Association between cannabis retail outlet availability and sources of cannabis acquisition among young adults in Washington State, 2015–2021

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A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Public Health

University of Washington

2025

Committee:

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Program Authorized to Offer Degree:

Epidemiology

University of Washington

Abstract

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This study examined associations between cannabis retail outlet availability and sources of cannabis acquisition among young adults, with particular focus on age-specific patterns and the potential modifying effects of the COVID pandemic. Data were from surveys from 4,252 young adults 18–25 years that used cannabis and were participating in the Washington Young Adult Health Survey (2015–2021). Cannabis retail outlet availability was defined as the presence of at least one licensed outlet within a 2-kilometer road network buffer of the participant's residence. Primary outcomes were five self-reported sources of cannabis acquisition in the past 30 days: retail outlet, friends, family, party, and gave money to someone to get it for me. Logistic regression models were used to examine associations between retail outlet availability and each source, with models stratified by age group (18–20 versus 21–25) and pre COVID pandemic

(2015–2019) versus COVID pandemic timing (2020–2021). Models adjusted for demographic and neighborhood covariates. Sensitivity analyses used a 1-kilometer buffer to define cannabis retail outlet availability. Adjusting for covariates, retail outlet availability within a 2-kilometer buffer was statistically significantly associated with the source "Gave money to someone to get it for me" for the 18–20 age group. For the 21–25 age group, after adjustment, retail outlet availability was positively associated with obtaining cannabis from a retail outlet and inversely associated with giving money to someone to obtain cannabis. When stratified by pandemic timing, among 18–20-year-olds, the association between retail outlet availability and giving money to someone was stronger in the pre-pandemic period compared to during the pandemic. During the pandemic, the association for giving money to someone was in the opposite direction for the 21–25 age group. Additionally, associations between retail outlet availability and obtaining cannabis from friends or at parties were stronger during the pandemic compared to the pre-pandemic period for the 21–25 age group. Sensitivity analyses using a 1-kilometer buffer yielded similar findings for the 21–25 age group; however, for the 18–20 age group, retail outlet availability was statistically significantly associated with obtaining cannabis from friends. Findings underscore the importance of considering how cannabis access and acquisition sources, shaped by age and legal context, may contribute to patterns of use and associated risks. Results, if replicated, may have implications for tailored public health messaging strategies.

Background and Significance

Cannabis is among the most commonly used substances by young adults in the United States.[1] As of February 2024, cannabis use for medical purposes is legal in 47 states, and 24 states have legalized adult use of cannabis for non-medical purposes, including Washington State.[2] A 2019 survey analysis across six metropolitan areas in the United States found that young adults 18–25 compared to other age groups showed the highest prevalence of use, with 23% reporting use in the past month.[3] Further, a study in Washington State examining trends in cannabis use since 2014, the year cannabis retail outlets were legally allowed to open, found that prevalence of cannabis use increased for young adults 18–25.[4] In 2021, approximately 58% of adults 18 or older surveyed in Washington indicated they had tried cannabis at least once in their lifetime, while 30% reported use in the past 30 days.[5] A study in Washington State has also found that following legalization, in addition to increased prevalence of use, the number of cannabis use disorder symptoms increased.[6] The increasing prevalence of cannabis use poses a public health concern due to its associated consequences, including the risk of cannabis use disorder and other physical and mental health conditions.[7]

As of 2024, the U.S. cannabis industry was valued at nearly $40 billion, with projections indicating continued annual growth through 2028.[8,9] As more states have legalized cannabis over the past decade, availability through retail outlets has increased,[10] and disapproval and perceived harms of cannabis have decreased.[1,8,11] Studies have found that proximity to retail outlets is associated with increased cannabis use, perceived access, and greater acceptance of cannabis use.[7,11,12] A cross-sectional study in California among 18–25-year-olds showed that a majority obtain cannabis from a retail outlet,[13] but it is unclear if proximity to a retail outlet is associated with patterns of acquisition.

The impact of retail outlet availability on cannabis sources, particularly among individuals aged 18–20, is not well understood. It is important to examine how age (18–20 versus 21–25) modifies the association between retail outlet availability and acquisition patterns as the purchase and possession of cannabis is not legal for those younger than 21. Although the landscape of cannabis acquisition has shifted with increased retail outlet availability, there are still many alternative points of access for young adults, such as family and friends. Studies have found that most youth under 18 received cannabis for free or bought cannabis from someone.[14] However, little is known about factors that influence individuals' choice to seek out regulated or unregulated sources.[15] Unregulated sources could have health implications if the potency is unknown. Studies have found associations between high potency cannabis and risk of cannabis use disorder, as well as mental health outcomes such as depression and anxiety.[16] Understanding sources of unregulated cannabis is crucial, as consumers may be unaware of the product's composition, potency, or potential contaminants.[8,17]

Further, studies have found that individuals who use cannabis primarily gain their knowledge of cannabis through personal experiences, online sources, and insights from family and friends.[18,19] Researchers are working to understand how people learn about the effects of cannabis, attempting to determine if individuals rely on friends on social media, healthcare providers, or staff at dispensaries.[20] Since individuals can be influenced by interpersonal relationships,[19] understanding where people get cannabis is additionally important as it can help target and refine public health messaging strategies related to physical and mental health effects of cannabis.[21]

It is important to also examine the impact of the COVID pandemic on the association between retail outlet availability and sources of cannabis acquisition. In Washington State,

cannabis retail outlets were declared essential businesses during the COVID pandemic.[22] During the pandemic, sales in Washington peaked, particularly from early 2020 to early 2021, despite minimal growth in the number of retail outlets.[23] Additionally, studies have found that many adults 18–25 reported their cannabis use increased resulting from the pandemic.[24] Analyzing the association between retail outlet availability and cannabis acquisition sources over years that include the COVID pandemic—a period when frequency of use increased[24] and use of legal sources possibly increased[25]—offers valuable insight into the this time period and its possible effect on acquisition patterns.

This study assessed cannabis acquisition from 2015–2021 for participants 18–20 and 21–25 in Washington State. This study sought to add to the current body of cannabis-related literature by evaluating the association between cannabis retail outlet availability and participant reported sources of cannabis using data from the Washington Young Adult Health Survey.

Findings could inform future research in other states that have legalized cannabis or have similar retail outlet availability. This work contributes to the broader literature on cannabis use, supports future studies on sources of cannabis acquisition, and emphasizes the importance of examining retail outlet availability as a potential factor in frequency of cannabis use. Additionally, it provides insights that can enhance public health messaging, particularly by incorporating source-based messaging strategies, helping inform prevention and intervention efforts.

Methods

Study Design and Population

The Washington Young Adult Health Survey (WYAHS) is a statewide online survey designed to track young adult health behaviors over time by inviting both new and returning participants annually. Each year since 2014, data were collected from a new cohort of 18–25-year-olds and participants who have already completed surveys were invited to participate again. More detailed information regarding data collection and participant recruitment is available elsewhere.[4]

First-time participants must be 18–25 years old and living in Washington State to be eligible to participate. Participants were recruited through a combination of 1) direct mail advertising to a random sample of 10,000 adults 18 to 25 years-old, whose names and addresses were provided by the Washington Department of Licensing (DOL), and 2) online platforms (Craigslist, Instagram, Facebook, the website for the study). Demographic data were monitored, and recruitment strategies were adjusted to engage underrepresented groups. Participants earned a $15 Amazon gift card after completing the baseline survey.

For this study, data were from baseline surveys from seven cohorts collected from 2015 to 2021 (n = 13,804), resulting in a repeated cross-sectional design. Only those participants who responded in the survey that they used cannabis at least one day in the past 30 days received the full series of cannabis acquisition questions. For this analysis, only data from individuals who responded to at least one of the cannabis acquisition questions were included (n = 4,252).

Measures

Cannabis Retail Outlet Availability

The primary exposure for this study was cannabis retail outlet availability. Spatial coordinates for licensed cannabis retailers were provided by the Washington Liquor and

Cannabis Board for each of the study years. Survey participants' addresses were geocoded, allowing for the linkage between residence and retail outlets. For this study, cannabis retail outlet availability was defined as the presence of at least one retail outlet within a 2-kilometer road network buffer of one's residence.[12] This definition is based on prior research showing that associations between cannabis retail outlet availability and cannabis use were strongest when using a 2-kilometer buffer compared to 0.5- and 1-kilometer buffers.[12] Sensitivity analyses also explored a 1-kilometer road network buffer. Retail outlet availability was evaluated as a binary variable (0: no presence within the buffer, 1: any presence of a retail outlet within the buffer).

Sources of Cannabis Acquisition

The primary outcome for this study was sources of cannabis acquisition. Participants who reported cannabis use were asked about a number of sources of acquisition during the past 30 days. For this analysis, we considered 10 specific items, summarized in Table 1. Participants responded yes (1) or no (0) to each source, except for the final question, which allowed an open-ended response. Participants could select 'yes' for all that apply among the 10 sources. After inspecting the distribution of responses across source categories, those with the highest frequencies were retained, while other source categories were either collapsed with similar categories or excluded from the analysis, which yielded five separate dichotomous outcomes as shown in Table 1.

Covariates

Covariates that were included in the analyses were sex assigned at birth (0: female, 1: male), employment (0: not employed full-time, 1: employed full-time), student status (0: not

currently a student, 1: currently a student), and race/ethnicity, which was combined from a question asking about ethnicity (a binary variable that asks if the survey participant is Hispanic or Latino) and questions about racial background (separate binary variables where participants select yes or no), and then categorized as non-Hispanic White (reference group), non-Hispanic Asian, non-Hispanic other race, and Hispanic (any race). Covariates at the census-tract-level include quintiles of census tract percent living in poverty and population density. Current studies suggest that non-medical cannabis retail outlets are often concentrated in racially diverse, economically disadvantaged communities,[26] and that cannabis use prevalence and frequency vary by race and ethnicity.[27] These covariates were included as confounders as they are believed to be associated with proximity to retail outlets and source of cannabis acquisition. Sex at birth was included as a precision variable as previous studies have identified males and females consume cannabis through different mechanisms which might affect where one might obtain cannabis,[28] but not proximity to retail outlets.

Data Analysis

Statistical analyses were performed in R (R version 4.4.1). To examine the association between retail outlet availability and each source of acquisition, five logistic regression models were run, treating each source as a distinct binary outcome. For both age groups, each model included retail outlet availability as a binary predictor (presence versus absence of a retail outlet within a 2-km buffer), with absence of a retail outlet as the reference category. Adjusted and unadjusted models were run. To determine whether age or COVID pandemic timing modified the association between retail outlet availability and source of cannabis acquisition, the adjusted models were stratified by age (age group: 18–20 versus age group: 21–25) (Table 4 and Table 5)

and pandemic timing (pre-pandemic [2015–2019] versus pandemic [2020–2021]) (Table 8). The ggpredict() function from the "ggeffects" package in R was used to compute adjusted predicted probabilities from logistic regression models, holding covariates at their reference levels, to facilitate interpretation of the exposure-outcome relationship by translating model estimates into predicted probabilities.

To assess the influence of spatial scale, a sensitivity analysis was conducted by rerunning the models using a 1-km road network buffer to define cannabis retail outlet availability (Appendix).

Results

A total of 13,804 participants completed the baseline survey. Of those, 9,552 were excluded due to missing age information (n = 514) or because they did not report cannabis use (n = 9,038), making the cannabis acquisition questions not applicable to them. As a result, data from 4,252 participants were included in the analysis. Table 2 presents the descriptive statistics for the study sample stratified by age group. If present, missing data are reported. Among the sample, 1,389 (32.7%) individuals were 18–20 and 2863 (67.3%) individuals were 21–25. Of the 18-20-year-olds, 69.6% were male, 17.8% were employed full time, 71.9% were currently students, and a majority identified as non-Hispanic White (60.8%). Among the 21–25 age group, 69.3% were male, 45.3% were employed full time, 35.1% were currently students, and a majority identified as non-Hispanic White (65.7%). For both age groups, a majority lived in a census tract with a population density of 3,000+ per square mile. For the 21–25 age group, the most reported cannabis source was retail outlets (82.5%) and the least common was giving

money to someone (5.5%). For 18–20-year-olds, the most common source was friends (69.4%) and the least common source was retail outlets (9.8%).

Table 3 presents descriptive statistics of the study sample stratified by retail outlet availability within each age group. Among the 18–20 and 21–25 age groups, 31.3% and 38.8% lived within 2-km of a retail outlet, respectively. Among 18–20-year-olds, 44.7% of those without a retail outlet within 2-km lived in areas with a population density of 3,000+ per square mile, compared to 76.1% of those with a retail outlet available. Among 21–25-year-olds with a retail outlet available, 81.0% lived in an area with a population density of 3,000+ per square mile, compared to 47.5% without a retail outlet available.

Results from the unadjusted and adjusted logistic regression models for the 18–20 age group are shown in Table 4. Among individuals aged 18–20, there was little evidence of an association between retail outlet availability and any cannabis acquisition source, except for giving money to someone as the source. Giving money to someone to obtain cannabis was more common among those with a retail outlet available within a 2-km buffer (42.3%) compared to those without a retail outlet available (36.2%). After adjusting for covariates, the association between retail outlet availability and giving money to someone was statistically significant (aOR = 1.34, 95% CI 1.02, 1.77).

Results for the 21–25 age group (Table 5) revealed a different pattern of associations than those observed among 18–20-year-olds. Individuals aged 21–25 living within 2-km of a retail outlet available compared to those who did not were more likely to report obtaining cannabis from a retail outlet (85.4% versus 80.7%). This difference was statistically significant in both unadjusted (OR = 1.40, 95% CI 1.14, 1.72) and adjusted models (aOR = 1.61, 95% CI 1.28, 2.03). Model predicted probabilities indicated that individuals with a retail outlet available within

2-km had a 12% probability of *not* obtaining cannabis from a retail source, compared to 18% among those without a retail outlet available. Conversely, retail availability was associated with *lower* odds of giving money to someone (OR = 0.59, 95% CI 0.41, 0.84; aOR = 0.67, 95% CI 0.44, 0.99). All other sources in the adjusted models were not significantly associated with retail outlet availability.

Table 6 (18–20 age group) and Table 7 (21–25 age group) display descriptive statistics of the sources of cannabis stratified by COVID pandemic timing (2015–2019 versus 2020–2021) and by retail outlet availability within each age group. The percentage obtaining cannabis from a retail outlet increased slightly for both age groups during the pandemic compared to pre-pandemic, regardless of cannabis retail outlet availability.

Results from the models stratified for age and time (pre-pandemic versus pandemic) are presented in Table 8. Among the 18–20 age group, after adjusting for all covariates, the pre-pandemic odds ratio for the association between retail outlet availability and retail outlets as the source of cannabis acquisition was close to the null (aOR = 1.07, 95% CI 0.63, 1.77). While this association was slightly stronger during the pandemic (aOR = 1.28, 95% CI 0.53, 3.12), neither was statistically significant. In the models stratified for age and time, the pre-pandemic association between retail outlet availability and giving money to someone was the strongest amongst all the sources (aOR = 1.51, 95% CI 1.09, 2.10), but was attenuated and non-significant in the pandemic model (aOR = 0.84, 95% CI 0.48, 1.46). Additionally, the associations between retail outlet availability and cannabis sources including friends, family, and party marginally shifted, going from a positive to an inverse association from pre-pandemic to during the pandemic. None of the associations were strong or statistically significant.

For the 21–25 age group, the adjusted odds ratio of the pre-pandemic association between retail outlet availability and obtaining cannabis from retail outlets was 1.54 (95% CI 1.19, 2.00) while the association during the pandemic was slightly attenuated (aOR = 1.26, 95% CI 0.75, 2.12). Other notable differences emerged across sources; for example, retail outlet availability was more strongly associated with obtaining cannabis from friends or parties during the pandemic, shifting from near-null associations pre-pandemic to positive associations during the pandemic. Additionally, pre-pandemic, 21–25-year-olds with a retail outlet available within 2-km had significantly lower odds of giving money to someone to obtain cannabis (aOR = 0.49, 95% CI 0.30, 0.90); however, during the pandemic, the association was in the opposite direction (aOR = 2.50, 95% CI 0.89, 4.80), though it was not statistically significant.

Sensitivity analyses were performed to examine the associations between retail outlet availability using a 1-km road network buffer and the five sources of cannabis acquisition. Descriptive statistics and analyses are presented in the Appendix. For the 18–20 age group, similar findings were observed using the 1-km buffer, with a few notable differences. Retail outlet availability was most strongly associated with friends as the source of cannabis acquisition (aOR = 1.66, 95% CI 1.10, 2.58) in the adjusted model, a statistically significant association stronger than that observed with the 2-km buffer. In both pre-pandemic and pandemic models, the association for 18–20-year-olds obtaining cannabis from a retail outlet were inverse, while the associations were positive when using a 2-km buffer. None of the associations for retail outlets as a source were statistically significant using either buffer for the 18–20 age group. For the 21–25 age group, findings were in the same direction, but somewhat attenuated, when using the 1-km buffer compared to the 2-km buffer, and none of the associations in any model were statistically significant.

Discussion

In this study of young adults in Washington State, for individuals aged 21 and older, the presence of a retail outlet within 2-km of their residence was positively associated with obtaining cannabis from a retail outlet and inversely associated with giving money to someone else. Among 18–20-year-olds, giving money to someone to obtain cannabis was the only source significantly associated with retail outlet availability such that individuals living within 2-km of a retail outlet, compared to those that did not, had higher odds of acquiring cannabis by giving money to someone after adjusting for covariates. However, our study did not identify clear evidence for associations between outlet availability and any other sources of cannabis acquisition among 18–20-year-olds.

Obtaining cannabis from retail outlets varied notably by age group, highlighting how retail outlet availability may influence sources of cannabis differently for those above and below the legal purchase age. The absence of a clear association between retail outlet availability and retail acquisition in the 18–20 age group in contrast with the positive association observed among those aged 21–25 may suggest that retail outlet availability does not translate to underage access at retail outlets. This aligns with the current legal rules and policy in place, which may suggest that the regulations on retail outlets to restrict underage access are successful.

In contrast to obtaining cannabis from a retail outlet directly, associations for giving money to someone else to obtain cannabis also varied by age, suggesting different access strategies possibly tied to retail outlet availability. Unlike the 21–25 age group, the 18–20 age group had a positive association between retail outlet availability and acquiring cannabis by giving money to someone. This may reflect a strategy to work around the legal minimum

purchase age of 21 for retail cannabis. The inverse association for 21–25-year-olds could mean that in areas with retail outlet availability, individuals are less likely to give money to someone to obtain cannabis for them because of the convenience, variety, perceived safety, and normalization. Individuals 18–20 may rely on social proxies to obtain cannabis, and in areas with more retail outlets and ability to find someone of age who has access, it is possible that giving money to someone might become more common and potentially support the idea that retail outlet availability may increase underage access indirectly, through older social sources. However, it's unclear if this is the case as the survey measure used in this study does not specifically ask about obtaining cannabis from older social sources.

After stratifying by time (pre-pandemic versus pandemic), some associations differed within age groups, indicating possible effect modification by pandemic timing for certain cannabis sources, while other associations remained stable. Interestingly, for the 21–25 age group, the association between obtaining cannabis from a retail outlet and the presence of a retail outlet was slightly lower during the pandemic, compared to pre-pandemic. Although cannabis retail outlets were designated as essential businesses during the pandemic, it appeared that associations of retail outlet availability and sources involving other people (sources: friends, party, gave money to someone) became stronger during the pandemic compared to pre-pandemic for the 21–25 age group. This might be due to a combination of factors like increases in cannabis use during the pandemic,[29] the potential changes in quality and quantity of friendships that occurred during the pandemic for young adults,[30] and possible changes in living areas or situations. For the 18–20 age group, the association between the availability of a retail outlet within 2-km and giving money to someone to obtain cannabis was stronger pre-pandemic (aOR = 1.51, 95% CI 1.09, 2.10), than during the pandemic (aOR = 0.84, 95% CI 0.48, 1.46). This

shift may suggest that prior to the pandemic, retail availability may have indirectly influenced this age group's access through social sources, whereas during the pandemic, changes in access patterns or social behaviors may have weakened this association.

Notably, when using the 1-km buffer compared to the 2-km buffer, the inverse association between retail outlet availability and obtaining cannabis from a retail outlet strengthened, while the positive associations with obtaining cannabis from friends or by giving money to someone became stronger for the 18–20 age group. Both associations were found to be statistically significant in the adjusted and pre-pandemic models, while associations with other sources remained non-significant. Determining relevant spatial scales is an ongoing challenge in neighborhood effects literature.[12,31] It will be important to better understand the most relevant spatial scale when assessing the potential influences of cannabis retail outlet availability.

This study had several limitations. Survey participants were recruited using a combination of Department of Licensing records and online platforms, so the sample may not fully represent the state's overall young adult population. Although relevant covariates were accounted for, it is possible there is confounding due to unmeasured variables. There are also other sources of cannabis acquisition that were not included in the analyses of this study, such as growing it or specifically getting it from someone with a medical marijuana card, although these categories had fewer responses. Additionally, the cross-sectional study design limits causal inference.

This study also had strengths. The use of an annual online survey facilitates broad geographic reach and reduces barriers to participation, which increases accessibility and potential diversity in the sample. This study included a large sample of over 4,000 participants. The primary study captured a wide range of the young adult population by including all residents

aged 18–25 as eligible first-time participants. This study examined sources of cannabis acquisition at an important age, as young adults 18–25 experience higher rates of cannabis use,[32] particularly during the pandemic.[29]

If replicated, these findings suggest important public health implications. Understanding where individuals obtain cannabis can help identify individuals at greater risk, as certain sources might be associated with riskier products or linked with behaviors like frequent use. It is important to consider not just where cannabis is obtained, but how access (shaped by legal constraints) affects patterns of cannabis use, such as frequency and type of product, which influences the risk of cannabis use disorder and related harms. Legal restrictions may limit direct retail access among 18–20-year-olds, but indirect strategies like proxy purchasing highlight the need for continued enforcement of regulations and can guide complementary public health efforts including targeted public health interventions, such as tailored messaging within retail outlets for specific subgroups,[33] or educational campaigns directed at underage individuals. Although this study did not utilize the data from returning participants and therefore did not look at within-person behavior changes over time, analyzing longitudinal data could potentially provide greater insight into these associations. Future studies should consider this association in relation to frequency and quantity of cannabis use, to potentially shed light on additional risk factors for use and implications regarding knowledge of potency.

Table 1. Sources of cannabis acquisition included in analysis

Sources of cannabis acquisition during the past 30 days	How source is included in analysis
Bought it from a retail store (using a fake ID)	Retail Outlet
Bought it from a retail store (NOT using a fake ID)	
Got it from a medical dispensary/service	
Stole it from a store or dispensary	
Gave money to someone to get it for me	Gave money to someone to get it for me
Got it from my parents with their permission	Family
Took it from my parents without their permission	
Got it from my sister/brother/other family member	
Got it from friends	Friends
Got it at a party	Party

Table 2. Descriptive statistics by age

	Total (N=4252)	Ages 18-20 (N=1389)	Ages 21-25 (N=2863)
Sex			
Female	1300 (30.6%)	422 (30.4%)	878 (30.7%)
Male	2952 (69.4%)	967 (69.6%)	1985 (69.3%)
Full-time Employment Status (40+hours/week)			

Not employed full time	2679 (63.0%)	1125 (81.0%)	1554 (54.3%)
Employed full time	1543 (36.3%)	247 (17.8%)	1296 (45.3%)
Missing	30 (0.7%)	17 (1.2%)	13 (0.5%)
Student Status			
Not currently a student	2249 (52.9%)	391 (28.1%)	1858 (64.9%)
Currently a student	2003 (47.1%)	998 (71.9%)	1005 (35.1%)
Race/Ethnicity			
White (non-Hispanic)	2727 (64.1%)	845 (60.8%)	1882 (65.7%)
Asian (non-Hispanic)	308 (7.2%)	99 (7.1%)	209 (7.3%)
Hispanic (any race)	665 (15.6%)	260 (18.7%)	405 (14.1%)
Other race (non-Hispanic)	552 (13.0%)	185 (13.3%)	367 (12.8%)
Survey Year			
2015	465 (10.9%)	162 (11.7%)	303 (10.6%)
2016	625 (14.7%)	180 (13.0%)	445 (15.5%)
2017	703 (16.5%)	234 (16.8%)	469 (16.4%)
2018	732 (17.2%)	251 (18.1%)	481 (16.8%)
2019	598 (14.1%)	220 (15.8%)	378 (13.2%)
2020	483 (11.4%)	132 (9.5%)	351 (12.3%)
2021	646 (15.2%)	210 (15.1%)	436 (15.2%)
Cannabis Retail Outlet within 2-km buffer			
Retail outlet not within 2-km buffer	2706 (63.6%)	954 (68.7%)	1752 (61.2%)
Retail outlet within 2-km buffer	1546 (36.4%)	435 (31.3%)	1111 (38.8%)
Population density per square mile			

<1,000	791 (18.6%)	274 (19.7%)	517 (18.1%)
1,000–2,999	765 (18.0%)	282 (20.3%)	483 (16.9%)
3,000+	2490 (58.6%)	757 (54.5%)	1733 (60.5%)
Missing	206 (4.8%)	76 (5.5%)	130 (4.5%)
Quintiles of census tract % living in poverty			
0 to 5.1	778 (18.3%)	293 (21.1%)	485 (16.9%)
5.1 to 8.1	785 (18.5%)	258 (18.6%)	527 (18.4%)
8.1 to 12.3	828 (19.5%)	269 (19.4%)	559 (19.5%)
12.3 to 19.6	880 (20.7%)	234 (16.8%)	646 (22.6%)
19.6 to 78.8	981 (23.1%)	335 (24.1%)	646 (22.6%)
Cannabis Source: Retail Outlet	2499 (58.8%)	136 (9.8%)	2363 (82.5%)
Cannabis Source: Friends	1968 (46.3%)	964 (69.4%)	1004 (35.1%)
Cannabis Source: Family	520 (12.2%)	282 (20.3%)	238 (8.3%)
Cannabis Source: Party	515 (12.1%)	293 (21.1%)	222 (7.8%)
Cannabis Source: Gave money to someone to get it for me	697 (16.4%)	539 (38.8%)	158 (5.5%)

Table 3. Descriptive statistics by age and cannabis retail outlet availability (2-kilometer buffer)

	Total		**Ages 18-20**		**Ages 21-25**	
	Retail outlet not within 2-km buffer (N=2706)	**Retail outlet within 2-km buffer (N=1546)**	**Retail outlet not within 2-km buffer (N=954)**	**Retail outlet within 2-km buffer (N=435)**	**Retail outlet not within 2-km buffer (N=1752)**	**Retail outlet within 2-km buffer (N=1111)**

Sex						
Female	873 (32.3%)	427 (27.6%)	310 (32.5%)	112 (25.7%)	563 (32.1%)	315 (28.4%)
Male	1833 (67.7%)	1119 (72.4%)	644 (67.5%)	323 (74.3%)	1189 (67.9%)	796 (71.6%)
Full-time Employment Status (40+hours/week)						
Not employed full time	1730 (63.9%)	949 (61.4%)	773 (81.0%)	352 (80.9%)	957 (54.6%)	597 (53.7%)
Employed full time	955 (35.3%)	588 (38.0%)	170 (17.8%)	77 (17.7%)	785 (44.8%)	511 (46.0%)
Missing	21 (0.8%)	9 (0.6%)	11 (1.2%)	6 (1.4%)	10 (0.6%)	3 (0.3%)
Student Status						
Not currently a student	1427 (52.7%)	822 (53.2%)	278 (29.1%)	113 (26.0%)	1149 (65.6%)	709 (63.8%)
Currently a student	1279 (47.3%)	724 (46.8%)	676 (70.9%)	322 (74.0%)	603 (34.4%)	402 (36.2%)
Race/Ethnicity						
White (non-Hispanic)	1736 (64.2%)	991 (64.1%)	591 (61.9%)	254 (58.4%)	1145 (65.4%)	737 (66.3%)
Asian (non-Hispanic)	172 (6.4%)	136 (8.8%)	60 (6.3%)	39 (9.0%)	112 (6.4%)	97 (8.7%)
Hispanic (any race)	437 (16.1%)	228 (14.7%)	188 (19.7%)	72 (16.6%)	249 (14.2%)	156 (14.0%)
Other race (non-Hispanic)	361 (13.3%)	191 (12.4%)	115 (12.1%)	70 (16.1%)	246 (14.0%)	121 (10.9%)

Survey Year						
2015	391 (14.4%)	74 (4.8%)	140 (14.7%)	22 (5.1%)	251 (14.3%)	52 (4.7%)
2016	450 (16.6%)	175 (11.3%)	139 (14.6%)	41 (9.4%)	311 (17.8%)	134 (12.1%)
2017	427 (15.8%)	276 (17.9%)	154 (16.1%)	80 (18.4%)	273 (15.6%)	196 (17.6%)
2018	423 (15.6%)	309 (20.0%)	159 (16.7%)	92 (21.1%)	264 (15.1%)	217 (19.5%)
2019	368 (13.6%)	230 (14.9%)	141 (14.8%)	79 (18.2%)	227 (13.0%)	151 (13.6%)
2020	288 (10.6%)	195 (12.6%)	90 (9.4%)	42 (9.7%)	198 (11.3%)	153 (13.8%)
2021	359 (13.3%)	287 (18.6%)	131 (13.7%)	79 (18.2%)	228 (13.0%)	208 (18.7%)
Population density per square mile						
<1,000	698 (25.8%)	93 (6.0%)	247 (25.9%)	27 (6.2%)	451 (25.7%)	66 (5.9%)
1,000–2,999	627 (23.2%)	138 (8.9%)	234 (24.5%)	48 (11.0%)	393 (22.4%)	90 (8.1%)
3,000+	1259 (46.5%)	1231 (79.6%)	426 (44.7%)	331 (76.1%)	833 (47.5%)	900 (81.0%)
Missing	122 (4.5%)	84 (5.4%)	47 (4.9%)	29 (6.7%)	75 (4.3%)	55 (5.0%)
Quintiles of census tract % living in poverty						
0 to 5.1	666 (24.6%)	112 (7.2%)	269 (28.2%)	24 (5.5%)	397 (22.7%)	88 (7.9%)
5.1 to 8.1	552 (20.4%)	233 (15.1%)	195 (20.4%)	63 (14.5%)	357 (20.4%)	170 (15.3%)
8.1 to 12.3	558 (20.6%)	270 (17.5%)	197 (20.6%)	72 (16.6%)	361 (20.6%)	198 (17.8%)
12.3 to 19.6	515 (19.0%)	365 (23.6%)	160 (16.8%)	74 (17.0%)	355 (20.3%)	291 (26.2%)
19.6 to 78.8	415 (15.3%)	566 (36.6%)	133 (13.9%)	202 (46.4%)	282 (16.1%)	364 (32.8%)

Table 4. Sources of cannabis acquisition among 18-20 year olds by retail outlet availability (2-kilometer buffer) with unadjusted and adjusted* odds ratios for their association

	Age (18-20)			
	Retail outlet not within 2-km buffer (N=954)	**Retail outlet within 2-km buffer (N=435)**	**Unadjusted OR (95% CI)**	**Adjusted OR (95% CI)**
Retail outlet	91 (9.5%)	45 (10.3%)	1.09 (0.74, 1.59)	1.13 (0.73, 1.73)
Friends	657 (68.9%)	307 (70.6%)	1.08 (0.85, 1.39)	1.01 (0.75, 1.35)
Family	197 (20.6%)	85 (19.5%)	0.93 (0.70, 1.24)	1.12 (0.80, 1.56)
Party	204 (21.4%)	89 (20.5%)	0.95 (0.71, 1.25)	1.08 (0.78, 1.51)
Gave money to someone to get it for me	355 (37.2%)	184 (42.3%)	1.24 (0.98, 1.56)	1.34 (1.02, 1.77)

* Adjusted models control for sex assigned at birth, employment status, student status, race/ethnicity, quintiles of census tract % living in poverty, and population density per square mile.

Table 5. Sources of cannabis acquisition among 21-25 year olds by retail outlet availability (2-kilometer buffer) with unadjusted and adjusted* odds ratios for their association

	Age (21-25)			
	Retail outlet not within 2-km buffer (N=1752)	**Retail outlet within 2-km buffer (N=1111)**	**Unadjusted OR (95% CI)**	**Adjusted OR (95% CI)**
Retail outlet	1414 (80.7%)	949 (85.4%)	1.40 (1.14, 1.72)	1.61 (1.28, 2.03)

Friends	605 (34.5%)	399 (35.9%)	1.06 (0.91, 1.24)	0.93 (0.78, 1.11)
Family	161 (9.2%)	77 (6.9%)	0.74 (0.55, 0.97)	0.86 (0.62, 1.18)
Party	127 (7.2%)	95 (8.6%)	1.20 (0.91, 1.58)	1.04 (0.76, 1.42)
Gave money to someone to get it for me	114 (6.5%)	44 (4.0%)	0.59 (0.41, 0.84)	0.67 (0.44, 0.99)

* Adjusted models control for sex assigned at birth, employment status, student status, race/ethnicity, quintiles of census tract % living in poverty, and population density per square mile.

Table 6. Descriptive statistics for 18-20 year olds by cannabis retail outlet availability and time

	COVID pandemic		**Pre COVID pandemic**		**Overall**	
	Retail outlet not within 2-km buffer (N=221)	**Retail outlet within 2-km buffer (N=121)**	**Retail outlet not within 2-km buffer (N=733)**	**Retail outlet within 2-km buffer (N=314)**	**Retail outlet not within 2-km buffer (N=954)**	**Retail outlet within 2-km buffer (N=435)**
Cannabis Source: Retail Outlet	22 (10.0%)	15 (12.4%)	69 (9.4%)	30 (9.6%)	91 (9.5%)	45 (10.3%)
Cannabis Source: Friends	154 (69.7%)	84 (69.4%)	503 (68.6%)	223 (71.0%)	657 (68.9%)	307 (70.6%)
Cannabis Source: Family	54 (24.4%)	22 (18.2%)	143 (19.5%)	63 (20.1%)	197 (20.6%)	85 (19.5%)
Cannabis Source: Party	42 (19.0%)	21 (17.4%)	162 (22.1%)	68 (21.7%)	204 (21.4%)	89 (20.5%)
Cannabis Source: Gave money to someone to get it for me	88 (39.8%)	45 (37.2%)	267 (36.4%)	139 (44.3%)	355 (37.2%)	184 (42.3%)

Table 7. Descriptive statistics for 21-25 year olds by cannabis retail outlet availability and time

	COVID pandemic		Pre COVID pandemic		Overall	
	Retail outlet not within 2-km buffer (N=426)	Retail outlet within 2-km buffer (N=361)	Retail outlet not within 2-km buffer (N=1326)	Retail outlet within 2-km buffer (N=750)	Retail outlet not within 2-km buffer (N=1752)	Retail outlet within 2-km buffer (N=1111)
Cannabis Source: Retail Outlet	373 (87.6%)	324 (89.8%)	1041 (78.5%)	625 (83.3%)	1414 (80.7%)	949 (85.4%)
Cannabis Source: Friends	88 (20.7%)	110 (30.5%)	517 (39.0%)	289 (38.5%)	605 (34.5%)	399 (35.9%)
Cannabis Source: Family	40 (9.4%)	25 (6.9%)	121 (9.1%)	52 (6.9%)	161 (9.2%)	77 (6.9%)
Cannabis Source: Party	19 (4.5%)	23 (6.4%)	108 (8.1%)	72 (9.6%)	127 (7.2%)	95 (8.6%)
Cannabis Source: Gave money to someone to get it for me	19 (4.5%)	18 (5.0%)	95 (7.2%)	26 (3.5%)	114 (6.5%)	44 (4.0%)

Table 8. Odds ratios for the association between cannabis retail outlet availability (2-km buffer) and sources of cannabis acquisition stratified by age and time, adjusted for covariates*

	Age (18-20)	Age (21-25)
	OR (95% CI)	OR (95% CI)
Source: Retail outlet		
Pre COVID pandemic	1.07 (0.63, 1.77)	1.54 (1.19, 2.00)

COVID pandemic	1.28 (0.53, 3.12)	1.26 (0.75, 2.12)
Source: Friends		
Pre COVID pandemic	1.07 (0.76, 1.51)	0.90 (0.73, 1.11)
COVID pandemic	0.80 (0.44, 1.46)	1.49 (1.02, 2.19)
Source: Family		
Pre COVID pandemic	1.25 (0.83, 1.86)	0.90 (0.61, 1.32)
COVID pandemic	0.86 (0.44, 1.67)	0.76 (0.41, 1.39)
Source: Party		
Pre COVID pandemic	1.18 (0.80, 1.73)	1.06 (0.75, 1.50)
COVID pandemic	0.74 (0.35, 1.51)	1.81 (0.85, 3.95)
Source: Gave money to someone to get it for me		
Pre COVID pandemic	1.51 (1.09, 2.10)	0.49 (0.30, 0.80)
COVID pandemic	0.84 (0.48, 1.46)	2.05 (0.89, 4.80)

* Adjusted models control for sex assigned at birth, employment status, student status, race/ethnicity, quintiles of census tract % living in poverty, and population density per square mile.

Appendix: Descriptive statistics and analyses using a 1-kilometer road network buffer

Appendix Table A. Descriptive statistics by age and cannabis retail outlet availability (1-kilometer buffer)

	Total	Ages 18-20	Ages 21-25

	Retail outlet not within 1-km buffer (N=3652)	Retail outlet within 1-km buffer (N=600)	Retail outlet not within 1-km buffer (N=1226)	Retail outlet within 1-km buffer (N=163)	Retail outlet not within 1-km buffer (N=2426)	Retail outlet within 1-km buffer (N=437)
Sex						
Female	1142 (31.3%)	158 (26.3%)	384 (31.3%)	38 (23.3%)	758 (31.2%)	120 (27.5%)
Male	2510 (68.7%)	442 (73.7%)	842 (68.7%)	125 (76.7%)	1668 (68.8%)	317 (72.5%)
Full-time Employment Status (40+hours/week)						
Not employed full time	2320 (63.5%)	359 (59.8%)	990 (80.8%)	135 (82.8%)	1330 (54.8%)	224 (51.3%)
Employed full time	1304 (35.7%)	239 (39.8%)	220 (17.9%)	27 (16.6%)	1084 (44.7%)	212 (48.5%)
Missing	28 (0.8%)	2 (0.3%)	16 (1.3%)	1 (0.6%)	12 (0.5%)	1 (0.2%)
Student Status						
Not currently a student	1926 (52.7%)	323 (53.8%)	354 (28.9%)	37 (22.7%)	1572 (64.8%)	286 (65.4%)
Currently a student	1726 (47.3%)	277 (46.2%)	872 (71.1%)	126 (77.3%)	854 (35.2%)	151 (34.6%)
Race/Ethnicity						
White (non-Hispanic)	2345 (64.2%)	382 (63.7%)	747 (60.9%)	98 (60.1%)	1598 (65.9%)	284 (65.0%)
Asian (non-Hispanic)	246 (6.7%)	62 (10.3%)	82 (6.7%)	17 (10.4%)	164 (6.8%)	45 (10.3%)
Hispanic (any race)	583 (16.0%)	82 (13.7%)	235 (19.2%)	25 (15.3%)	348 (14.3%)	57 (13.0%)
Other race (non-Hispanic)	478 (13.1%)	74 (12.3%)	162 (13.2%)	23 (14.1%)	316 (13.0%)	51 (11.7%)
Survey Year						
2015	443 (12.1%)	22 (3.7%)	157 (12.8%)	5 (3.1%)	286 (11.8%)	17 (3.9%)
2016	572 (15.7%)	53 (8.8%)	169 (13.8%)	11 (6.7%)	403 (16.6%)	42 (9.6%)

2017	598 (16.4%)	105 (17.5%)	210 (17.1%)	24 (14.7%)	388 (16.0%)	81 (18.5%)
2018	603 (16.5%)	129 (21.5%)	209 (17.0%)	42 (25.8%)	394 (16.2%)	87 (19.9%)
2019	513 (14.0%)	85 (14.2%)	191 (15.6%)	29 (17.8%)	322 (13.3%)	56 (12.8%)
2020	406 (11.1%)	77 (12.8%)	115 (9.4%)	17 (10.4%)	291 (12.0%)	60 (13.7%)
2021	517 (14.2%)	129 (21.5%)	175 (14.3%)	35 (21.5%)	342 (14.1%)	94 (21.5%)
Population density per square mile						
<1,000	774 (21.2%)	17 (2.8%)	270 (22.0%)	4 (2.5%)	504 (20.8%)	13 (3.0%)
1,000–2,999	729 (20.0%)	36 (6.0%)	271 (22.1%)	11 (6.7%)	458 (18.9%)	25 (5.7%)
3,000+	1980 (54.2%)	510 (85.0%)	620 (50.6%)	137 (84.0%)	1360 (56.1%)	373 (85.4%)
Missing	169 (4.6%)	37 (6.2%)	65 (5.3%)	11 (6.7%)	104 (4.3%)	26 (5.9%)
Quintiles of census tract % living in poverty						
0 to 5.1	736 (20.2%)	42 (7.0%)	286 (23.3%)	7 (4.3%)	450 (18.5%)	35 (8.0%)
5.1 to 8.1	686 (18.8%)	99 (16.5%)	236 (19.2%)	22 (13.5%)	450 (18.5%)	77 (17.6%)
8.1 to 12.3	725 (19.9%)	103 (17.2%)	247 (20.1%)	22 (13.5%)	478 (19.7%)	81 (18.5%)
12.3 to 19.6	757 (20.7%)	123 (20.5%)	214 (17.5%)	20 (12.3%)	543 (22.4%)	103 (23.6%)
19.6 to 78.8	748 (20.5%)	233 (38.8%)	243 (19.8%)	92 (56.4%)	505 (20.8%)	141 (32.3%)

Appendix Table B. Descriptive statistics for 18-20 year olds by age, cannabis retail outlet availability, and time

		COVID		**Pre-COVID**		**Overall**

	Retail outlet not within 1-km buffer (N=290)	Retail outlet within 1-km buffer (N=52)	Retail outlet not within 1-km buffer (N=936)	Retail outlet within 1-km buffer (N=111)	Retail outlet not within 1-km buffer (N=1226)	Retail outlet within 1-km buffer (N=163)
Cannabis Source: Retail Outlet	33 (11.4%)	4 (7.7%)	90 (9.6%)	9 (8.1%)	123 (10.0%)	13 (8.0%)
Cannabis Source: Friends	198 (68.3%)	40 (76.9%)	638 (68.2%)	88 (79.3%)	836 (68.2%)	128 (78.5%)
Cannabis Source: Family	67 (23.1%)	9 (17.3%)	181 (19.3%)	25 (22.5%)	248 (20.2%)	34 (20.9%)
Cannabis Source: Party	54 (18.6%)	9 (17.3%)	205 (21.9%)	25 (22.5%)	259 (21.1%)	34 (20.9%)
Cannabis Source: Gave money to someone to get it for me	110 (37.9%)	23 (44.2%)	351 (37.5%)	55 (49.5%)	461 (37.6%)	78 (47.9%)

Appendix Table C. Descriptive statistics for 21-25 year olds by age, cannabis retail outlet availability, and time

	COVID		Pre-COVID		Overall	
	Retail outlet not within 1-km buffer (N=633)	Retail outlet within 1-km buffer (N=154)	Retail outlet not within 1-km buffer (N=1793)	Retail outlet within 1-km buffer (N=283)	Retail outlet not within 1-km buffer (N=2426)	Retail outlet within 1-km buffer (N=437)
Cannabis Source: Retail Outlet	558 (88.2%)	139 (90.3%)	1433 (79.9%)	233 (82.3%)	1991 (82.1%)	372 (85.1%)
Cannabis Source: Friends	148 (23.4%)	50 (32.5%)	693 (38.7%)	113 (39.9%)	841 (34.7%)	163 (37.3%)
Cannabis Source: Family	59 (9.3%)	6 (3.9%)	152 (8.5%)	21 (7.4%)	211 (8.7%)	27 (6.2%)
Cannabis Source: Party	31 (4.9%)	11 (7.1%)	154 (8.6%)	26 (9.2%)	185 (7.6%)	37 (8.5%)

Cannabis Source: Gave money to someone to get it for me	30 (4.7%)	7 (4.5%)	110 (6.1%)	11 (3.9%)	140 (5.8%)	18 (4.1%)

Appendix Table D. Sources of cannabis acquisition among 18-20 year olds by retail outlet availability (1-kilometer buffer) with unadjusted and adjusted* odds ratios for their association

	Age (18-20)			
	Retail outlet not within 1-km buffer (N=1226)	**Retail outlet within 1-km buffer (N=163)**	**Unadjusted OR (95% CI)**	**Adjusted OR (95% CI)**
Retail outlet	123 (10.0%)	13 (8.0%)	0.78 (0.41, 1.36)	0.81 (0.42, 1.48)
Friends	836 (68.2%)	128 (78.5%)	1.71 (1.16, 2.56)	1.66 (1.10 2.58)
Family	248 (20.2%)	34 (20.9%)	1.04 (0.69, 1.54)	1.27 (0.80, 1.98)
Party	259 (21.1%)	34 (20.9%)	0.98 (0.65, 1.45)	1.07 (0.678, 1.66)
Gave money to someone to get it for me	461 (37.6%)	78 (47.9%)	1.52 (1.10, 2.11)	1.64 (1.14, 2.37)

* Adjusted models control for sex assigned at birth, employment status, student status, race/ethnicity, quintiles of census tract % living in poverty, and population density per square mile.

Appendix Table E. Sources of cannabis acquisition among 21-25 year olds by retail outlet availability (1-kilometer buffer) with unadjusted and adjusted* odds ratios for their association

	Age (21-25)

	Retail outlet not within 1-km buffer (N=2426)	Retail outlet within 1-km buffer (N=437)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
Retail outlet	1991 (82.1%)	372 (85.1%)	1.25 (0.95, 1.67)	1.35 (1.00, 1.84)
Friends	841 (34.7%)	163 (37.3%)	1.12 (0.91, 1.38)	1.05 (0.84, 1.32)
Family	211 (8.7%)	27 (6.2%)	0.69 (0.45, 1.03)	0.78 (0.47, 1.17)
Party	185 (7.6%)	37 (8.5%)	1.12 (0.76, 1.60)	1.02 (0.68, 1.50)
Gave money to someone to get it for me	140 (5.8%)	18 (4.1%)	0.70 (0.41, 1.13)	0.83 (0.47, 1.39)

* Adjusted models control for sex assigned at birth, employment status, student status, race/ethnicity, quintiles of census tract % living in poverty, and population density per square mile.

Appendix Table F. Odds ratios for the association between cannabis retail outlet availability (1-km buffer) and sources of cannabis acquisition stratified by age and time, adjusted for covariates*

	Age (18-20)	Age (21-25)
	OR (95% CI)	**OR (95% CI)**
Source: Retail outlet		
Pre COVID pandemic	0.89 (0.39, 1.83)	1.25 (0.89, 1.80)
COVID pandemic	0.54 (0.14, 1.66)	1.24 (0.68, 2.39)
Source: Friends		

Pre COVID pandemic	1.83 (1.10, 3.16)	1.03 (0.78, 1.36)
COVID pandemic	1.36 (0.64, 3.03)	1.38 (0.91, 2.078)
Source: Family		
Pre COVID pandemic	1.46 (0.84, 2.48)	0.99 (0.57, 1.64)
COVID pandemic	0.95 (0.39, 2.16)	0.43 (0.16, 0.99)
Source: Party		
Pre COVID pandemic	1.16 (0.67, 1.96)	0.97 (0.60, 1.52)
COVID pandemic	0.80 (0.32, 1.86)	1.71 (0.74, 3.73)
Source: Gave money to someone to get it for me		
Pre COVID pandemic	1.68 (1.07, 2.63)	0.70 (0.33, 1.33)
COVID pandemic	1.43 (0.73, 2.82)	1.46 (0.53, 3.63)

* Adjusted models control for sex assigned at birth, employment status, student status, race/ethnicity, quintiles of census tract % living in poverty, and population density per square mile.

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