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Recreational Cannabis Legalization and Proximity to Cannabis Retailers as Risk Factors for Adolescents' Cannabis Use

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Abstract

Within-person studies are lacking regarding how recreational cannabis legalization (RCL) and the numbers of neighborhood cannabis retailers relate to adolescents' cannabis use. Study participants were 146 offspring (55% girls; 77% White non-Latinx) of men recruited in childhood from neighborhoods with high delinquency rates. Youth were assessed for past-year cannabis and alcohol use one or more times from ages 13 to 20 years (age M[*SD*] = 16.4 [2.1] years across 422 observations) while they were living in Oregon or Washington from 2005 to 2019 (where cannabis retail stores opened to adults ages 21 years and older in 2014 and 2015, respectively). We calculated distances between addresses of licensed cannabis retailers and participants' homes. Multilevel models that accounted for effects of age on cannabis use did not support that the number of retail stores within 2-, 5-, 10-, or 20-mile radii of adolescents' homes increased likelihood of past-year cannabis use at the within- or between-subjects levels. Likewise, primary models did not support a greater likelihood of cannabis use among youth whose adolescence coincided more fully with the post-RCL period. A secondary model suggested that after adjusting for adolescents' concurrent alcohol use as a marker of general substance use risk, RCL was associated with cannabis use (between-subjects *B* [95% CI] = .35 [.05-.66], *p* = .024). Further research is needed with larger prospective samples, at-risk subgroups, and as cannabis markets mature.

Keywords

cannabis legalization; cannabis retail; adolescents; longitudinal; alcohol use

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Conflict of Interest. David Kerr, Lee Owen, Stacey Tiberio, and Julia Dilley each declare they have no conflicts of interest.

Ethical Approval. All study procedures were reviewed and approved by the Institutional Review Board of Oregon Social Learning Center. The study was performed following the ethical principles regarding all research involving humans as subjects as set forth in the Declaration of Helsinki, the Nuremburg Code, and the National Commission for the protection of Human Subjects of Biomedical and Behavioral Research entitled Ethical Principles and Guidelines for the Protection of Human Subjects of Research: The Belmont Report. In addition, the requirements set forth in Title 45, Part 46 of the Code of Federal Regulations were followed.

Informed Consent. Participants and their parents/guardians gave their informed assent and consent, respectively, for all study activities.

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Quantifying the associations that recreational cannabis legalization (RCL) and the proliferation of retail markets have with cannabis use among adolescents is an area of active inquiry. Although minors cannot legally purchase or use cannabis for nonmedical purposes, there are reasons to expect that RCL and the presence of retail stores in adolescents' communities may hasten onset of cannabis use and increase prevalence of use.

First, parents and other significant adults may be more likely to model cannabis use and communicate permissive substance use norms, increasing risk for children's use (Bailey et al., 2016). Indeed, the prevalence of cannabis use and pro-marijuana use norms increased after RCL among parents in Washington state compared to those in non-RCL states (Epstein et al., 2020). More generally, adults' attitudes about cannabis have become increasingly liberal in recent years (Pew Research Center, 2019) and perceptions of the harms of regular cannabis use are at an all-time low (Schulenberg et al., 2020). Moreover, adults' cannabis use has increased following RCL (Cerdá et al., 2020) and under conditions of greater retail access (Everson et al., 2019; Pederson et al., 2021). Second, RCL and retail availability may increase adolescents' access to cannabis that was legally purchased but diverted via friends, who are the most common source of the drug for adolescents (Wagner et al., 2021). Third, cannabis retail stores and local marketing such as billboards are visible—especially to adolescents (Rup et al., 2020). This visibility may increase youth exposure to cannabis products, consumers, and health and lifestyle claims, and ultimately influence their cannabis use and intentions to use (D'Amico et al., 2015). Of note, research on tobacco and alcohol, which is also illegal for minors to purchase and use, has indicated that the density of outlets near adolescents' homes relates to their greater use (e.g., Lipperman-Kreda et al., 2014; Shih et al., 2015).

The evidence above provides a foundation for hypotheses that RCL and retail cannabis availability will increase risk for adolescents' cannabis use by altering norms and increasing access and exposure to the drug. However, findings on the effects of legalization have not all supported these predictions. Paschall et al. (2021) found that in the context of trends across 2010–2019, cannabis use prevalence increased among California adolescents following state RCL. However, no such change was observed among Colorado youth (Brooks-Russell et al., 2019), and—in sharper contrast—Dilley and colleagues (2019) found *decreases* in the statewide prevalence of cannabis use among 8th and 10th graders following Washington RCL, and no effect for 12th graders. At least four studies of RCL effects have used youth in non-RCL states as a comparison group. Cerdá and colleagues (2017) found relative increases in cannabis use and decreases in perceived harmfulness among 8th and 10th graders in Washington following RCL, compared to peers in non-RCL states, but no effects for Washington 12th graders or Colorado 8th–12th graders. Coley and colleagues' (2021) study of 47 states' Youth Risk Behavior Surveillance data through 2017 found RCL to be associated with decreases in levels of cannabis use among adolescents reporting any past month use, but not with the prevalence of use. Two studies of college students documented greater increases in use from pre- to post-RCL at Oregon universities (2008–2016; Kerr et al., 2018) and at colleges in seven RCL states (2008–2018; Bae & Kerr, 2020) compared to institutions in non-RCL states. The latter study found these effects were significant within 18–20 year olds, who cannot legally purchase cannabis.

Evidence for effects of the local recreational cannabis retail context on adolescents' cannabis use is indirect and inconclusive. Studies of youth in Oregon (Paschall & Grube, 2020) and Colorado (Brooks-Russell et al., 2019) found that the prevalence of cannabis use was higher among adolescents living in cities or counties that permitted retail sales of cannabis compared to those that opted out. However, those differences by region also pre-dated state RCL, suggesting effects may be attributable to local norms and climate rather than retail exposure. In another study, the 30-day prevalence of cannabis use and frequent use among college students increased after RCL and continued to increase up to 6 years later relative to that of non-RCL state peers (Bae & Kerr, 2020). Such increases are consistent with effects of a growing retail environment, although other interpretations such as changing community norms are possible.

Most studies of RCL effects have relied on repeated cross-sectional surveys. Longitudinal studies are needed, as such designs permit evaluation of between- and within-person effects of changing state cannabis policy and community retail availability, and determination of whether such changes represent deviations from typical age-related increases in cannabis use. We are aware of four longitudinal studies of youth that have addressed cannabis policy effects. First, Rusby and colleagues (2018) assessed changes in cannabis use and intentions among Oregon youth from Grades 8 to 9 in two cohorts; the Grade 9 assessment pre-dated RCL in one cohort and post-dated RCL in the other. Legalization was not associated with cannabis initiation but was associated with greater increases in use among youth who already used cannabis. Furthermore, the effects of legalization on use and intentions to use were conditioned by whether communities had opted out of permitting retail sales. In a second somewhat similar design, Stormshak and colleagues (2019) assessed cannabis use in two cohorts of youth living in the same urban neighborhoods in Oregon, but recruited 10 years apart. Although the two cohorts showed similar demographics and rates of cannabis use in adolescence, rates were higher for the second cohort at ages 20-22 and 22-24 years when RCL was in effect. Third, in Bailey and colleagues' (2020) accelerated longitudinal study of youth living in Washington before and after RCL, they found RCL was associated with an increased likelihood of cannabis use in the past year. Finally, Bailey et al. (2022) combined these longitudinal data with data from Oregon and New York youth, but reported that cannabis use across adolescence was not associated with more years of RCL exposure. With the exception of Rusby and colleagues' (2018) consideration of community sales (i.e., opt-out or not) effects, there have been no longitudinal studies of effects of the retail environment on adolescents' cannabis use.

In sum, although there is broad concern regarding potential effects of cannabis policy on adolescents, findings are inconclusive and there has been a lack of longitudinal studies examining the effects of RCL and the retail environment on adolescents' cannabis use. Furthermore, community cannabis environments are changing rapidly (Everson et al., 2019), and there is a need for timely data to inform current and future RCL state policies. Therefore, in the current longitudinal study of youth in two RCL states, we examined the extent to which the numbers of cannabis retail stores near adolescents' homes are associated with their cannabis use.

The primary within-subjects hypotheses were that, after accounting for increases with age, the odds of adolescents' past-year cannabis use would be higher under RCL (vs. pre-RCL years or in non-RCL states) and positively associated with the number of retail cannabis locations near their homes; a 2-mile radius was initially selected *a priori* based on prior research on recreational and medical cannabis dispensaries and tobacco outlets (Everson et al., 2019; Lipperman-Kreda et al., 2014; Shi et al., 2018), a decision that had to be revisited in light of the data. The between-subjects hypotheses were that participants who spent more of their adolescence exposed to RCL and who lived in proximity to more cannabis retailers would be more apt to report past-year cannabis use.

In secondary models, we tested whether the associations hypothesized above would be weaker or stronger after adjusting for adolescents' past-year alcohol use. Risk factors for early cannabis use overlap with those of substance use more generally (e.g., Kerr et al., 2015). Thus, we reasoned that if adjusting for alcohol use weakens associations that RCL and retail exposure have with cannabis use, then the effects may be better explained by contextual risks that are confounded with the retail environment. Alternatively, if adjusting for alcohol use strengthens the association (i.e., suppression effect), then effects of the retail environment on adolescents' cannabis use risk may be distinct from propensities driving early alcohol use.

Support for these hypotheses would have a number of implications. For example, policy makers and their constituents could use the findings as they refine state and community regulations regarding the density, location, and characteristics (e.g., advertising) of cannabis retailers. Also, the hypothesized associations could prompt prevention scientists to probe the mechanisms of such effects, and to identify youth populations in need of selective prevention given elevated community risk.

Method

Participants.

Participants were 146 (81 girls [55%]; 113 White non-Latinx [77%], 11 Native American [8%], 9 biracial [6%], 13 African American, Latinx, or Asian American (9%]) offspring of 86 men originally recruited in childhood to the longitudinal Oregon Youth Study (OYS) during the mid-1980s (Patterson & Bank, 1986); the OYS recruited these boys from fourth grade classrooms in schools in neighborhoods with higher than average rates of juvenile delinquency. When OYS participants became fathers, these men, their children, and their children's mothers were recruited to the Three Generational Study focused on the development of those offspring (Capaldi et al., 2018). Thus, whereas the OYS was a traditional cohort study (e.g., all boys were approximately age 10 years in 1984 and living in the same area in Oregon), there was considerable variability in when the offspring in the Three Generational Study were born and where they lived, and thus in the timing of RCL and extent of cannabis retail exposure during their adolescence.

Focal participants were assessed at target ages of 18 months, and 3, 5, 7, 9–10, 11–12, 13–14, 15–16, 17–18, and 19–20 years. Although cannabis use was first queried at ages 11-12 years the behavior was too infrequent (*n*=2) to include this assessment wave in growth models. Children living in RCL states other than Oregon or Washington (*n* = 28) were omitted, given that we did not have access to retail metrics for other states. Thus, children were included in the present analyses if they were assessed one or more times from ages 13–14 to 19–20 years between March 2005 and October 2019, and at least one assessment occurred while they were living in Oregon (*n* = 137) or Washington (*n* = 11; these two sample sizes do not sum to 146 because two children had observations in both states). For the analytic sample, the 422 person-year assessments occurred in Oregon (*k* = 388), Washington (*k* = 30), or a non-RCL state (*k* = 4). In terms of participation by assessment wave, sample sizes at ages 13–14, 15–16, 17–18, and 19–20 years were *n* = 139, 129, 104, and 50, respectively; mean (SD) age across the 422 assessments was 16.4 (2.1) years. Note, sample sizes were lower at the older adolescent waves because many study participants were not yet old enough to participate.

Demographics of youth in the analytic sample at ages 13-14 years were as follows. Annual combined parent income quartiles were ≤ $19,000 (*n* = 36; 25%), $19,001-$40,500 (*n* = 36; 25%), $44,800-$60,000 (*n* = 38; 26%), and higher than $60,000 (*n* = 34; 24%); by contrast, median family income for a four-person Oregon family in 2005 was $61,945 (U.S. Census Bureau, n.d.). Highest educational degree for either mother or father was less than high school (9%), high school (26%), 1-3 years college (56%), or 4 years or more of college (9%). Youth lived with both biological parents (36%), one parent only (15%) or in a part-time arrangement (4%), one parent and a partner (37%), or another arrangement (9%).

Substance Use Measures.

Past-year cannabis and alcohol use were queried by interview at every assessment from ages 11 to 20 years. *Cannabis use* was based on whether in the past 12 months the child reported trying marijuana (1) or not (0). *Alcohol use* was based on whether in the past 12 months the child had beer, wine cooler, wine, or hard liquor (queried separately) and how much they consumed; those who did not report use or reported only sips or less than one can/bottle were coded 0, and use of any form at a higher volume was coded 1. To assess whether any associations persisted using a higher threshold of use (i.e., a marker of higher substance use risk), we conducted post hoc sensitivity analyses using monthly alcohol use in the past year, coded 1 (at least monthly) or 0 (no use, or less than monthly).

Recreational Cannabis Legalization Measures.

Washington state legalized cannabis use and sales to adults ages 21 years and older in December 2012 and July 2014, respectively. Oregon permitted cannabis use in July 2015, followed by early retail sales through existing medical dispensaries in October 2015, and licensed cannabis retail stores in October 2016. Youth assessment dates were used to code whether (1) or not (0) *recreational cannabis legalization (RCL)* was in effect at the time of the assessment, defined in terms of the dates that adult nonmedical use of cannabis became legal in Washington (December 2012) and Oregon (July 2015). RCL was coded 0 for observations in non-RCL states.

Cannabis Retail Measures.

To identify the numbers of recreational cannabis retail locations in various distance categories as a time-varying predictor, we used adolescents' home addresses, which were updated at every assessment, and addresses of licensed Oregon and Washington cannabis retail stores operating in the same month of the assessment[1]. Geocoding of the adolescents' homes was completed using ArcGIS World Geocoding Service. Of the addresses geocoded, 98% had a single location match score greater than 90 out of 100, and all but 2 addresses had a match score greater than 81. Geocodes for the cannabis retailers were provided by the relevant regulatory agencies.

Exposure was characterized as the number of retail stores within 2-, 5-, 10-, and 20-mile radii of the participant's home on the date of each assessment. Rather than transportation-based designs (e.g., "driving distance"), we used simple Euclidian distance ("as the crow flies," ignoring obstacles and borders among states) measures, given that we did not have information on youth mobility and transportation modes (e.g., walking, biking, riding a bus, driving with parents, driving themselves), which could vary by age and location (e.g., urban/rural). Additionally, we did not expect cannabis retailers to influence youth through direct sales to them, given state reports of low violation rates in compliance checks (e.g., Oregon Liquor Control Commission, 2020; Washington State Liquor and Cannabis Board, 2021). Rather, community cannabis retail activity was expected to have more indirect influence via storefront and other advertising, accessibility of cannabis sales to adults, and "normalization" of cannabis use. Euclidian distance from every adolescent address to every operating retailer address was calculated using PostgreSQL "ST_Distance" function with an equidistant projection. No participants lived within 20 miles of retailers in California or Nevada (RCL states).

Data Analysis.

In model 1, we used multilevel modeling to test effects of numbers of retail stores within a given distance category on the likelihood of past-year cannabis use (binary) at the within- (level-1) and between-subjects (level-2) levels. Specifically, we examined whether exposure to more retail stores would be associated at level-1 with increased likelihood of adolescents' cannabis use across ages 13-20 years, after accounting for overall age trends. At level-2, we tested whether adolescents exposed to more stores (grand mean centered at age 16 years) showed higher likelihood of past-year cannabis use. Models were estimated in MPlus version 8.4. Dependence among siblings' scores was accounted for using the *TYPE = COMPLEX* option to adjust the standard errors.

Given the range of birth years, some children were not yet old enough to have participated in later assessments but are not considered missing. Retention of eligible participants from assessment wave to wave averaged 80% in adolescence. Cases with partially missing

[1]We did not separately consider medical dispensaries. Lists included only Oregon licensed medical dispensaries that participated in early retail sales beginning in October 2015. Most converted to become adult-use retail outlets, beginning when such outlets were licensed in 2016. Oregon's medical and adult-use markets have almost entirely converged: to date, there are only two exclusively medical dispensaries remaining in Oregon. Washington never licensed medical dispensaries; therefore, those were not included in our dataset.

outcome data were included in the model. We used maximum likelihood with robust standard errors (MLR) as the missing data estimator.

The model-building procedure was first to estimate a grand mean only model and then test for significant linear and quadratic changes in the probability of cannabis use across ages 13-20 years. Sex (coded as male = 0 or female = 1) was considered as a level-2 covariate. To test our hypotheses, the retail exposure measure was included as both a level-1 and level-2 predictor of cannabis use. At level-1, the time-variant exposure predictor was person-mean centered to denote within-person effects of retail exposure on cannabis use across adolescence. At level-2, the time-invariant exposure predictor was coded as the average exposure to retail stores across age and then group-mean centered within participant. Thus, the level-2 effect denotes between-person associations between retail exposure and cannabis use; that is, the extent to which youth were more likely to use cannabis if they were exposed to higher numbers of retail stores across more versus fewer years (including none at all) of their development.

Model 2 used the same approach to test effects of RCL as a binary predictor of adolescents' cannabis use at level-1 and level-2. The level-1 predictions were that the likelihood of cannabis use would be higher when RCL was in effect. The level-2 predictions were that, relative to other youth, adolescents for whom RCL was in effect across a greater proportion of their development would have a higher likelihood of using cannabis.

Models 1 and 2 were repeated, adjusting for past-year alcohol use as a binary covariate at level-1 and an average at level-2 to evaluate the secondary hypotheses regarding effects of retail exposure (Model 3) and RCL (Model 4) on adolescents' cannabis use. For all tests we used a two-tailed alpha level of .05 to judge significance.

Results

Descriptive Statistics

Table 1 includes the proportion of the observations in which youth reported past-year cannabis use, alcohol use, and use of alcohol monthly or more, as well as the proportion of youth who ever reported these outcomes. In the analytic sample, rates of past-year cannabis and alcohol use, respectively, were 10.1% and 13.7% at ages 13-14 years, and 35.7% and 39.5% at ages 15-16 years. By comparison, in 2012 (the midpoint of 2005–2019) national annual prevalence estimates from Monitoring the Future for marijuana and alcohol use, respectively, were 11.4% and 23.6% for 8th graders, and 28.0% and 48.5% for 10th graders (Johnston et al., 2022).

Table 1 also lists the proportion of youth living in Oregon or Washington post-RCL, and the numbers of retail cannabis outlets at various distance categories from their residence at each assessment age. State RCL was in effect for at least one observation for 97 participants, and at 137 person-year assessments overall. For observations collected after RCL, the medians and interquartile ranges (in parentheses) for the numbers of retail stores in the 2-, 5-, 10-, and 20-mile distance categories were 0 (2), 3 (10), 7 (28), 32 (30), respectively. Figure 1 depicts the proportion of the sample living within various distance categories of any licensed cannabis retail store in each year. Given that for more than 80% of observations the number of stores in the 2-mile distance category was zero, we instead selected the 5-mile category for the primary models, and considered the models based on 2-, 10-, and 20-mile categories exploratory. Counts of retail stores were log transformed to reduce skewness (which was >3 for all categories).

Multilevel Models for Effects of Retail Exposure and RCL on Past-Year Cannabis Use

Initial models indicated that the likelihood of cannabis use increased with age in a quadratic fashion (linear *b*[*se*] = .60 [.13], $p < .001$; quadratic *b*[*se*] = −.09 [.04], $p < .05$). Results of primary hypothesis tests are presented in Table 2. Model 1 (see column 1 of Table 2) did not support significant within- or between-level effects of the number of cannabis retailers within the 5-mile category of adolescents' homes on their past-year cannabis use. That is, after adjusting for age-related changes in likelihood of use, participants were no more likely to use cannabis in years of their lives when there were more stores in their vicinity than when there were fewer (or no) stores (level-1; OR [95% CI] = 1.31 [.87-1.95]), and the estimated likelihood of participants' past-year cannabis use (centered at age 16 years) was not a function of the numbers of stores within 5 miles of their homes (level-2; *B* [95% CI] = −.03 [−.39-.33]).

Similarly, in Model 2 there were no significant effects of RCL at the within- or between-subjects levels (Table 2, column 2). There were age-related increases in the likelihood of annual cannabis use within person; however, adolescents were not significantly more likely to use cannabis at assessments occurring when RCL was in effect than they were when it was not (OR (95% CI) = 2.48 [.95-6.47]). The estimated likelihood of past-year cannabis use was not different for participants who were age 16 years when RCL was in effect than for those who were age 16 years when it was not (*B* [95% CI] = .07 [−.25-.40]).

Model 3 in column 3 built on the retail model in column 1 and indicated there were significant associations between past-year alcohol and cannabis use at the within- (OR [95% CI] = 3.57 [1.50-8.47], $p = .002$) and between-person (*B* [95% *CI*] = .39 [.09-.68], $p = .011$) levels. Adjusting for increases with age, adolescents were more likely to use cannabis in years they used alcohol (level 1), and adolescents who used alcohol were more apt to use cannabis than youth who did not use alcohol (level 2). However, after accounting for past-year alcohol use, adolescents' cannabis use still was not predicted at either the within- (OR [95% CI] = 1.37 [.92-2.04]) or between-level (*B* [95% CI] = .13 [−.22-.48]) from the numbers of licensed retail stores within a 5-mile radius of their homes. Model 4 (Table 2, column 4) also added past-year alcohol use to the RCL effects model in column 2. Patterns by age and alcohol use were similar as in Model 3, but the between-subjects effect of RCL was significant (*B* [95% CI] = .35 [.05-.66], $p = .024$). Specifically, after accounting for the higher likelihood of past-year cannabis use among adolescents with past-year alcohol use, those who spent more of their adolescence at a time when adult recreational cannabis use was legal had a higher probability of using cannabis than those who spent less (or none) of their development under RCL. However, in post-hoc sensitivity analyses[2] that accounted for

[2]This analysis was requested in review, and was not part of an *a priori* hypothesis.

the even higher likelihood of past-year cannabis use among adolescents reporting at least monthly alcohol use, the effect of RCL was not significant at either level.

None of the exploratory models that examined the numbers of retail stores in the 2-, 10-, and 20-mile radius categories as predictors of adolescents' past-year cannabis use were significant at either level. Likewise, in post-hoc sensitivity analyses[2], we again examined the effects of having more cannabis retailers within a 5-mile radius of home, but within the subsample of participants who had the opportunity of being exposed, defined as living within the 20-mile category of a retail store at one or more observations; still, the retail exposure measure was not a significant predictor of cannabis use.

Discussion

There are limited longitudinal data on (a) how age-related increases in the likelihood that adolescents' cannabis use may be affected by the recreational legalization context and retail environments surrounding them and (b) the extent to which cannabis use is more likely among adolescents who experienced these contexts and environments than among those who did not. In the present study, participants were assessed across ages 13-20 years or portions thereof (for those born later) from 2005–2019, thus spanning the periods before and after RCL and retail growth in Washington and Oregon. Overall, models did not support that the numbers of licensed cannabis retailers within a 5-mile radius (or 2-, 10-, or 20-mile) of adolescents' homes were associated with an increased risk of cannabis use in the past year, at the within- or between-subjects levels. Furthermore, in the primary models there was no evidence that adolescents' past-year cannabis use was related to whether or not state RCL was in effect.

As null findings do not constitute evidence for an absence of effect, we cannot conclude, for example, that cannabis retail environments are innocuous for youth living in close proximity to them. Still, as we previously discussed, other studies of population- and community-based samples of adolescents also have retained the null hypothesis of no RCL or retail effect, for some states or age groups (e.g., Bailey et al., 2022; Brooks-Russell et al., 2019; Cerdá et al., 2017; Dilley et al., 2019; Paschall & Grube, 2020). Null findings may suggest that it is not essential to account for RCL in studies of adolescents' cannabis use that do not concern policy effects. However, further research is needed: with larger samples, in other states with other RCL policy and retail conditions, after markets have had more time to mature, and within at-risk subgroups. For example, although the present study was not sufficiently powered to consider moderators, other studies of RCL in young samples have been; specifically, RCL had stronger associations with cannabis use among college women than men, those over age 21 years than minors, and those living off- vs. on-campus (Bae & Kerr, 2020). Other potential subgroups of adolescents who may be more sensitive to legalization and retail cannabis effects include those whose parents use cannabis heavily. Additionally, studying other indicators of the salience of cannabis retail in adolescents' communities, such as advertising and sales data, may be fruitful.

Whereas some adolescents use alcohol but abstain from cannabis, nearly all who use cannabis also have used alcohol (Patrick et al., 2018). Furthermore, many of the risk factors for adolescents' cannabis use and early onset overlap with those for early alcohol use (e.g., Kerr et al., 2015). Thus, in secondary models we tested whether apparent effects of retail environment and RCL on cannabis use might be explained by adolescents' alcohol use in the past 12 months, a marker of a variety of family, peer, and contextual influences common to both substances; alternatively, the model tested whether effects specific to cannabis use could be clarified by adjusting for this more general risk (i.e., alcohol use as a suppressor). Of note, we could not make assumptions about temporal ordering, given that we measured past-year alcohol and cannabis use concurrently and that RCL also has been found to relate to decreased prevalence of alcohol and dual alcohol–cannabis use in adolescent and young adult samples (Alley et al., 2020; Kim et al., 2021). Still, this secondary analysis was valuable, given the limited information available on these issues. The primary predictor of interest—number of cannabis retailers in a 5-mile radius—remained nonsignificant when alcohol use was controlled, but a between-subjects effect of RCL emerged as significant. That is, after accounting for the higher likelihood of cannabis use among youth who had used alcohol, those whose development occurred post-RCL were more likely to have used cannabis in the past year than youth of comparable ages who grew up when adult use was illegal. If reproduced, this finding may inform the design of prevention programs. It would suggest that, in addition to targeting common risk factors for substance use that may be present regardless of state RCL status, additional prevention efforts specific to cannabis may be needed for adolescents in RCL states. Overall, we interpret this finding with caution and maintain that it requires replication as a secondary hypothesis. Furthermore, we note that this finding was not evident in a post-hoc analysis requested in review in which we adjusted for a higher threshold of early alcohol use.

Limitations

The study had several limitations. Participants had a 12-month cannabis use prevalence similar to that of national peers (Johnston et al., 2022), but were not sampled to be representative of RCL states, and their family demographics (i.e., primarily White non-Latinx and lower income) and other characteristics (e.g., lower alcohol use prevalence) may limit generalizability. The present study also had a smaller sample size and thus lower statistical power than RCL studies using cross-sectional national samples. Although person-year observations were more numerous in within-subjects analyses, there were relatively few observations post-legalization, when youth were living in close proximity to a retail outlet. Prior studies of cannabis, alcohol, and tobacco retail have focused on radii of less than 2 miles, to encompass areas that youth may encounter with some frequency such as when walking. Although such distances may be relevant for urban samples, they may be less so in more rural or suburban settings where youth do not walk to school or shopping areas. Future longitudinal studies could focus on associations of retailers in urban samples, use different distances for urban and rural communities, and account for youth mobility and transportation methods. Relatedly, we did not account for neighborhood factors potentially confounded with the presence of more cannabis retailers. Also, we were not able to account for the potential influences of unlicensed "gray-market" retail stores, and did not examine youth exposure to Oregon's medical cannabis dispensaries before RCL.

Additionally, although we included youth living in both Oregon and Washington to maximize the numbers of participants and observations, cannabis retail environments may differ by state. For example, state regulatory frameworks specify limitations on promotion and hours operation (e.g., Prevention Technology Transfer Center, n.d.). Some communities in Oregon and Washington also have applied further local limitations on hours of operation, storefront signage, and other promotions, or ban retail sales. Whereas our models did not incorporate local policy variation, our measures of exposure would reflect the effects of local retail bans.

Finally, whereas a strength of the current study was the variability in adolescents' ages at the time of RCL and retail growth, this feature could also present a weakness. For children born to younger parents, adolescence occurred primarily before cannabis legalization and growth in retail; whereas, the adolescence of children with older parents coincided more completely with the years of cannabis legalization. Given that early parenthood is associated with higher-risk characteristics for parents and their offspring—including early onset cannabis use in both generations (Henry et al., 2021)—parent age effects that ameliorate children's risk may have offset or counteracted adverse retail and legalization effects. Although cohort and period effects could not be disentangled in this study, larger samples or synthesis of data (see Tiberio et al., 2020) from states that differed on the timing of RCL could clarify these issues.

Conclusions

The present study is among the first to examine within-person RCL effects. We did not find evidence that adolescents' residential proximity to cannabis retail or exposure to state RCL were associated with an increased likelihood of cannabis use in the past year. However, the sample size was relatively small and limited to a single region, and there were relatively few observations post-legalization. There was some support for an association between greater exposure to RCL (more years of development when adult use was legal) and cannabis use after accounting for elevated risk associated with past-year alcohol use. Future studies of legalization effects—including as cannabis markets mature—should include alcohol measures, larger prospective samples, and examine at-risk subgroups.

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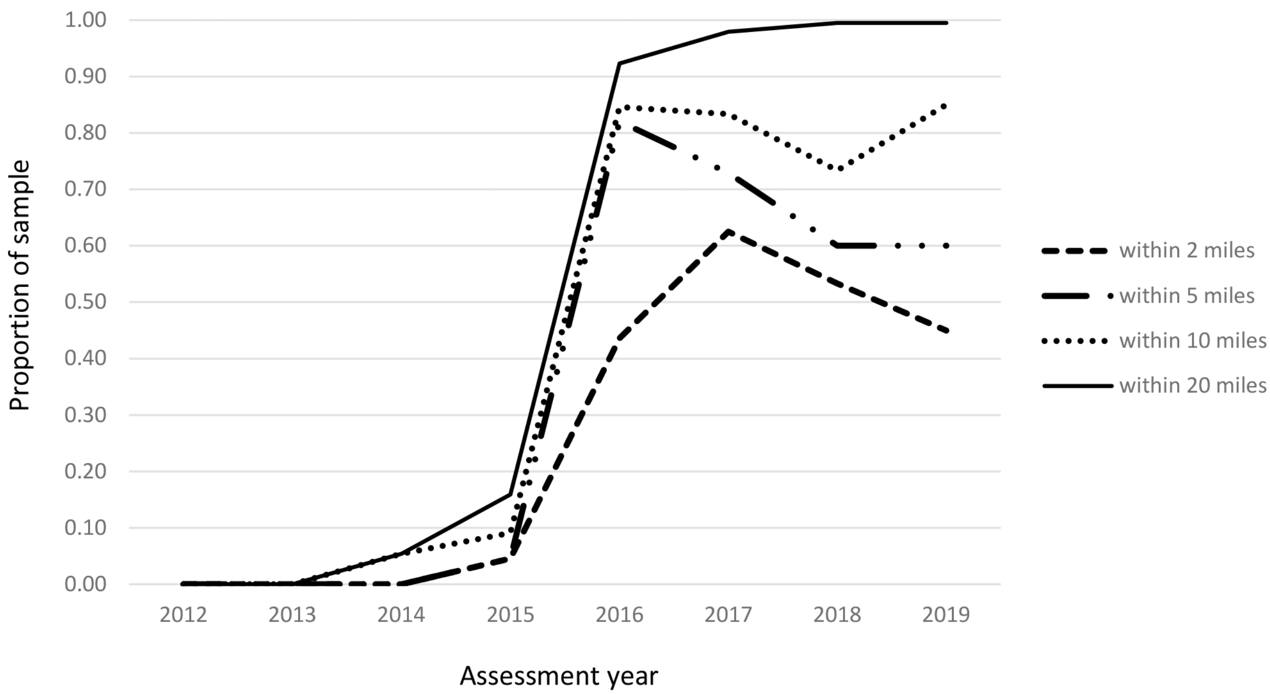

Figure 1.
Proportions of the Sample at Each Assessment Year Living Within Various Distances of Any Licensed Retail Cannabis Store (Non-RCL Years of 2005–2011 Are Not Shown as There Were No Stores)

Table 1

Descriptive Statistics on Study Variables for All Observations (Ages 13-20 Years) and Cumulatively Across Observations for Individuals

	Total observations *k* = 422, *k* (%) endorsed/present	**Total participants *n* = 146, *n* (%) ever endorsed/present**
Cannabis use (past year)	125 (29.6%)	78 (53.4%)
Alcohol use (past year)	170 (40.3%)	87 (59.6%)
Alcohol use, monthly or more (past year)	64 (15.2%)	42 (28.8%)
Lived in OR or WA post-RCL	137 (32.5%)	97 (66.4%)
≥1 cannabis retail store within:		
2 miles of home	66 (15.6%)	55 (37.7%)
5 miles of home	90 (21.3%)	70 (47.9%)
10 miles of home	107 (25.4%)	78 (53.4%)
20 miles of home	127 (30.1%)	90 (61.6%)

Note. k = cumulative total of all observations across participants; *n* = total number of participants; OR = Oregon; WA = Washington; RCL = recreational cannabis legalization.

Table 2

Multilevel Regression Models Predicting Adolescents' Past-Year Cannabis Use from (Log) Number of Cannabis Retail Stores within a 5-Mile Radius of Their Home and Recreational Cannabis Legalization, with Adjustment for Past-Year Alcohol Use

	Model 1 Retail		Model 2 RCL		Model 3 Retail and alcohol use		Model 4 RCL and alcohol use	
Predictors	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Within-subjects (level-1)								
Age	1.75***	1.35-2.26	1.70***	1.30-2.22	1.48**	1.13-1.94	1.48**	1.11-1.97
Age^2	0.92*	0.85-0.99	0.91*	0.85-0.98	0.92*	0.86-0.997	0.92*	0.85-0.99
Retail stores	1.31	0.87-1.95	.	.	1.37	0.92-2.04	.	.
RCL	.	.	2.48	0.95-6.47	.	.	2.77	0.98-7.85
Alcohol use	.	.	.	.	3.57**	1.50-8.47	3.22**	1.34-7.70
Predictors	***B***	**95% CI**	***B***	**95% CI**	***B***	**95% CI**	***B***	**95% CI**
Between-subjects (level-2)								
Retail stores	−.03	−.39-.33	.	.	.13	−.22-.48	.	.
RCL	.	.	.07	−.25-.40	.	.	.35*	.05-.66
Alcohol use	.	.	.	.	.39*	.09-.68	.50***	.22-.78
Male	.09	−.42-.59	.11	−.40-.61	−.13	−.62-.37	−.16	−.63-.32

Note. RCL = recreational cannabis legalization. OR = odds ratio. 95% CI = 95% confidence interval. *B* = standardized beta. Estimated p-values and associated significance levels for within-subjects effects (level-1) are based on the logit parameters.

* $p < .05$.

** $p < .01$.

*** $p < .001$