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Retail cannabis environment and adolescent use: the role of advertising and retailers near home and school

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Abstract

Youth cannabis use is influenced by overlapping environmental contexts. We examined the associations between proximity to cannabis retailers and seeing cannabis advertisements and cannabis use behaviors in Oregon, a state with adult cannabis legalization. We used 2017 anonymous survey data from 24,154 Oregon 8th and 11th grade students. After adjustments for student and school district characteristics, advertising for 8th graders and presence of a retailer within a mile from school for 11th graders were associated with cannabis use and perceived harm. Additional policy efforts may further reduce youth exposure to cannabis.

Introduction

More than one-third of the US population live in states with legalized production and retail sales of cannabis for adults (21+ years) as of November 2020.(Fertig and Zhang, 2020) There are concerns that the presence of cannabis retail outlets may influence youth by normalizing cannabis use, exposing them to pro-use messages, and increasing availability and variety of cannabis products. Nationally, adolescent treatment admission for cannabis have declined (Mennis, 2020), yet rates of cannabis use disorder among youth (12 to 17 years) have increased by 25% in states with adult use cannabis laws, despite no measurable increases in youth cannabis use, compared to changes in youth living in states without these laws.(Cerdá et al., 2020) Disordered cannabis use during adolescence is linked to developing

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major depression and anxiety.(Gobbi et al., 2019) These findings suggest that the modes and products youth are using in legalized states may be influencing increases in disordered use or addiction(Tormohlen et al., 2019).

Manufactured cannabis products such as edibles and concentrates, used for dabbing and vaping, account for a substantial and growing share of cannabis retail sales(C. L. Firth et al., 2019). Adult cannabis consumers were more likely to consume edibles, use concentrates, particularly for vaping, and use these products more frequently if they lived in legalized states, compared to adults living in states without legal access.(Hammond and Goodman, 2020) Manufactured cannabis products typically contain high doses of THC (Raber et al., 2015) which may lead to adverse experiences like panic attacks, anxiety, or acute psychotic episodes.(Cao et al., 2016; Kim and Monte, 2016) Calls to U.S. poison centers for manufactured cannabis products are increasing (Dilley et al., 2021) and there is some evidence of increases in underage use of these products.(Tormohlen et al., 2019) For adolescents, use of manufactured products creates specific concerns. In addition to general adverse effects of cannabis use in adolescence on cognitive, socio-emotional and physical health, high doses of THC may also amplify youth risk for developing psychotic and cannabis use disorders.(van der Steur et al., 2020)

Environment plays a key role in adolescent substance use, including through exposure to retail outlets and advertising.(Bostean et al., 2016; Cederbaum et al., 2015) Substance use behaviors often initiate during adolescence and are influenced by overlapping social and built environment contexts: where adolescents live, study, and socialize.(Huang et al., 2020) Estimating the simultaneous effects of school and neighborhood contexts on adolescent substance use is a growing area of research.(Huang et al., 2020) For example, liquor store density around adolescents' homes has been correlated with binge drinking(Chen et al., 2010) and tobacco outlet density with cigarette use.(Finan et al., 2019) Similarly, retail outlet density around schools has also been correlated with substance use: having vaping stores near high schools was associated with adolescent e-cigarette use.(Giovenco et al., 2016) In addition to their presence, advertising related to these markets may also influence underage product use and perceptions of harm.(Giovenco et al., 2016) Consistent with studies that have examined the influence of tobacco and alcohol advertising exposure on behaviors,(DiFranza et al., 2006; Finan et al., 2020) recent studies of retail cannabis advertising exposure, both online and on storefronts, have shown associations with adolescent cannabis use(Fiala et al., 2020) and intentions to use.(Hust et al., 2020)

Oregon was one of the first states to legalize adult use and establish a retail cannabis market, where legal sales began in October 2015. Unincorporated counties and cities within Oregon can prohibit cannabis retailers and manufactures from operating in their jurisdictions, after the first year of licensed cannabis retailers, 96% percent of the state population lived in a county with at least one retailer.(Dilley, 2022) To protect youth, Oregon requires cannabis retailers to be at least 1,000 feet (i.e., 0.19 miles) from schools, and restricts advertisements that appeal to children (e.g., ads that feature cartoons or images of minors).(Fiala et al., 2020) Previous work has demonstrated that county-level density of cannabis retailers in Oregon was associated with adolescent cannabis use(Paschall and Grube, 2020) and more than half of Oregon's 8th and 11th graders have seen cannabis advertising in the past month.

(Fiala et al., 2020) However, no study has simultaneously examined proximity of retailers from home and school environments, and exposure to cannabis advertising as related to adolescent cannabis behaviors.

The present study is guided by developmental socio-ecological and life-course theories(e.g., Bronfenbrenner, 1977; Catalano and Hawkins, 1996; Elder, 1998) that recognize development is embedded in multiple interconnected contexts that may independently and jointly influence behaviors; moreover, the salience of these ecological contexts and the interactional associations among them and the developing individual can change over time. This theoretical framework has been used widely in the study of etiology of substance use behaviors (for review, see e.g., Nargiso et al., 2015; Trucco, 2020) as well as in the planning of prevention and intervention efforts aimed at reducing adolescent substance use and promoting adolescent health (e.g., Catalano et al., 2012; Corbett, 2001; Hawkins et al., 1992). Regarding cannabis use, macro-level contexts that include societal forces such as state-level legalization of cannabis may influence other, more proximal, contexts such as schools and communities in which the lives of adolescents are embedded and which in turn may increase the risk of adolescent substance use.(Catalano et al., 2018; Johnson and Guttmannova, 2019) For example, the commercialization of cannabis may influence adolescent use by increasing access to cannabis and variety of manufactured products near schools and their homes and also by promoting – through advertising – beliefs that cannabis use is safe and normative.(D'Amico et al., 2015; Lipperman-Kreda and Grube, 2018) The objective of this study is to assess whether multidimensional cannabis environment measures are associated with youth cannabis use and perceptions of harm caused by cannabis. We hypothesize that 8th and 11th grade students who live or go to school near cannabis retailers and students who have reported seeing cannabis advertising on storefronts will be more likely to use manufactured cannabis products available in retail stores (e.g., edibles, vapes, concentrates) than students attending schools in different environments.

Methods

Data sources

This multi-level cross-sectional study drew from three existing data sources. First, Oregon Healthy Teens (OHT) is an anonymous, school-based survey administered to 8th and 11th grade students during odd-numbered school years.(Oregon Health Authority, n.d.) Surveys are intended to monitor the health and well-being of Oregon youth and include questions specific to cannabis use. During the 2016–2017 school year, 84 Oregon school districts participated in the survey; representing 68% of the statewide population. When weighted, survey data are representative of all students in the state of Oregon. Our analysis used unweighted OHT data to understand how students' exposures to cannabis environment, at the school and school district level, were associated with cannabis outcomes. Second, addresses for licensed cannabis retail outlets were obtained from the Oregon Liquor Control Commission (OLCC), a state agency that regulates the market, on June 16th 2017.(Oregon Liquor Control Commission, 2017) Third, we obtained school building addresses from the Oregon Department of Education (ODE) and school district demographic data from ODE's 2016-2017 School District Report Cards.(Oregon Department of Education, 2019)

This study was determined as exempt from review by the Oregon State Institutional Review Board.

Measures

We examined five cannabis-related outcomes: four modes of cannabis use (smoking, dabbing, eating (i.e., using edibles), and vaping) and perceived harm of cannabis use, which is a risk factor for future cannabis use. To assess modes of cannabis use, students who reported any cannabis use in the past 30 days were asked how they consumed cannabis (multiple responses were allowed so students could indicate all the ways they had used). We created a binary variable for each cannabis mode (1: used that mode 1+ times in the past 30 days, 0: did not use that mode in the past 30 days or did not use any cannabis in the past 30 days). Our fifth outcome was perceived harm (1: moderate or great risk, 0: slight or no risk), from responses to the question "How much do you think people risk harming themselves (physically or in other ways) if they use cannabis at least once or twice a week?" Dichotomizing the perceived harm outcomes aligns with reporting from the National Survey on Drug Use and Health. (Mariani and Williams, 2021)

Cannabis retail environment measures

We developed two proximity-based measures– for school and community–and one advertising measure to capture different aspects of the Oregon retail cannabis environment in 2017. We relied on built environment, social ecology, and adolescent health research, including the roles of tobacco and cannabis retailers, to inform how we operationalized proximity to cannabis retailers from school and community. Prior work has used data-driven and contextual approaches to determine thresholds for calculating cannabis retailer exposure. Such methods include using percentiles to create cut points from the distribution of distances to outlets (e.g., categorized cannabis retailer access by ventiles (Everson et al., 2019)), counting the number of retailers at administrative spatial units (e.g. number of retailers within Portland, Oregon, neighborhoods (C. Firth et al., 2020)), or proximity to a retailer by road network distance (e.g., at least one retailer within 1 or 2 kilometers, 0.6 to 1.2 miles, from home(Rhew et al., 2022)). Beyond cannabis research, built environment features, such as recreational facilities, that are within 2 kilometers of home were correlated with youth physical activity (Loh et al., 2019), and tobacco outlets within 3/4 and 1 mile from home were associated with smoking frequency(Lipperman-Kreda et al., 2014). A walkable neighborhood includes amenities that are within a 1-mile or 20-minute walk from home.(Talen and Koschinsky, 2013) These studies were conducted in urban areas which may not be generalizable to youth living in rural communities. Data from the 2017 U.S. National Household Travel Survey points to differences in travel behaviors between youth living in urban and rural areas, such as, 29% of rural students walk to school when it's within a mile compared to 22% of urban students(Kontou et al., 2020). Based on these studies, we operationalized proximity as having at least one cannabis retailer within 1 mile from school or at the community-level, using a dichotomized measure in analysis. We chose a 1-mile buffer, as opposed to a shorter threshold, because half of the Oregon school districts included in our study were in rural counties (40/82 districts), where population and road network density is lower than metropolitan areas.

The school-based measure approximated exposure to retailers around students' schools. Retailers' distance from school buildings was calculated from the minimum Euclidean distance between edge of school campus and cannabis retailer. Addresses were geocoded in ArcGIS Pro, and the Near tool was used to calculate distance. Proximity to a school building was dichotomized as 1: <1 mile; 0: ≥ 1 miles. The school proximity measure was joined to OHT survey data by school.

The school district area (community) measure approximated exposure to retailers near students' homes. School district areas are catchment areas for Oregon public schools. Community proximity was assessed as the minimum distance to a cannabis retailer, on average, at the school district area-level. This method has been used previously to calculate zip code-level proximity to cannabis retailers.(Everson et al., 2019) Community proximity was created with three steps. First, a grid of 5,000 square feet cells was overlaid on the state of Oregon and the minimum distance between the center of each grid cell and geocoded cannabis retailer was calculated. We used a 5,000 square feet resolution to create aggregate measures for different administrative spatial scales (e.g., school districts, zip codes) that do not align with census-defined boundaries (e.g., census tracts). Then, we joined 2010 U.S. Census data to weigh each grid cell by population. Finally, these weighted measures were aggregated to the school district-level and represent the average proximity of all grid cells across the district. The final variable was dichotomized as 1: average proximity was <1mile and 0: average proximity ≥1 mile and linked to OHT survey data by school district.

Exposure to cannabis storefront advertising was based on the OHT question: had students seen "advertisement for marijuana products or stores: on a storefront or on the sidewalk (like signs or people wearing/waving signs)" in the past 30 days. Advertising exposure was coded '1' for students who reported seeing storefront advertisements and '0' for students who did not report seeing any advertisement or were unsure they had seen a relevant ad.

Socio-demographic characteristics

We adjusted for student gender (male, female, non-binary), race/ethnicity (non-Latinx white, Asian, Native Hawaiian/Pacific Islander, Black/African American, American Indian/Alaska Native, and multiracial, and Latinx), socioeconomic status, and whether an adult used cannabis at home in our multi-level logistic regression models. Student socioeconomic status was measured with the Family Affluence scale(Currie et al., 2008) by aggregating responses from four questions: whether the student's family owns a car, traveled on vacation in the past year, how many computers they own, and whether the student has their own bedroom. The distribution of the family affluence scale was divided into tertiles: ranging from "least" to "most" affluence.

We used ODE data to adjust for school district-level characteristics that represent the environments where students lived, including proportion of students who are economically disadvantaged (i.e., students who are eligible for free or reduced lunch) and proportion of non-Latinx white students for each grade. We selected these two measures because cannabis retailers were more common in economically disadvantaged neighborhoods in Portland, Oregon, (C. Firth et al., 2020) and students of color were more likely to receive exclusionary discipline compared to white students in Oregon(Burke and Nishioka, 2014)

which may influence their willingness to respond to questions on substance use. In addition, we included a county density variable, based on whether the school district was within an urban or rural/frontier county, using the Oregon Office of Rural Health Geographic Definitions.(Oregon Health & Science University, n.d.)

Statistical analysis

First, we described the socio-demographic characteristics of students using weighted data to be representative of students in the state. Then, we used unweighted survey data in multi-level logistic regression models to assess the relationships between cannabis retailer environment and our five cannabis outcomes. Survey weights are intended for statewide prevalence estimates and were not appropriate for our inferential analysis that examined individual-level cannabis outcomes within schools and school districts. We stratified our models by grade, because 8th grade students attended middle schools and 11th graders in high schools. In each model, we included the three cannabis retail environment measures and adjusted for individual-level socio-demographic (gender, race/ethnicity, socioeconomic status, adult used cannabis at home) and school district-level (% economically disadvantaged, % non-Latinx white, urban school district) covariates.

We included random intercepts at the school and school district levels to account for clustering between students within the same school and district and estimate the contextual effects of the school environment. The results of our fixed effects are reported as prevalence odds ratios (PORs) and interpreted as the prevalence of each cannabis outcome among students exposed to each retail environment measure compared to students who were not exposed. We presented the school and school district level random intercepts on the logit scale and as median odds ratios (MOR),(Merlo et al., 2006) which can be interpreted like an odds ratio, and correspond to the median value of school and school district level residuals for each outcome. It helps to understand variation in outcomes that were not explained by other model covariates. A MOR >1.0 suggests that different environments, such as schools where cannabis use is more common, is correlated with the probability that a student would adopt the behavior.

In addition, we conducted sensitivity analyses that considered proximity to retailers from schools and at the school-district level at 1/2 mile, 3/4 mile, and 2 mile thresholds. All analyses were conducted in Stata/IC 15.1.

Results

Our study included 24,154 students who completed the 2016–2017 OHT survey and responded to question on cannabis use in the past 30 days (11.0% or 1,628 8th graders and 8.1% or 965 11th graders skipped cannabis questions, see Supplemental Table 1 for analysis of missing survey data). Student demographic characteristics are summarized in Table 1.

Cannabis use in the past 30 days was more common among 11th grade students (20.3%) than 8th graders (6.5%). Smoking cannabis was the most common mode in both grades, 87.6% of 8th grade and 92.1% of 11th grade cannabis users smoked. Over 40% of cannabis

users in either grade reported using manufactured products in the past 30 days (i.e., dabbing, using edibles, and/or vaping cannabis products, Table 2), and 86% of students who used manufactured cannabis products also smoked cannabis in the past month (data not shown). The most common manufactured products used were edibles by 8th graders and dabs by 11th graders. Most 8th grade students perceived cannabis use as harmful (62.7%), and about half of 11th graders (48.1%).

The average distance between a school and cannabis retailer in Oregon during 2017 was 8.7 miles (range: 0.3 miles to 159.6 miles, data not shown). Using the community proximity measure, students lived an average of 6.3 miles from a retailer (range: 0.5 miles to 117.6 miles, data not shown). There was no pattern in retail proximity by grade: 31.8% of 8th grade students and 32.1% of 11th graders had a cannabis retailer within 1 mile of their school, and about half as many lived in communities where cannabis retailers were within 1 mile of homes (15.3% among 8th grade and 12.1% among 11th grade students, Table 2). Seeing storefront cannabis advertising was more common than living or going to school near a retailer; 35.9% of 8th grade students and 41.5% of 11th grade students reported seeing advertising in the past 30 days.

Associations for 8th grade students

None of the five cannabis outcomes were significantly associated with middle schools that had a cannabis retailer within 1 mile away (Table 3, full model results in Supplemental Table 2). Though, community proximity was associated with perceiving cannabis as less harmful (POR: 0.79, 95% CI: 0.66,0.94). Exposure to cannabis storefront advertising was associated with all five outcomes; the prevalence of using edibles, dabbing, or vaping cannabis was almost twice as high for students who reported seeing advertising compared to students who did not see advertising (used edibles POR: 1.80, 95% CI: 1.34,2.42; dabbed POR: 1.94, 95% CI: 1.40,2.69; vaped POR: 1.85, 95% CI: 1.23,2.78). Advertising exposure was also associated with smoking cannabis (POR: 1.31, 95% CI: 1.11,1.55) and perceiving cannabis as less harmful (POR: 0.87, 95% CI: 0.80,0.95).

The residual heterogeneity between schools, as measured by MOR, was 1.83 in the edible model (Table 3) and can be interpreted as similar students may be nearly twice as likely to use edibles if they are in a school where edible use was more common. Similarly, school environment was associated with smoking, dabbing, and perception of harm, but not vaping.

Associations for 11th grade students

The prevalence of 11th grade students using edibles, dabbing, and smoking cannabis, but not vaping, were significantly associated with having a cannabis retailer within one mile of high school (Table 4, full model results in Supplemental Table 3). Specifically, the prevalence of using edibles was 45% higher and dabbing and smoking cannabis were 43% higher among students who attended a high school within 1 mile from a cannabis retailer. Students also perceived cannabis as less harmful when there was a retailer within 1 mile from their high school (POR: 0.71, 95% CI: 0.61,0.83), although the opposite relationship was observed with community proximity (POR: 1.27, 95% CI: 1.01,1.60). Exposure to storefront cannabis advertising was associated with using edibles, dabbing, and vaping cannabis (POR:

1.40, 95% CI: 1.15,1.70; POR: 1.39, 95% CI: 1.15,1.68; POR: 1.45, 95% CI: 1.10,1.92, respectively), but not smoking or perceptions of harm.

The MOR for schools exceeded 1 in all models, which suggested that normative school environments—schools where students were more likely to engage in cannabis outcomes or perceive cannabis as less harmful—could influence a student's behavior, even after adjustment for measured cannabis retail environment factors.

Sensitivity analyses

Relationships between cannabis proximity measures, at the school and school district (community) level, and cannabis outcomes fluctuated with the addition of more restrictive (½ mile and ¾ mile) and less restrictive (2 mile) thresholds. There were 9 schools and 1 community with at least one retailer within ½ mile and 40 schools and 2 communities with a retailer within ¾ mile. Roughly, 60% of our student sample attended school or lived in a community within two miles from a retailer. There were no correlations between school or community level proximity and cannabis outcomes for 8th graders at the ½, ¾, or 2 mile thresholds, this is consistent with results using 1 mile threshold; except for a positive correlation between retailers within ½ mile of school and consuming edibles (POR: 2.63, 95% CI: 1.10,6.30) (Supplemental Table 4). For 11th graders, more restrictive buffers were generally consistent with using a 1-mile threshold; smoking cannabis and consuming edibles were positively correlated with school (at ½ and ¾ mile thresholds) and community proximity (at ½ mile threshold) (Supplemental Table 5). Though, the link between dabbing and school proximity at the 1-mile level was not observed in sensitivity analyses. Perceived harm of cannabis was negatively correlated with community proximity at the ½ mile threshold and school proximity within ¾ and 2 miles.

Discussion

This is the first study to simultaneously consider the links between adolescent cannabis behaviors and various aspects of cannabis retail environment, namely exposure to storefront advertising and access to cannabis retailers at multiple spatial scales. We accounted for students living and attending school near cannabis retailers and examined how these relationships varied by student grade. Furthermore, this study examined use of manufactured cannabis products, which were made more common by the commercialized cannabis industry.

Different aspects of the cannabis retail environment were relevant at different grades. For younger students, community advertising may be a crucial factor. Cannabis use was uncommon among Oregon 8th graders but is slightly higher than national trends (using weighted data for 2017, 7% of Oregon 8th graders reported current cannabis use compared to 6% among 14 and 15 year olds, nationally).(Oregon Public Health Division, 2019; Substance Use and Mental Health Administration, 2019) The national average age for initiating cannabis use is 10th grade(Richmond-Rakerd et al., 2017), yet eighth graders were more likely to smoke, use edibles, dab, or vape cannabis if they had seen storefront advertising in the past month, but living or going to school near a cannabis retailer was not associated with any particular mode of cannabis use. The absence of associations

between proximity to retailers and cannabis outcomes was unexpected, but it demonstrates that the presence of cannabis retailers, after adjustment for advertisement exposure, may not influence 8th grade cannabis use. In addition, our sensitivity analyses supported these findings, with the exception that 8th graders who attended schools within ½ mile of a retailer had a higher prevalence of consuming edibles. This finding extends those from a study on medical marijuana advertising which showed that advertising exposure was associated with intentions to use and cannabis use among middle school students.(D'Amico et al., 2015) In another study, retail cannabis advertising has been associated with adolescents (13 to 17 years old) intentions to use cannabis, particularly among adolescents who lived near a cannabis retailer.(Hust et al., 2020)

In contrast, 11th graders who attended high school within 1 mile from a cannabis retailer were more likely to use edibles, dab, or smoke cannabis. These findings were consistent with our hypothesis, proximity to retailers would be associated with higher prevalence of cannabis outcomes. In sensitivity analysis, high schools that were within ½ or ¾ mile from retailers was also positively correlated with 11th graders consuming edibles and smoking cannabis. Cannabis advertising was not associated with smoking cannabis or perceived harm among 11th graders. Oregon law requires cannabis retailers to be ≥ 1,000 feet from schools,(Dilley et al., 2016) yet students still used edibles, dabbed and vaped cannabis which require concentrated products that are sold by cannabis retailers. Existing studies are mixed; evidence from Colorado showed no association between cannabis use and retailers within 2 miles of schools(Harpin et al., 2018) while a study in Los Angeles showed frequent use of concentrated cannabis products (e.g., waxes used for dabbing) even before cannabis retailers were legally operating.(Barrington-Trimis et al., 2020). Of note, cannabis use among 11th grade Oregon students is substantially higher than national estimates, using weighted data from 2017, 21% of Oregon 11th graders reported using in the past 30 days compared to 13% among 16 and 17 year olds, nationally, which may affect the generalizability of our study findings outside of Oregon.(Oregon Public Health Division, 2019; Substance Use and Mental Health Administration, 2019) Grade differences may be driven by changes in socializing over the course of adolescence that influence cannabis use,(Guttmannova et al., 2019) but longitudinal studies are needed to disentangle how this relates to cannabis environment exposures and specific modes of cannabis use.

Having a retailer near home, as measured in our study, was not associated with any mode of cannabis use, except in sensitivity analyses of ½ mile, having a retailer near home was positively correlated with 11th grade edible use and smoking cannabis–exposure was rare, 3.2% of students lived with a retailer within ½ mile. It is possible that our community proximity measure did not adequately capture exposure near homes, or alternatively that it does not contribute meaningfully after inclusion of school proximity. Though, prior work has shown that having a retailer within 1-kilometer, or 0.6 miles, of home was associated with perceived cannabis access and use among young adults living in Washington state(Rhew et al., 2022). However, 8th graders who lived near a cannabis retailer perceived cannabis as less harmful than students who lived farther from retailers.(Lipari et al., 2016) This finding is supported by previous ecological studies which found that Oregon counties with licensed cannabis retailers had more students who used cannabis in the past 30 days(Paschall and Grube, 2020) and time-varying proximity to cannabis retailers at the

zipcode-level was associated with increased adult cannabis use in Washington state after legalization(Everson et al., 2019)

Our study examined different dimensions of “risky behaviors” for youth rather than “any cannabis use” alone. We examined use of manufactured cannabis products because they are both increasingly available in legal cannabis outlets and pose potentially more health risks for adolescents than using dried cannabis flower due to higher THC concentration. Our finding that using these specific products increased with exposure to retail environments supports the concern that retail environments are influencing not only any underage cannabis use, but also riskier use behaviors. Though we did not assess how youth obtained different cannabis products, our findings suggest that legal efforts to curb youth exposure through land use and advertisement restrictions may not be enough to prevent youth from using cannabis products that are sold in licensed adult-use retailers. We also examined perceived harm because reductions in perception of harm from cannabis use are associated with future likelihood of use. In our study, community proximity to cannabis retailers was linked to reduced perceptions of risk among younger students, but increased perceptions of risk among older students. This paradox could be explained by education efforts targeted toward high school students in communities with cannabis markets, or it may be spurious. Future studies should examine consumption patterns in more detail (e.g., days used per month) to further inform understanding about how retail environments affect youths’ perceptions of risk and subsequent behavior choices.

Data collection for our study took place during the 2016-17 school year, one year after legal retail sales began in Oregon (October 2015). Other studies have documented that reported exposure to cannabis marketing was very prevalent among young people at this time.(Fiala et al., 2020) One consideration when interpreting our study’s findings is that data collection occurred when the market was still relatively “new”; thus, advertising from this nascent industry may be more noticeable. The influence of cannabis retail markets on youth may change as the market becomes more established. Further study in different settings and over time is needed.

Limitations

Some limitations need to be considered when interpreting the findings of our study. First, the cross-sectional design limits the ability to infer a temporal relationship between cannabis retail environment and underage cannabis use and perceptions of harm. For example, students who already use cannabis may be more likely to notice cannabis advertising compared to students who do not use, or more cannabis retailers may be in areas with higher underage cannabis use. Second, licensed retailers are likely not the only source of cannabis for youth. Despite efforts to eliminate prominent unlicensed cannabis retailers, illicit markets are difficult to monitor. In addition, Oregon allows for adults (21+ years) to grow cannabis at home and store usable product, which could be another unmeasured source for youth.(Dilley et al., 2016) Influence of these other sources would likely have attenuated our findings. Third, we relied on students to self-report cannabis use, and students may be less forthcoming given that underage cannabis use is illegal. Using school-based survey data also limits the generalizability of findings. Youth who have dropped out of school

or are institutionalized are excluded from the OHT survey and are also at higher risk of substance use.(Tice, 2013). Last, modeling specific modes of cannabis use, particularly for rare outcomes like vaping (less than 2% of students reported vaping in the past 30 days), may have contributed to the wide confidence intervals of our estimates.

There is no 'gold standard' for GIS-based cannabis retailer exposure or proximity measures. Different contexts, across places and populations, will likely require different distance-based thresholds. For example, larger buffers may be more relevant in studies among young adults because the size of activity spaces tend to decline with age.(Morency et al., 2011) While car-dependent metropolitan areas may rely on thresholds derived from driving times, whereas areas with greater population and amenity density may use road network buffers, at relatively smaller spatial scales. Despite work in this area being heterogeneous, our study adds two contributions: 1) measuring proximity to cannabis retailers at two spatial scales, representing different environmental contexts that influence adolescent behaviors (Johnson and Guttmannova, 2019), and 2) including sensitivity analyses, using different distance-based thresholds, to assess the robustness of our findings.

Conclusion

We found that exposure to Oregon's cannabis retail environment was correlated with adolescent cannabis use and beliefs in 2017, including specifically use of manufactured cannabis products that are becoming common in a legal cannabis market. Younger student cannabis use was most often linked to cannabis advertising exposure, while older student cannabis use was more common among students who attended high schools within 1 mile from a cannabis retailer. These findings have direct implications for policy makers as they develop rules for where cannabis retailers operate and how they are allowed to advertise, while also protecting the health of youth. Furthermore, findings related to youths' perception of harm suggest that prevention and intervention efforts should include education about the effects of cannabis use and specific products on adolescents.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- Cannabis retailers, near school or home, or cannabis ads may influence youth use
- Higher cannabis use reported by 11th graders in schools <1 mile from a retailer
- Cannabis outcomes were higher for 8th and 11th graders who saw cannabis ads
- Perceived harm of cannabis use was lower for 8th graders living near retailers
- Perceived harm was correlated with 11th graders living or in school near retailers

Table 1.

Demographic characteristics of Oregon 8th and 11th grade students who responded to cannabis questions on the Oregon Healthy Teens survey, 2016–2017

	8th grade students N=13,224		11th grade students N=10,930	
Individual student characteristics	**Unweighted count**	**Weighted %**	**Unweighted count**	**Weighted %**
Gender				
Male	6,111	45.9%	4,945	45.4%
Female	6,389	49.0%	5,340	49.0%
Non binary/gender nonconforming	665	5.1%	613	5.7%
Race/ethnicity				
Non Latinx (NL) American Indian/Alaska Native	493	3.6%	224	2.2%
NL Asian	517	4.1%	412	3.7%
NL Black/African American	280	2.2%	216	2.1%
NL Native Hawaiian/Pacific Islander	121	0.9%	92	0.9%
Latinx	3,161	27.4%	2,416	24.3%
NL Multiracial	520	4.1%	338	3.1%
NL White	7,645	57.8%	6,938	63.6%
Socio-economic status (Family Affluence Scale)				
1: Least affluence	1,305	10.6%	990	9.8%
2	4,047	32.4%	3,722	35.0%
3: Most affluence	7,511	56.9%	6,051	55.2%
Adult use cannabis at home	2,252	17.6%	2,041	19.7%
Urban school district	9,626	77.6%	7,516	76.7%
Student characteristics within School Districts	*median*	*25th – 75th percentile*	*median*	*25th – 75th percentile*
% of non-Latinx white students	64%	(51%-77%)	66%	(54%-78%)
% of students enrolled in free and reduced meals programs	53%	(42%-66%)	45%	(38%-55%)

Note: Table 1 describes the student sample in the OHT 2016–2017 survey and uses state-level weights to report statewide prevalance estimates of each socio-demographic factor.

Table 2.

Cannabis outcomes and cannabis retail environment measures, Oregon 8th and 11th grade students, 2016–17 school year

	8th grade		11th grade	
	Unweighted count	**Unweighted %**	**Unweighted count**	**Unweighted %**
Cannabis outcomes				
Used any cannabis in the past 30 days	855	6.5%	2224	20.3%
Manufactured cannabis product use (any)	375	2.8%	933	8.5%
Ate	237	1.8%	534	4.9%
Dabbed	202	1.5%	575	5.3%
Vaped	123	0.9%	246	2.3%
Smoked cannabis	749	5.7%	2049	18.7%
Used 2+ cannabis modes in past 30 days	314	2.4%	814	7.5%
Smoked + manufactured cannabis use	312	2.4%	809	7.5%
Used 2+ manufactured cannabis modes and did not smoke	63	0.5%	124	1.1%
No cannabis use in past 30 days	12,369	93.5%	8,706	79.7%
Perceived regular cannabis use as harmful	7,763	62.7%	5,054	48.1%
Cannabis retail environment exposures				
School building proximity: < 1 mile to retailer	4,163	31.8%	3,475	32.1%
School district area (community) proximity: < 1 mile to retailer	2,020	15.3%	1,326	12.1%
Self reported storefront cannabis ad exposure	4,754	35.9%	4,541	41.5%

Table 3.

Associations between cannabis outcomes and retail environment exposures. Oregon 8th grade students, 2016–2017*

	Consumed cannabis edibles	Dabbed cannabis	Vaped cannabis	Smoked cannabis	Moderate/great risk
School building proximity: < 1 mile to retailer (POR)	1.00 (0.62-1.61)	0.87 (0.56-1.35)	1.21 (0.80-1.84)	0.86 (0.63-1.17)	0.98 (0.85-1.12)
School district area (community) proximity: < 1 mile to retailer (POR)	1.30 (0.62-2.76)	1.40 (0.73-2.66)	0.98 (0.54-1.80)	1.44 (0.96-2.15)	**0.79 (0.66-0.94)**
Self reported storefront cannabis ad exposure (POR)	**1.80 (1.34-2.42)**	**1.94 (1.40-2.69)**	**1.85 (1.23-2.78)**	**1.31 (1.11-1.55)**	**0.87 (0.80-0.95)**
School-level (MOR) **	1.83 (1.44-2.72)	1.53 (1.22-2.45)	.	1.62 (1.45-1.85)	1.22 (1.15-1.31)

Note: results of each model are presented as Prevalence Odds Ratio (POR) (95% Confidence Interval). Bold results indicate statistical significance (p-value <0.05).

* Each model was adjusted for student covariates (gender, race/ethnicity, socio-economic status, adult used cannabis at home) and school-district covariates (% non-Latinx white students, % economically disadvantaged students, urban school district). Full models are in supplemental materials.

** The median value of school-level residuals in each model is reported as the Median Odds Ratio (MOR) and is interpreted like an odds ratio that represent the probabiliy of a cannabis outcome attributed to the school environment.

Table 4.

Associations between cannabis outcomes and retail environment exposures, Oregon 11th grade students, 2016–2017 *

	Consumed cannabis edibles	Dabbed cannabis	Vaped cannabis	Smoked cannabis	Moderate/great risk
School building proximity: < 1 mile to retailer (POR)	**1.45 (1.05-1.98)**	**1.43 (1.11-1.83)**	1.05 (0.73-1.52)	**1.43 (1.14-1.78)**	**0.71 (0.61-0.83)**
School district area (community) proximity: < 1 mile to retailer (POR)	0.71 (0.43-1.17)	0.75 (0.51-1.10)	1.09 (0.65-1.83)	0.87 (0.61-1.23)	**1.27 (1.01-1.60)**
Self reported storefront cannabis ad exposure (POR)	**1.40 (1.15-1.70)**	**1.39 (1.15-1.68)**	**1.45 (1.10-1.92)**	1.09 (0.97-1.21)	1.06 (0.97-1.16)
School-level (MOR) **	1.55 (1.38-1.81)	1.27 (1.13-1.61)	1.37 (1.17-1.88)	1.42 (1.27-1.67)	1.24 (1.17-1.34)

Note: results of each model are presented as Prevalence Odds Ratio (POR) (95% Confidence Interval). Bold results indicate statistical significance (p-value <0.05).

* Each model was adjusted for student covariates (gender, race/ethnicity, socio-economic status, adult used cannabis at home) and school-district covariates (% non-Latinx white students, % economically disadvantaged students, urban school district). Full models are in supplemental materials.

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