 0.5 km radius (consistent with previously published approaches), including stratified for general and specialized storefronts. In addition, analyses will seek

to assess the community and institutional characteristics which significantly increase risk for a school's proximity to specialized tobacco or vape retailers.

METHODS

This study was conducted in two phases. The first phase involved data collection of TROs licensed to do business in California and store type category matching by cross-referencing with publicly available data from the business listing and ratings platform Yelp. The second phase involved data analysis of proximity of licensed TROs to California middle and high schools and testing associations with demographic and academic characteristics for potential relationships with tobacco-related health disparities.

Data Collection

A list of California licensed tobacco retailers and their addresses was obtained from the California Department of Tax and Fee Administration, current as of May 16, 2019. The list provides information on tobacco wholesalers, distributors, retailers, and individual sellers (sole proprietors), who are licensed to sell tobacco and ENDS products within California. Store names and locations were cross-referenced with yelp.com publicly available business listing information to obtain retailers' Yelp store categories (e.g., Grocery Store, Tobacco Shop, Vape Shop, Sporting Goods, Restaurants, etc.). Specifically, after collecting CDTFA licensure data, we used a custom programming script written in the Python programming language to collect data directly from Yelp using web scraping in order query and match the retailer's name and business addresses to CDTFA licenses. Additionally, Google Maps API was used to obtain latitude and longitude coordinates for every licensed tobacco retailer.

A shapefile of California's 23,194 census tracts was then obtained from the US Census Bureau. This shapefile included a geodatabase with spatial variables with the count of total population and counts of the following population types: White, African American, American Indian/Alaska Native, Asian, Hawaiian/Pacific Islander, Hispanic, multiracial, male, female, under age 5 years, age 5-9 years, age 10-14 years, age 15-19 years, age 20-24 years, age 25-34 years, age 35-44 years, age 45-54 years, age 55-64 years, age 65-74 years, age 75-84 years, age 85 years and over. These data were used for purposes of exploring potential associations with TRO location and community demographic factors at the census track level.

Polygons for all middle and high schools in California were then obtained from the Stanford Prevention Research Center (SPRC) to plot onto the CA shapefile. Variables specific to public middle and high school characteristics were obtained from the California Department of Education and therefore covered additional domains when compared to the geodatabase obtained from the US Census Bureau, which focused on demographic characteristics. School institution variables were total enrollment, Hispanic enrollment, White enrollment, Black enrollment, Asian/Pacific Islander enrollment, American Indian/Alaska Native enrollment, male enrollment, female enrollment, percent eligible for free and reduced price meals (FRPM), percent foster care, percent homeless, average English and Language Arts test score (distance of average score from minimum "level 3" score defined by the California Department of Education), average Mathematics test score (distance from level 3), percent chronic absenteeism, five-year graduation rate, percent Advanced Placement test score for each level (one through five), percent SAT college career readiness benchmark met. These variables were chosen on the basis of their potential association with tobacco-related health disparities and social determinants of health related to the school environment.

Data Analysis

Data on total population of census tracts was used to calculate percentages for race, gender, and age demographic variables from the US Census Bureau. Similarly, total school enrollment was used to calculate percentages for institutional variables from the California Department of Education.

ArcGIS Desktop 10.7 was used to apply a buffer area to the polygons for all middle and high schools in California. Studies have previously used distances of 0.5, 0.75, or 1.0 miles as thresholds for proximity,[22,24] which is approximately consistent with the 1.0 kilometer (0.62 miles) threshold for walkable distance of 0.5 miles found in federal guidelines (from the Economic Research Service of the US Department of Agriculture).[28] This study applied a 0.5 km buffer area due to the availability of resolute geospatial data at the census tract level. Additionally, this spatial threshold represents a heightened degree of risk posed by entities whose influence on tobacco behaviors are mediated by proximity. Procedurally, an intersect between the buffer shapes (schools plus 0.5 kilometer buffer area) and other geospatial data (i.e. retailer and demographic data) generated a datafile with cases as middle or high schools and variables corresponding to retailer counts and averages for community and institutional data. Visualizations were produced to illustrate the spatial distributions for middle and high school buffer areas with point coordinates for retailers and a choropleth gradient for community demographics.

Retailers denoted as "Tobacco Shop" or "Vape Shop" on Yelp were designated as specialized stores and mapped separately from non-specialized licensed retailers (e.g., convenience stores). R version 4.0.3 was used to compute Spearman rank coefficients between the binary characteristic of having a specialized retailer within 0.5 km of school premises and each community and institutional covariate. In addition, backwards selection was used to build logistic regression models of the proximity to specialized retailers. With the dependent variable as the binary characteristic of having a specialized retailer within 0.5 km of school premises, three separate models were built: (1) a logistic regression model using only institutional covariates, (2) a model with only community covariates, and (3) final model with all covariates. Nagelkerke's R^2 and Akaike's information criterion (AIC) are reported as fit statistics for multivariable regression models.

RESULTS

Out of 2,999 California middle and high schools included in this study, 422 (14%) had TRO storefronts located within 0.5 kilometers of their address, with 979 (33%) schools having a specialized tobacco/vape shop within 1.0-kilometer proximity. Analogously, out of 1800 TROs assessed in this study, 484 (27%) were within 0.5 kilometers of middle/high schools, with 1055 (59%) of storefronts being within 1.0-kilometer proximity to middle/high schools.

Hypothesis-generating analyses were conducted to determine the potential relationships between a school being in close proximity to TROs (within 0.5 km) and predictors that described the school and its surrounding community demographics. Predictors were adjusted for underlying population whenever possible. For example, the counts of individuals in given age groups were converted to percentages of the overall census tract.

Table 1. Bivariate associations between 0.5-kilometer school-retailer proximity and sets of covariates from (**A**) averages of census tracts within 0.5-kilometer buffer area and (**B**) characteristics of school student bodies. Red text denotes statistical significance.

A. Community-Level Variables

Covariate	Pearson's Rho	*p*
% Hispanic	0.045	0.014
% White	-0.042	0.021
% Black	0.098	<0.001
% Asian	0.078	<0.001
% American Indian-Alaska Native	-0.045	0.014
% Hawaiian-Pacific Islander	0.046	0.011
% Multi-Racial	0.065	<0.001
% Other Race	0.043	0.019
% Male	-0.040	0.027
% Female	0.040	0.027
% Age 5-9 Years	-0.121	<0.001
% Age 10-14 Years	-0.141	<0.001
% Age 15-19 Years	-0.052	0.004
% Age 20-24 Years	0.149	<0.001
% Age 25-34 Years	0.173	<0.001
% Age 35-44 Years	0.094	<0.001
% Age 45-54 Years	-0.062	<0.001
% Age 55-64 Years	-0.074	<0.001
% Age 65-74 Years	-0.075	<0.001
% Age 75-84 Years	-0.014	0.452
% Age 85+ Years	0.041	0.026

B. School Variables

Covariate	Pearson's Rho	*p*
% Hispanic	0.087	<0.001
% Black	0.058	0.002
% White	-0.051	0.007
% Asian-Pacific Islander	0.029	0.123
% American Indian-Alaska Native	-0.023	0.218
% Male	-0.047	0.014
% Female	0.046	0.015
% Eligible for FRPM	0.052	0.007
% Foster care	0.027	0.165
% Homeless	0.050	0.009
English Language Arts Test Score	-0.029	0.141
Math Test Score	-0.059	0.003
Chronic Absenteeism	0.020	0.452
Graduation Rate	-0.023	0.374

In bivariate analyses, all census tract variables except percent age 75-85 were significantly associated with a high school having a tobacco/vape storefront within 0.5 kilometers, potentially reflecting the multivariable component of spatial risk across age. Ten of these bivariate associations exhibited positive correlations (percent Hispanic, percent Black, percent Asian, percent Hawaiian-Pacific Islander, percent multi-racial, percent other race, percent female, percent age 20-24, percent age 25-34, percent age 35-44, and percent age 85+), and nine variables were negatively correlated (percent White, percent American Indian-Alaska Native, percent male, percent age 5-9, percent age 10-14, percent age 15-19, percent age 45-54, percent age 55-64, and percent age 65-74). When restricted to variables where the correlation rho exceeded an absolute value of 0.1, two variables were positively correlated (percent age 5-9 and percent age 10-14) and two variables were negatively correlated (percent age 20-24 and percent age 25-34; see **Table 1A**).

Bivariate analysis also revealed that eight out of 14 institutional variables for schools were significantly associated with the 0.5-kilometer proximity to TROs. Five were positively correlated (percent Hispanic, percent Black, percent female, percent eligible for FRPM, and percent homeless), and three were negatively correlated (percent White, percent male, and average math test score). Out of these variables, no Spearman's correlation coefficient (rho) exceeded an absolute value of 0.1 (**Table 1B**).

Backwards selection of school enrollment variables revealed a four-covariate model, including percent female, percent Hispanic, percent American Indian-Alaska Native, and percent eligible for FRPM, which explained 14.7% of variability in proximity of schools to TROs. All variables were positively associated except for percent American Indian-Alaska Native (**Table 2A**). Similarly, a model of census tract variables explained 13.1% of the variability in 0.5-kilometer storefront proximity, with nine variables included: percent female, percent White, percent Black, percent Asian, percent age 5-9, percent age 15-24, percent age 25-34, percent age 55-64, and percent age 65-74. All variables were negatively associated except percent female (**Table 2B**).

Backward selection of both sets of variables revealed a model with four school enrollment variables (percent female, percent Hispanic, percent White, percent eligible for FRPM) and six census tract variables (percent male, percent age 5-9, percent age 15-24, percent age 25-34, percent age 55-64, and percent age 65-74), cumulatively explaining 24.7% of the variability in high school proximity to TROs. In this final model, all school enrollment variables were positively related, and all community variables were negatively related (**Table 2C**).

Table 2. Multivariable logistic regression models, assembled using backwards selection, among covariates from (**A**) census tract averages, (**B**) student traits, and (**C**) both of these.

A. School-Level Variables (Nagelkerke's $R^2 = 0.147$, AIC = 2190)

Variable	Estimate	Std. Error	z	*p*
Intercept	-3.359	0.385	-8.717	<0.001
% Female	0.020	0.007	2.826	0.005
% Hispanic	<0.001	<0.001	3.941	<0.001
% AIAN	-0.091	0.043	-2.140	0.032
% Eligible for FRPM	0.009	0.001	4.089	<0.001

B. Community Variables (Nagelkerke's $R^2 = 0.131$, AIC = 2230)

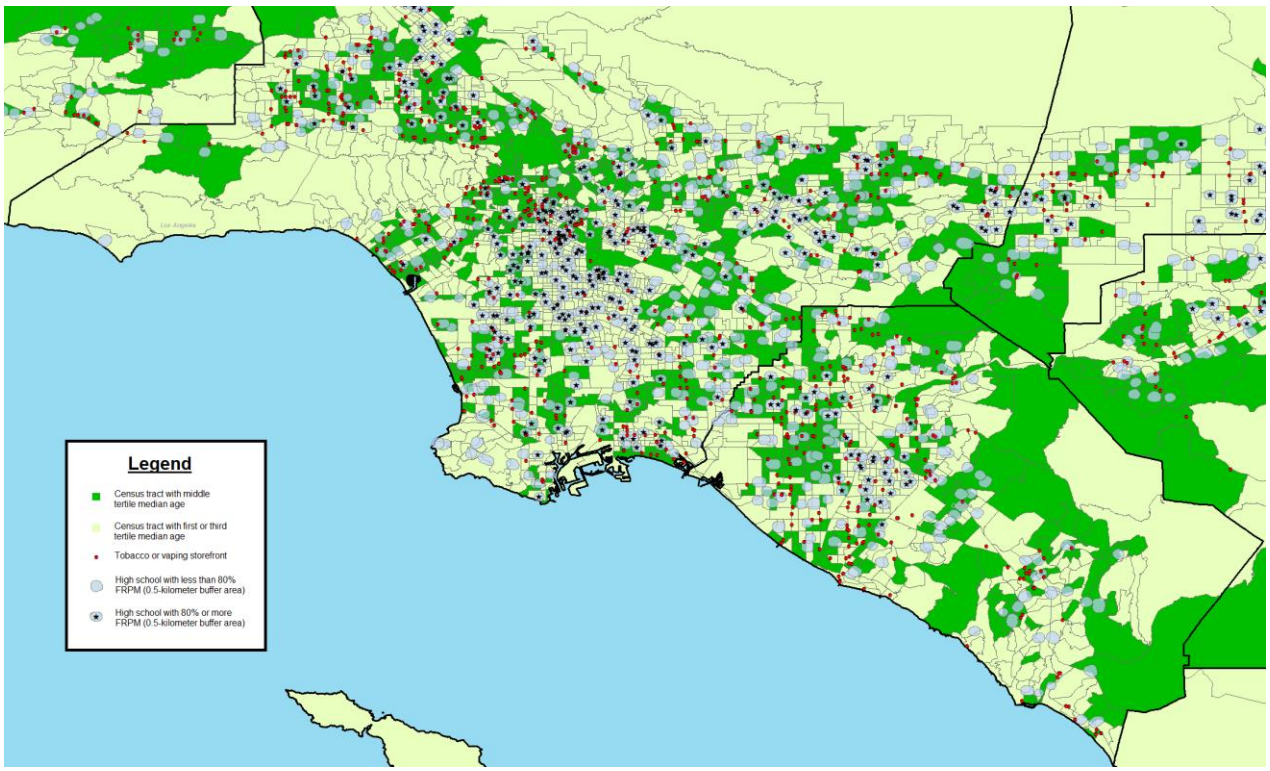
Variable	Estimate	Std. Error	z	*p*
Intercept	7.005	2.278	3.075	0.002
% Female	0.136	0.028	4.815	<0.001
% White	-0.029	0.007	-3.933	<0.001
% Black	-0.036	0.010	-3.659	<0.001
% Asian	-0.041	0.008	-5.001	<0.001
% age 5-9 years	-0.757	0.072	-10.440	<0.001
% age 15-19 years	-0.215	0.039	-5.426	<0.001
% age 25-34 years	-0.138	0.034	-4.009	<0.001
% age 55-64 years	-0.263	0.051	-5.143	<0.001
% age 65-74 years	-0.289	0.063	-4.585	<0.001

C. All Variables (Nagelkerke's $R^2 = 0.247$, AIC = 2015)

Variable	Estimate	Std. Error	z	*p*
Intercept	14.550	2.226	6.536	<0.001
% Female in school vars	0.002	0.007	2.839	0.005
% Hispanic in school vars	<0.001	<0.001	3.489	<0.001
% White in school vars	0.009	0.004	2.253	0.024
% Eligible for FRPM	0.017	0.003	5.132	<0.001
% male in community	-0.109	0.028	-2.893	<0.001
% age 5-9 in community	-0.688	0.068	-10.186	<0.001
% age 15-24 in community	-0.217	0.039	-5.460	<0.001
% age 25-34 in community	-0.147	0.036	-4.114	<0.001
% age 55-64 in community	-0.292	0.055	-5.302	<0.001
% age 65-74 in community	-0.306	0.067	-4.558	<0.001

Regression modeling revealed that risk for a high school being within 0.5-kilometer proximity to a TRO corresponded largely to demographic variables, namely the age distribution of the applicable residential community, and also to school percentage FRPM. The spatial distribution of tertiles of residential median age were also visualized for Los Angeles Basin (representing approximately 45% of California's residents and a high density of schools), with the following tertile thresholds: below age 33.5 years, 33.5-40.9 years, and over 40.9 years. The distribution of middle/high schools (including 0.5-kilometer buffer areas) and tobacco/vape retailers were also visualized, and middle/high schools with high burden of FRPM (top tertile, greater than 80% FRPM) were symbolically denoted (**Figure 1**).

Geospatial patterns observed in Los Angeles Basin indicated that high FRPM burden increased risk of school-retailer proximity in areas which were in the middle age tertile, but not in areas which were in the first or third age tertiles, thereby suggesting that school FRPM percentage may function as a moderator for the association between residential demographics and school-retailer proximity.



DISCUSSION

The objective of this study was to use interdisciplinary methods in data mining, statistical analysis, and geospatial analysis to assess the risk environment associated with TRO proximity to California public schools, while also examining potential tobacco-related health disparity correlates. Overall, our study found that 14% of middle and high schools have the presence of a TRO within 0.5 kilometers and that more than a quarter (27%) of TROs are located within 0.5 kilometers of schools. Equally concerning, a third of schools have a specialized vape shop within 1.0 kilometers, concerning as these types of retailers are dedicated to the marketing, promotion and sale of highly addictive and popular emerging ENDS products.

Importantly, the study identified specific tobacco-related health disparity characteristics among school areas with closer proximity to TROs and specialized TROs that require further study. For example, the proportion of students in a school with family income qualifying for FRPM, as well as the proportion of students identifying as Hispanic, significantly increased risk for 0.5-kilometer proximity to TROs. Furthermore, in geospatial visualization of the Los Angeles Basin, we observed that some spatial clustering of high-FRPM schools clustered in areas with high density of TROs (e.g. Koreatown, Los Angeles) but other clusters were in areas of low TRO density (e.g. South Los Angeles), indicating that the influence of FRPM as a facilitator of TRO proximity is highly spatially-dependent.

The study also found that TROs tend to be in areas where the median age of residents is skewed toward the center, away from places where extremely young or old people tend to predominantly reside. This finding suggests that there may be an increased risk for underage access to e-cigarettes among students whose schools are in areas with lower concentrations of elderly individuals or families with children. Also, schools with nearby TROs tended to have student bodies which are more Hispanic and are more economically disenfranchised (as reflected by FRPM) indicating that potential future socioeconomic disparities in vaping may derive from school geographic location. While most (95%) of the 21 community variables were significantly associated with retailer proximity, the associations for only 57% of the 14 institutional variables met statistical significance. Furthermore, the only four

variables with exceeding rho=|0.1| were community-level variables. This pattern suggests that TRO location is more responsive to resident demographics than the specific community composition of school areas. However, multivariable modeling revealed a similar fit for models derived from both sets of variables.

Interestingly, the final model explaining high school proximity to retailers exhibited positive directionality for all school variables and negative directionality for all community variables, with percent White student body switching from negative to positive, and percent age 25-34 residents switching from positive to negative. These results may suggest that influential school characteristics may counterbalance influential community demographics. Interestingly, the opposite effects of gender between community composition (negative association of females) and school composition (positive association of females) suggests that schools with highest likelihood of 0.5-km proximity to TROs have relatively high proportions of females in their student bodies while being in communities with relatively low proportions of females, although these associations should be further examined in hypothesis-confirming studies. Overall, model results indicate that the schools with greatest likelihood to have a nearby TRO are those whose student demographics have a high proportion of Hispanics, females, and suffer from low economic status indicators, who also reside in communities that have low densities of men, children, and elderly populations.

The significance of percent eligible for FRPM in multivariable modeling represents an aberration in the list of included variables, which otherwise entirely pertained to demographics. Eligibility for FRPM is derived from the National School Lunch Program (NSLP), which denotes eligibility based on household income or when a child meets the definition of foster, homeless, migrant, or runaway.[29] The household income threshold in school year 2021-2022 for a family of four in California was $34,450 per year.[30] Findings from this study indicate that children from these households are more likely to go to a middle or high school that is close to a TRO, representing a significant tobacco health disparity-related data point that requires further analysis.

Prior research has identified that communities with high proportions of young adults are more likely to have TROs.[6] Results from this study suggest that the distribution of residential age groups also influences TRO activity in school areas. In addition, this study indicates that schools with more socioeconomically impacted student bodies have even greater risk of exposure and access to tobacco and ENDS products that can lead to greater uptake, potential adverse health effects, and disease burden.

The uneven distribution of TROs across schools in California may exacerbate existing disparities in uptake, initiation and use of tobacco and ENDS products targeted towards at-risk youth and adolescents. Our study provides important preliminary analysis of the location and characteristics of TROs and their proximity to CA schools. However, the association of retailer proximity with schools according to institutional/community characteristics needs to be further analyzed and delineated at a more resolute local and community level for the purposes of developing targeted interventions, local policies and ordinances, and health promotion efforts to limit uptake and use among this critical population in order to prevent a new generation of nicotine addicted Californians.

Limitations

This study used official state licensing records and business listing data from social media to identify tobacco and vape retailers. There exists the possibility of selection bias as the adequacy of state records for TROs to submit documentation, and there may also exist classification bias based on how Yelp allows retailers to self-categorize businesses as a "Tobacco Shop" or "Vape Shop." The effect sizes

observed in bivariate analyses in this study were also small, indicating that these variables have real-world predictive power which are individually negligible. Furthermore, logistic regression modeling using backward selection of a comprehensive set of variables revealed an R^2 of 0.247, indicating that the cumulative effect of these variables in predicting school-retailer proximity were meaningful though largely incomplete. Finally, though predictors were adjusted for overall census tract population, the census tracts themselves are unequal in physical size which therefore introduces population density as a possible confounder in observed associations. Future studies should investigate the impact of community demographics and school traits in influencing the risk of heightened access for tobacco/vape products among adolescents and also assess local, city, and county differences in potential associations and tobacco-related risk factors for these communities.

CONCLUSIONS

Over one in ten middle/high schools in California is within 0.5 kilometers of a tobacco or vaping retailer. The traits of middle and high schools and their surrounding communities appear to influence the risk that they are within walking distance of a tobacco or vaping storefront. The significant associations between school-retailer proximity with age, race, and socioeconomic status may threaten to exacerbate disparities in tobacco/vaping uptake. Tobacco control policies and local interventions need to be tailored towards this unique TRO risk environment in close proximity to schools.

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CRediT Author Statement

Raphael Cuomo: Conceptualization, Formal Analysis, Investigation, Methodology, Project Administration, Software, Supervision, Validation, Visualization, Writing – Original Draft. **Vidya Purushothaman:** Data Curation, Formal Analysis, Methodology, Resources, Software. **Joshua Yang:** Conceptualization, Funding Acquisition, Writing – Review & Editing. **Tim Mackey:** Conceptualization, Funding Acquisition, Project Administration, Resources, Supervision, Writing – Review & Editing.

Data Availability Statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Approval

Not applicable

Declaration of Interests

TM is an employee of the startup company S-3 Research LLC. S-3 Research is a startup funded and currently supported by the National Institutes of Health – National Institute on Drug Abuse through a Small Business Innovation and Research contract for opioid-related social media research and technology commercialization. Author reports no other conflict of interest associated with this manuscript.

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