Density of Tobacco Retailers Near Schools: Effects on Tobacco Use Among Students

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Objectives. We examined the relationship between students' tobacco use and the density and proximity of tobacco retailers near their schools.

Methods. We used data from the 2003–2004 California Student Tobacco Survey and California retail licensing data. Measures included students' self-reported tobacco use and geocoded state-reported locations of tobacco retailers. We used random-intercept generalized linear mixed modeling to jointly evaluate individual-level and school-level predictors.

Results. Density of retailers was associated with experimental smoking (odds ratio [OR]=1.11; 95% confidence interval [CI]=1.02, 1.21) but not established smoking (OR=1.06; 95% CI=0.94, 1.20). The effects on experimental smoking were confined to high school students (OR=1.17; 95% CI=1.06, 1.29) in urban areas (OR=1.11; 95% CI=1.01, 1.21); no effects were observed among middle school students or in rural schools. High school students were more likely to obtain cigarettes from a retailer; middle school students relied more heavily on social sources.

Conclusions. Our results support the plausibility of reducing rates of students' experimental smoking, but not established smoking, by restricting their access to commercial sources of tobacco in urban areas. (*Am J Public Health.* 2009;99: 2006–2013. doi:10.2105/AJPH.2008.145128)

The dominant approach to minimizing illicit drug use among adolescents in the United States has been supply reduction, often dubbed the "war on drugs." By contrast, the dominant approach to minimizing tobacco use among underaged children and adolescents has been demand reduction. However, tobacco control activists have been showing increased interest in supply reduction as a complement to existing prevention efforts and in response to evidence that perceived availability of tobacco is perhaps the most important predictor of tobacco use initiation among young people.[1]

One way to reduce adolescents' access to tobacco is to advocate for the licensing of tobacco retailers and the revocation of licenses if retailers sell tobacco to minors.[2] But the consensus seems to be that enforcement of state laws against selling tobacco products to minors as the way to prevent underaged adolescents from purchasing these products has been insufficiently effective in terms of reducing adolescent tobacco use.[3] Such efforts have not been without impact, however, because they appear to have influenced adolescents to obtain their tobacco primarily from social sources, such as older siblings and older friends, as opposed to commercial sources.[3–5]

Tobacco control activists have begun exploring another way to prevent underaged adolescents from purchasing tobacco. The Institute of Medicine recently called for states to limit the number of tobacco retail outlets for the express purpose of reducing tobacco use through reduced access.[6] Activists are beginning to recommend that communities adopt zoning restrictions and conditional use permits to limit sales of tobacco products near schools.[7] Although such an approach might help reduce access to tobacco products among students, it is unclear whether reducing access would lead to actual reductions in tobacco use. Evidence of the positive impact of reductions in the density of alcohol outlets on alcohol-related problems (e.g., violent assaults) encourages those who believe that reducing the density of tobacco outlets could reduce problems related to tobacco use.[6,8]

Existing observational data can be used to begin evaluating the premise that proximity of tobacco retailers to school sites might influence student tobacco use. The limited research in this area suggests that presence of tobacco retailers near homes and schools may influence adolescent tobacco use by making cigarettes easier to procure. Novak and associates[9] reported recently that, after control for census tract–derived school neighborhood characteristics, the density of tobacco retailers in the Chicago area was associated with students' reported tobacco use. Novak and his associates were not able to provide data on adolescents' tobacco purchasing patterns or gauge their perceived ease of obtaining tobacco products. Leatherdale and Strath[4] found that increased density of tobacco retailers near schools in Ontario, Canada, was associated with a greater likelihood that student smokers would purchase cigarettes rather than obtaining them from social sources.

Evidence also suggests that the density and proximity of tobacco retailers influence adults' smoking behaviors, including number of cigarettes smoked per day.[10] One non-school-based study[11] confirmed that retail tobacco availability, defined as the number of retailers that illegally sold tobacco per 1000 young people residing in the community, was associated with initiation of tobacco use but not with rates of established smoking.

Using a large statewide survey of students in randomly sampled California schools, we investigated whether similar effects would be found for the geographically and demographically more heterogeneous California student population. If increased adolescent tobacco use were found to be associated with tobacco retailer density near schools in California, such findings should be pertinent to most other states as well. The reason is that the situation in these other states is similar to that in California as a result of the Congressional mandate called "the Synar amendment"[12]; that is, laws and enforcement standards are in place in these states to sanction adolescent possession, use, or purchase of tobacco.[13]

In theory, the Synar amendment requires all states to enforce prohibitions on the sale of

tobacco products to minors and document that no more than 20% of their tobacco retailers are selling tobacco products to minors or be faced with the loss of millions of dollars of federal aid. If tobacco retailers were totally compliant with state prohibitions on the sale of tobacco products to minors, then student tobacco users would have to rely on older individuals procuring cigarettes for them, and student tobacco use rates would be unaffected by the density of tobacco retailers around schools. Annual evaluations in which underaged confederates have been used to purchase cigarettes continue to show significant noncompliance, however (e.g., see http://ww2.cdph.ca.gov/programs/tobacco/Documents/CTCPResultsYouthTobaccoPurchaseSurvey2008.pdf).

We attempted to extend current research by evaluating measures of tobacco retailer density and proximity in relation to student tobacco use, tobacco purchasing patterns, and perceived ease of obtaining cigarettes, as assessed through random sample surveys of adolescent students in California and use of geocoded information on state licensing of tobacco retailers. In addition to including diverse neighborhoods in our study, ranging from densely populated urban centers to sparsely populated rural areas, we assessed various neighborhood-level (e.g., tobacco retailer density), school-level, and student-level characteristics given that they can contribute to students' susceptibility to tobacco use. Age, gender, and racial/ethnic background are all student-level characteristics that have been shown to influence tobacco use.[14] Thus, we included these variables along with parental educational attainment, another consistent correlate of adolescent tobacco use.[15] We also assessed students' perceptions of the prevalence of tobacco use among their peers.

METHODS

We used data from California's 2003–2004 In-School Evaluation of Tobacco Use Prevention Education Programs, which included administration of the California Student Tobacco Survey, a cross-sectional survey designed to collect information on student tobacco use and correlates at 261 schools randomly sampled proportional to size from a directory of California public schools.[16] Self-report surveys were administered in class by trained survey proctors between October 2003 and March 2004. After adjustment for schools missing the address information necessary for coding each school in terms of its exact longitude and latitude, the analysis included 245 schools. In terms of demographics, the 245 schools retained in the analysis were similar to the 261 in the original sample (all *t*-test comparisons on demographic measures were nonsignificant [$P>.10$]). The resulting analytic sample included 19 306 students.

The response rates for schools (85.0%) and students (66.3%) were adequate, that is, consistent with response rates reported in previous student tobacco use survey research.[17] All student participation required active parental consent, which is typically associated with participation rates approximately 10% to 25% lower than those normally associated with passive parent consent.[18] In previous studies on student tobacco use comparing prevalence estimates obtained under active and passive parent consent procedures, only minimal differences in estimates have been detected when response rates are high, despite the differences in the percentages of participating students.[18,19]

Measures

Most of the items used in the California Student Tobacco Survey were derived from national surveys, particularly the National Youth Tobacco Survey, the Youth Risk Behavior Survey, and the Behavioral Risk Factor Survey. Detailed information on the psychometric properties of the survey items is available at the Web sites dedicated to these surveys (http://www.cdc.gov/tobacco/data_statistics/surveys/nyts/index.htm, http://www.cdc.gov/HealthyYouth/yrbs/questionnaire_rationale.htm, and http://www.cdc.gov/BRFSS/technical_infodata/surveydata/2008.htm, respectively).

Study outcome measures. Students' tobacco use was assessed in terms of whether they were established or experimental smokers. Established smoking was defined as smoking cigarettes at least 1 day in the preceding 30 days and having ever smoked 100 or more cigarettes.[20] Experimental smoking was defined as smoking cigarettes at least 1 day in the preceding 30 days and not having smoked at least 100 cigarettes.[20] Data were also gathered on average number of cigarettes smoked on days when respondents smoked. These smoking status measures have been validated and used in previous studies,[21–23] and adolescents' self-reports of tobacco use have been shown to be generally valid.[24]

Two additional tobacco-related outcome measures focused on students' usual source of cigarettes in the preceding 30 days and, if they purchased tobacco products, the usual commercial venue where they did so. The question addressing usual commercial venues included the following options: gas station, convenience store, grocery store, drug store, vending machine, Internet, and other. Both questions were derived from the National Youth Tobacco Survey.[25]

Covariate measures. When practical, we dichotomized the study covariates to minimize loss of degrees of freedom and to facilitate the interpretation of our results. We conducted sensitivity analyses demonstrating that different categorizations of study covariates did not change our overall findings. For instance, no differences in our findings were observed when friends' smoking was dichotomized as all 4 best friends smoke versus 3 or fewer best friends smoke as opposed to when it was dichotomized as 2 or more best friends smoke versus 1 or no best friends smoke. The final model odds ratios (ORs) for this covariate were 5.49 (95% confidence interval [CI]=4.04, 7.45) under the first formulation and 4.85 (95% CI=4.26, 5.53) under the second formulation. All other statistically significant associations with risk of experimental smoking remained significant no matter how friends' smoking was operationalized.

The individual-level measures used as study covariates included age, gender, race/ethnicity, English-language use in the home, self-reported previous year's grades, perceived prevalence of peer smoking, friends' smoking, ease of obtaining cigarettes, and depressive symptoms. Most of these items were derived from the National Youth Tobacco Survey[25] and the Youth Risk Factor Survey.[26] The peer tobacco use measure assessed whether or not respondents perceived most of their peers (61%–100%) as smoking. The friends' smoking measure indicated whether most (≥2) of one's 4 best friends smoked. A 4-point Likert scale (very

easy, sort of easy, sort of hard, very hard) was used to determine students' perceived ease of obtaining cigarettes.

Depressive symptoms were measured with a single item, derived from the Youth Risk Behavior Survey,[26] that assessed prolonged self-reported hopelessness and feelings of sadness in the preceding year. English-language use in the home was assessed according to the frequency with which English was spoken in the student's home (always, often or sometimes, almost never).

School-level or community-level covariates included school type (middle versus high school), whether or not the school was located in a rural area (school rurality), and school-level parental education. School-level parental education, used as a proxy for socioeconomic status, was based on school averages in terms of parents' self-reported educational attainment (less than high school, high school, some college, college, postgraduate education); schools report this information annually to the California Department of Education.[27]

School rurality was determined by the population category associated with a school's zip code as designated by the 2000 census.[28] The census classifies areas associated with zip codes into one of 8 categories, ranging from large cities to rural areas. For ease of interpretation, the 2 categories containing the word rural were designated rural; all other categories were designated urban.

Main predictor variables. The primary study predictors, retailer density and proximity, addressed the presence of tobacco retailers near schools. Retailer density was assessed with 2006 California Board of Equalization data on tobacco retail licensees. The board provided a list of all organizations and businesses required to pay excise taxes to the state of California, and this master list was edited to include only businesses that paid the cigarette and tobacco products retailer license tax (other tax licensees were not included because they were usually wholesalers rather than retailers).

We used a batch geocoder based on Google Maps (http://www.batchgeocode.com) to translate the addresses of these businesses and the addresses of the schools in our analytic sample to geocodes (longitude and latitude data associated with a specific address). We imported the resulting geocodes into ArcGIS version 9.2 (ESRI, Redlands, CA) geographic information systems to generate points on a map. Because of geocoding limitations, not all of the data were geocodable; as a result, we excluded 237 of the 22165 retailers (1.1%) from our analyses.

A 1-mile (1.6 km) radius buffer area was created around each school to represent the area most likely to be frequented by the school's students. One mile was considered the outer limit of the distance that most students would walk or bike regularly to school in urban areas but the distance minimally necessary in rural areas to encompass at least one tobacco retailer near most rural schools. We overlaid a map of the retailer locations with a map of the school buffer zone areas (this double overlaying is called a "spatial join") to determine the number of tobacco retailers within each school's buffer zone.

To spatially join these data, we converted projections of the maps to the NAD 1983 State Plane—one of a few consensus coordinate systems used by states to provide precise location information across different map layers—so that they would be consistent with the US census California state boundary file (http://www.census.gov/geo/www/cob/st2000.html). This standardization of projections allowed us to minimize variability in distances because all map layers could appear on the same longitude–latitude plane.

A projection of school buffer zones was spatially joined to the projection of geocoded tobacco retailers, yielding the number of tobacco retailers within each school's 1-mile buffer zone. As with most count data involving a positive skew, the resulting density measure required a natural log transform.[29] As a separate measure of proximity, the average straight-line distance from the main office of the school to each retailer within the school's 1-mile buffer was measured in feet.

We conducted model-based rather than design-based analyses[30] because the general concept being evaluated here—that density and proximity of tobacco retailers to schools may be associated with student tobacco use—was not expected to be limited to California. Thus, for model-testing purposes, we ignored the sampling weights associated with the complex design of the California Student Tobacco Survey. As a result, our findings should not be interpreted as representative of California.

Data Analysis

We used Stata versions 9.2 and 10.1 (Stata Corp LC, College Station, TX) in conducting all of our analyses. The first step was to determine the demographic characteristics of the study sample (Table 1). This analysis suggested that the analytical sample (n=19306) was highly similar to the overall sample (n=25973). Characteristics of both samples are shown in Table 1.

Second, we assessed smoking outcome frequencies, as well as frequency values for the main predictors and cigarette access behaviors, for the overall analytic sample and according to school type (high school or middle school) and school rurality. We used multilevel logistic regression to examine differences associated with school type and rurality.

Third, we used random-intercept models in a generalized linear mixed-model framework to examine the possible influence of tobacco retailers on student tobacco use as well as the influence of confounders. We initially assessed the effects of density of retailers and then examined the effects of retailer proximity. We tested models on both the overall sample and 4 subsamples: high schools, middle schools, urban areas, and rural areas. All regression analyses controlled for student-level and school-level covariates.

RESULTS

Descriptive data on the analytical sample (Table 1) showed that demographic characteristics were consistently associated with tobacco use status. For example, established smokers were older and reported lower letter grades for the previous year. In addition, male students, White students (versus students from other racial/ethnic groups), students with depressive symptoms (versus students without such symptoms), and students residing in rural areas were more likely to be established smokers.

Descriptive results for student tobacco use are reported in Table 2. More than 9% of students reported having smoked on at least 1 day in the preceding 30 days, but fewer than one third of these students had smoked 100

TABLE 1—Demographic Characteristics of the Full Sample and Analytic Sample, Along With Smoking Prevalence Estimates for the Analytic Sample: California Student Tobacco Survey, 2003–2004

Characteristic	Full Sample (n = 25 973), % or mean (SD)	Analytic Sample (n = 19 306), % or mean (SD)	Established Smokers, % or mean (SD)	Experimental Smokers, % or mean (SD)
Race/ethnicity				
African American	7.1	6.6	1.8	4.7
American Indian/ Native Alaskan	2.6	1.6	2.8	6.3
Asian	12.8	13.2	1.6	3.7
Hispanic/Latino	33.6	31.9	2.0	7.9
Native Hawaiian/Pacific Islander	2.6	2.7	4.6	8.6
White	41.9	43.9	4.3**	6.0**
Gender				
Boys	46.9	45.7	3.8	6.4
Girls	53.1	54.3	2.4**	6.2
Frequency of English-language use in the home				
Almost always	66.5	67.4	3.4	6.2
Often or sometimes	27.4	26.7	2.1	6.5
Almost never	6.0	5.9	3.3**	6.9
Felt sad/hopeless almost every day in preceding year				
Yes	27.6	27.3	4.7	10.3
No	72.4	72.7	2.3**	4.8**
Smoking among peers				
Most peers smoke (61%–100%)	10.8	10.7	8.9	16.1
Other	89.2	89.3	2.3**	5.1**
No. of best friends who smoke				
2–4	13.9	13.8	15.7	23.4
0–1	86.1	86.2	1.0**	3.6**
Location of school				
Urban	91.9	90.8	2.9	6.4
Rural	8.1	9.2	4.5*	5.5
Type of school				
High school	57.9	61.2	4.5	8.1
Middle school	42.1	38.8	0.7**	3.4**
Age, y	14.9 (1.9)	15.1 (1.9)	16.6 (1.4)**	15.8 (1.9)**
Previous-year grade point average[a]	3.1 (0.8)	3.1 (0.8)	2.6 (1.0)**	2.6 (1.0)**
School-level parental education rating[b]	2.9 (0.7)	3.0 (0.6)	3.0 (0.6)	2.9 (0.6)**

Note. *P* values for cross tabulations are from χ^2 tests; *P* values for means are from *t* tests.
[a]On a traditional 4.0 grade point scale.
[b]Ratings were on a 5-point scale (1 = less than high school, 2 = high school, 3 = some college, 4 = college, 5 = postgraduate education).
*$P \leq .01$; **$P \leq .001$.

cigarettes or more; thus, more than 6% were experimental smokers with a limited history of previous smoking. Table 3 presents (separately for established and experimental smokers) data on sources of cigarettes among respondents who smoked. Overall, fewer than one third of students who had smoked during the preceding 30 days purchased cigarettes from a store; the majority of smokers obtained cigarettes from social sources.

Multilevel Modeling Results

The pattern of intraclass correlations across multilevel logistic models illustrated in Table 4 suggests that most of the variance in smoking behavior was explained by the individual- and school-level predictors in the final model. After control for these predictors, clustering effects were reduced and lost significance when density of tobacco retailers was included in the final, full model (the intraclass correlation changed from 0.08 to 0.006; Table 4). In the case of experimental smoking, but not established smoking, the addition of the measure of tobacco retailer density nonetheless significantly reduced the unexplained between-school variance in the null model by 4.6%, beyond the 68.9% reduction already obtained through the inclusion of 13 individual-level and 3 school-level covariates in the model (likelihood $\chi^2_1 = 5.49$; $P = .02$).

The density of tobacco retailers near their school did not seem to be significantly associated with students' established smoking behaviors (OR = 1.06; 95% CI = 0.94, 1.20) but was associated with experimental smoking (OR = 1.11; 95% CI = 1.02, 1.21). There were racial/ethnic differences in the relationship between retailer density and smoking, with lower prevalence rates of experimental smoking among Asian and African American students than among White students in the final model.

Additional differences emerged when we stratified the analytic sample according to school type and rurality (data not shown). Among high school students, who are more likely than middle school students to obtain cigarettes from a retailer, tobacco retailer density significantly contributed to higher experimental smoking prevalence rates (OR = 1.18; 95% CI = 1.06, 1.30). This did not hold true for middle school students (OR = 0.91; 95% CI = 0.76, 1.08), who relied more heavily on social sources.

The tobacco retailer density measure was associated with experimental smoking among students residing in urban areas (OR = 1.11; 95% CI = 1.01, 1.21). With the inclusion of tobacco retail density in the final model, school rurality and school-level average parental education no longer had an influence on risk of experimental smoking. Surprisingly, inclusion

TABLE 2—Results for Smoking Status and Tobacco Retailer Measures, by Type and Rural Status of School: California Student Tobacco Survey, 2003–2004

Measure	Overall (n = 19 306), % (95% CI) or mean (SD)	High School (n = 11 825), % (95% CI) or mean (SD)	Middle School (n = 7481), % (95% CI) or mean (SD)	Urban (n = 17 532), % (95% CI) or mean (SD)	Rural (n = 1774), % (95% CI) or mean (SD)
Established smoking[a]	3.0 (2.7, 3.4)	4.5 (4.1, 5.0)	0.7 (0.5, 0.9)	2.9 (2.5, 3.3)	4.5 (3.3, 6.1)
Experimental smoking	6.3 (5.8, 6.9)	8.1 (7.5, 8.8)	3.4 (2.9, 4.0)	6.4 (5.8, 7.0)	5.5 (4.3, 7.0)
No. of retailers within 1 mi[a]	10.8 (8.9)	10.5 (8.9)	11.1 (9.0)	11.6 (8.9)	2.9 (3.3)
Distance from school to retailer, ft[a,b]	3602 (952)	3623 (948)	3568 (958)	3507 (871)	4539 (1182)

Note. CI = confidence interval; SD = standard deviation. CIs were based on Taylor linearization variance estimations for data clustered in schools. For all measures, mean differences between high school and middle school students significant at the $P < .001$ level.
[a]Mean differences between rural and urban students significant at the $P < .001$ level.
[b]Average straight-line distance in feet from the main office of the school to each retailer within the school's 1-mile buffer.

of tobacco retail density did not reduce the size of the association between experimental smoking and either perceived ease of access to tobacco products or whether most of one's best friends smoked.

Sources of and Perceived Ease in Obtaining Cigarettes

Students who reported that their usual source of cigarettes was a retail tobacco store also reported greater perceived ease in obtaining cigarettes (with a mean rating on the 4-point Likert scale of 3.54; 95% CI=3.46, 3.62) than did adolescent smokers who reported obtaining cigarettes from most of the other sources. Students who encountered challenges

TABLE 3—Usual Sources of Tobacco Among Established and Experimental Smokers, by Type and Location of School: California Student Tobacco Survey, 2003–2004

	Overall, No. or % (95% CI)	High School, No. or % (95% CI)	Middle School, No. or % (95% CI)	Urban, No. or % (95% CI)	Rural, No. or % (95% CI)
			Established smokers		
No. of established smokers	582	531	51	503	79
Source of tobacco					
Store	31.8 (27.7, 36.2)	33.5 (29.2, 38.2)	13.7 (6.4, 27.1)	32.8 (28.4, 37.5)	25.3 (15.9, 37.8)
Vending machine	1.2 (0.6, 2.5)	0.9 (0.40, 2.2)	3.9 (0.9, 14.8)	1.2 (0.5, 2.6)	1.3 (0.6, 2.6)
Purchased by someone else	30.8 (27.1, 34.7)	30.9 (27.0, 35.0)	29.4 (18.5, 43.3)	30.0 (26.1, 34.2)	35.4 (25.8, 46.4)
Borrowed	12.5 (10.0, 15.6)	13.2 (10.5, 16.4)	5.9 (1.4, 21.6)	11.9 (9.2, 15.3)	16.5 (10.8, 24.2)
Provided by person older than 18 y	6.7 (4.8, 9.2)	6.8 (4.8, 9.4)	5.9 (1.8, 17.3)	6.6 (4.6, 9.4)	7.6 (4.0, 14.0)
Taken from store or family member	6.2 (4.4, 8.6)	4.5 (2.9, 6.9)	23.5 (14.8, 35.2)	7.0 (5.0, 9.7)	1.3 (0.2, 8.8)
Other	10.8 (8.8, 13.3)	10.2 (8.2, 12.6)	17.6 (9.0, 31.7)	10.5 (8.3, 13.3)	12.7 (8.1, 19.2)
			Experimental smokers		
No. of experimental smokers	1195	946	249	1098	97
Source of tobacco					
Store	12.6 (10.4, 15.0)	14.2 (11.7, 17.1)	6.4 (3.9, 10.4)	12.8 (10.6, 15.4)	9.3 (4.8, 17.2)
Vending machine	1.8 (1.2, 2.8)	1.5 (0.9, 2.4)	3.2 (1.5, 6.6)	1.9 (1.2, 2.9)	1.0 (0.2, 6.5)
Purchased by someone else	14.6 (12.5, 16.9)	14.7 (12.4, 17.4)	14.1 (10.4, 18.8)	14.8 (12.6, 17.2)	12.4 (7.7, 19.3)
Borrowed	34.8 (31.8, 38.0)	38.8 (35.4, 42.3)	19.7 (15.1, 25.3)	33.6 (30.5, 36.9)	48.4 (40.6, 56.4)
Provided by person older than 18 y	11.8 (9.9, 14.0)	12.3 (10.1, 14.8)	10.0 (6.8, 14.5)	11.9 (10.0, 14.2)	10.3 (5.7, 18.0)
Taken from store or family member	8.8 (7.1, 10.9)	6.0 (4.5, 8.0)	19.3 (14.9, 24.6)	9.2 (7.4, 11.4)	4.1 (1.5, 10.8)
Other	15.6 (13.5, 18.1)	12.6 (10.5, 14.8)	27.3 (21.6, 33.9)	15.8 (13.5, 18.3)	14.4 (9.3, 21.6)

Note. CI = confidence interval. To determine usual sources of tobacco, students were asked "How did you usually get your cigarettes in the past 30 days?" CIs based on Taylor linearization variance estimations for data clustered in schools. For both established smokers and experimental smokers, distributions of responses between high school and middle school students were significantly different at the $P < .001$ level; there were no differences in the distributions of responses between urban and rural students.

TABLE 4—Odds Ratios and Comparisons for Models Predicting Risk of Experimental Smoking Among Members of the Analytic Sample: California Student Tobacco Survey, 2003–2004

Predictor	First Model,[a] OR (95% CI)	Second Model,[b] OR (95% CI)	Third Model,[c] OR (95% CI)	Full Model, OR (95% CI)
Age, y	1.23 (1.18, 1.27)	1.08 (1.04, 1.12)	1.06 (1.00, 1.12)	1.06 (1.00, 1.12)
Male	0.96 (0.85, 1.05)	1.00 (0.88, 1.13)	1.00 (0.88, 1.14)	1.00 (0.88, 1.14)
African American	0.63 (0.48, 0.84)	0.71 (0.53, 0.95)	0.67 (0.50, 0.90)	0.67 (0.50, 0.90)
American Indian/Native Alaskan	1.09 (0.68, 1.76)	1.03 (0.63, 1.70)	1.01 (0.61, 1.67)	1.01 (0.61, 1.67)
Asian	0.68 (0.54, 0.87)	0.80 (0.63, 1.03)	0.77 (0.60, 0.98)	0.75 (0.59, 0.97)
Hispanic	1.04 (0.89, 1.22)	1.15 (0.98, 1.36)	1.05 (0.89, 1.25)	1.05 (0.88, 1.24)
Native Hawaiian/Pacific Islander	1.28 (0.92, 1.78)	1.23 (0.87, 1.74)	1.16 (0.82, 1.65)	1.15 (0.81, 1.63)
English use in home	1.04 (0.93, 1.17)	1.05 (0.93, 1.18)	1.05 (0.93, 1.18)	1.06 (0.95, 1.20)
Previous-year grades	0.58 (0.55, 0.62)	0.69 (0.65, 0.74)	0.70 (0.65, 0.75)	0.70 (0.65, 0.75)
Hopelessness in past year	1.94 (1.72, 2.20)	1.57 (1.38, 1.79)	1.57 (1.38, 1.78)	1.57 (1.38, 1.78)
Most peers smoke		1.54 (1.33, 1.80)	1.54 (1.33, 1.80)	1.55 (1.33, 1.80)
A majority of best friends smoke		4.86 (4.26, 5.54)	4.86 (4.26, 5.54)	4.85 (4.26, 5.53)
Perceived ease of access to cigarettes		1.46 (1.35, 1.57)	1.46 (1.35, 1.57)	1.46 (1.35, 1.57)
School-level average parental education			0.87 (0.77, 0.98)	0.89 (0.79, 1.00)
School location (rural vs urban)			0.71 (0.56, 0.91)	0.81 (0.62, 1.06)
Type of school (high school vs middle school)			1.12 (0.88, 1.42)	1.12 (0.88, 1.42)
No. of retailers within 1 mi of school				1.11 (1.02, 1.21)
Model statistics				
Between-school SE	0.2695	0.2104	0.1710	0.1455
Intraclass correlation	0.0216	0.0133	0.0088	0.0064
Model comparison				
χ^2 (*df*)	591.60 (10)	856.88 (3)	13.95 (3)	5.49 (1)
P	<.001	<.001	.003	.02

Note. CI = confidence interval; OR = odds ratio. Each model was evaluated relative to the previous model (listed to its left). The null model is not shown; its between-school standard error was 0.5495, and its intraclass correlation was 0.0840. The null model is the one against which the first model was compared. (n = 19 306)

[a]Including demographic and psychological correlates.

[b]First model plus smoking precursors.

[c]Second model plus school and community influences.

in obtaining cigarettes were more likely than those who did not encounter challenges to report using social sources (e.g., older friends) to obtain their cigarettes. Despite this association of students' perceived ease of obtaining cigarettes with reported purchase of cigarettes from tobacco retail stores, there was no association between perceived ease of obtaining cigarettes and retail store density (r=0.009).

There was no association between tobacco retail density and student reports of purchasing cigarettes from a store. However, there was a significant linear trend indicating increases in the prevalence of experimental smokers who reported having borrowed a cigarette with decreasing quintiles of tobacco retailer density (trend P=.01), indicating some association between tobacco retail density and how smokers procured their cigarettes.

Among students who reported purchasing cigarettes in the preceding 30 days, the most frequent commercial sources were as follows: gas stations (24.3%), convenience stores (22.8%), drug stores (5.2%), grocery stores (4.7%), vending machines (2.0%), and the Internet (0.9%). Many respondents also reported "other" as their commercial source (40.2%). A multilevel model including age, gender, school-level average parental education, and school type indicated that school rurality was negatively associated with purchasing cigarettes from convenience stores (OR=0.45; 95% CI=0.23, 0.89). Gas stations were the most popular commercial source among rural students (37.8%), with convenience stores far behind (15.6%), whereas these 2 commercial sources were equally popular (23%) among urban students.

When the outcome measure was the number of cigarettes smoked on days when respondents smoked, no relationship was observed with either retailer density or retailer proximity. Tobacco retailer proximity, in contrast to tobacco retailer density, was not associated with either established or experimental smoking in any of the samples analyzed.

DISCUSSION

Our study extends previous research by examining student tobacco use data from an entire state with a heterogeneous student population. The study sample included 245 schools, thereby allowing more sensitive school-level comparisons than was possible with, for example, the 29 schools examined by Leatherdale and Strath.[4] In addition, our data permitted an assessment of the association between student tobacco use and type of neighborhood environment (rural or urban). Our results showed that, among high school students and urban students but not middle school students or rural students, there seems to be a small but nonetheless significant relationship between the density of retailers within 1 mile of a school and students' reports of smoking initiation.

Although tobacco retailer density has been operationalized in different ways, the same pattern has been observed in most reports; that is, increasing tobacco retailer density is associated with increasing risk of tobacco use among adolescents (in our study, we observed this effect for experimental smoking but not for

established smoking). The finding that number of cigarettes smoked per day is related to retailer concentration and distance, as noted in a previous study involving adult smokers,[10] was not confirmed among the adolescent respondents surveyed here.

Although the density of tobacco retailers near a school was positively related to the prevalence of students reporting experimental smoking, the proximity of tobacco retailers showed no such relation. This suggests that it is not the mere presence of a tobacco retailer near a school that might influence students to experiment with smoking; rather, if there is to be an association, several tobacco retailers must be within walking distance of the school.

When students were asked to report what kind of store provided them with cigarettes, 2 specific types of outlets were mentioned most often: gas stations and convenience stores. These outlets were cited more than 4 times as often as any other specific source, including grocery stores. Despite the frequency with which consumers purchase other products from grocery stores, student smokers cited grocery stores as the source of their cigarettes only one fifth as often as they cited gas stations and two thirds less often than had been the case nationally during 1997 through 1999.[31] Fewer than 1% of student smokers mentioned the Internet as a source of their cigarettes, even though age verification is seldom required for Internet tobacco purchases.[32]

Limitations

Several limitations of this study should be noted. First, the mode of transportation used by students to get to and from school was not measured and could have varied according to area of residence (rural or urban). Students who walk or ride bikes to school may be more likely than those who drive to school to encounter tobacco retailers. Second, we relied on a simple straight-line method to estimate distances from schools to retailers and to create buffer zones. Use of information about street contours near schools could provide more accurate and realistic measures of distance.

Third, we used a 1-mile-radius, straight-line distance to define the area in which tobacco retailers were counted because we wanted the largest possible area in which students could imaginably have walked or rode a bike from their school to the retailer. Although some researchers have used a 0.5-mile radius,[33] we viewed this criterion as overly restrictive because it could lead to many rural schools appearing to have no tobacco retailers nearby; in addition, some high schools with large sporting activity areas might occupy much of the 0.5-mile distance adjacent to the main office address used to geocode school locations.

Fourth, unlike previous studies,[4,9] we did not enumerate tobacco retailers near schools through direct inspection. As with all government lists, some of the information on our list of tobacco retailers was outdated by the time we obtained the list. Moreover, the characteristics associated with the zip code of a school may not fairly represent the true characteristics of the students attending the school. Finally, as with all cross-sectional studies, causal inferences are easily challenged. More confident inferences require prospective, longitudinal data.

Conclusions

The associations we observed between density of tobacco retailers and experimental smoking risk and the lack of association with established smoking risk suggest that tobacco retailers' greatest influence may be on adolescents who are not yet addicted but are willing to try smoking opportunistically. Once they are addicted, adolescents who smoke may be affected less by retailer proximity and more by internal physiological cues.[34] Future studies are needed to confirm and explain why experimental smoking but not established smoking among students might be influenced by the presence of tobacco retailers close to their school.

Educating tobacco retailers about the importance of not selling tobacco products to minors has limited effectiveness.[5,35] Using the leverage of licensing restrictions to motivate tobacco retailers' compliance with the law not to sell to minors may be more effective.[36] One way to reduce both direct and indirect sales to students is to create zoning restrictions or conditional use permits that can be used to prohibit the operation of tobacco retailers close to schools.[7,37] The city council of Tempe, Arizona, recently adopted an amendment to its zoning and development code limiting tobacco retailers from locating within one fourth mile of any elementary or secondary school (see http://www.tempe.gov/clerk/history_03/20070628dsrl04.pdf). Also, the city council of La Mirada, California, recently adopted a conditional use permit limiting tobacco retailers from locating within 600 ft (183 m) of a school (see http://www.amlegal.com/nxt/gateway.dll/California/lamirada_ca/cityoflamiradacaliforniacodeofordinances?f=templates$fn=default.htm$3.0$vid=amlegal:lamirada_ca).

Our results confirm the plausibility of the notion that zoning restrictions can help reduce tobacco use initiation by students attending secondary schools. More targeted interventions might be equally effective, however. For example, zoning restrictions may not be needed for grocery stores but might be needed for convenience stores around schools because of evidence that grocery stores comply with state laws banning the sale of tobacco products to minors more often than do convenience stores. Prospective, longitudinal data would be helpful in clarifying whether and how much restricting the density and proximity of tobacco retailers around schools affects students' risk of tobacco use. ■

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Contributors

W.J. McCarthy originated the study, led the writing, and supervised all aspects of study implementation. R. Mistry, Y. Lu, and W.J. McCarthy conducted the analyses. M. Patel completed the geocoding of tobacco retailers and participating schools. H. Zheng served as the data manager in the original data collection process. B. Dietsch supervised the original data collection and contributed to the writing of the article. All of the authors helped to interpret findings and review drafts of the article.

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Human Participant Protection

This study was approved by the institutional review board at the University of California, Los Angeles.

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