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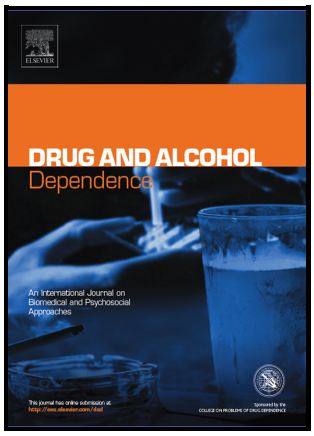

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Associations of Cannabis Product Source and Subsequent Cannabis Use among Adolescents

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ABSTRACT

Background: Cannabis is obtained from a variety retail and illicit sources, with unknown implications for youth cannabis use. This study assessed whether source of obtaining cannabis was associated with future cannabis use among adolescents.

Methods: High-schoolers (N=835) completed 3 semiannual surveys, reporting use of 7 cannabis sources (i.e., free, [online/brick-and-mortar] medical dispensary with/without valid card, bought from someone, self-grown; separate dichotomous exposure variables) at wave 1 (n=621; M[SD] age=17.14[.40]) or wave 2 (n=622; M[SD] age=17.51[.39]). Past-6-month (yes/no) and number of past-30-day (0-30) non-medical use of any cannabis product, combustible, edible, and vaporized cannabis, blunts, and concentrates (i.e., dabs) were reported at waves 2-3. Random-effect time-lagged repeated-measures regression was used to test longitudinal associations of youth's cannabis source (waves 1-2; time-varying exposure) with cannabis use outcomes 6 months later (waves 2-3).

Results: Most youth (72.1%) received cannabis for free; 50.9% bought cannabis from someone, 15.9% used a valid medical card at a brick-and-mortar dispensary, and 3.9% grew cannabis. Buying cannabis from someone (OR=1.46, 95% CI: 1.07-1.99, p=.02) or using a valid medical card (OR=1.99, 95% CI: 1.20-3.31, p=.008) conferred greater odds of any cannabis product use 6 months later. Buying from someone predicted subsequent past-30-day use frequency (RR=1.25, 95% CI:1.05-1.48, p=.01). Some associations between particular cannabis sources and products were observed.

Conclusions: Adolescents may access cannabis from several sources. Those who purchase cannabis illicitly from someone or from a brick-and-mortar dispensary using a valid medical card may be at increased risk for more persistent and frequent patterns of non-medical cannabis use.

Keywords: cannabis, adolescence, sources, product availability, medical card, dispensary

1. INTRODUCTION

Given the increase in cannabis legalization and commercialization in the United States, the sources from which people obtain cannabis products have become increasingly diversified. What was previously bought illicitly, nearly always in cannabis flower form, is now manufactured on a larger scale and available in various product types (e.g., edibles, vaporized products, concentrates [i.e., 'dabs'], etc.) across multiple formal and informal marketplaces (e.g., brick and mortar retail cannabis dispensaries, online dispensaries, etc.; Davenport and Caulkins, 2016; Rotermann, 2020). Furthermore, restrictions on non-retail means of obtaining cannabis have been legalized, including privately growing cannabis under certain restrictions (Pacula et al., 2014). The implications of increasing diversity of means to obtain cannabis products for non-medical cannabis use among adolescent is unknown. However, given the increased options of where to buy cannabis and the wider selection of available products, it is possible that youth have a greater chance of finding desirable or high-potency

products. Furthermore, some cannabis sources may afford increased ease of access. Taken together, specific cannabis sources may confer risk of greater cannabis use. This is of particular public health concern given that non-medical cannabis use among youth is associated with increased risk for altered neurocognitive development, psychiatric disorders, poor educational attainment, and cannabis use disorder (Hall and Degenhardt, 2009, 2014; Volkow et al., 2014).

Some sources of cannabis, such as purchasing cannabis from a medical dispensary, may provide a wider and more potent range of cannabis products. Evidence suggests that increased access to a greater variety of cannabis product types – including high-potency products – may be associated with increased risk of cannabis use initiation, use of a greater variety of cannabis products, and perpetuation of adolescent cannabis use and associated health sequelae (Arterberry et al., 2019; ElSohly et al., 2016). Furthermore, where youth obtain cannabis may also be linked to the variety of cannabis product types adolescents use, an important consideration given that some products are higher in potency and may pose unique risks to users, including greater frequency of use (Borodovsky et al., 2017; Hines et al., 2020; Spindle et al., 2019). Cannabis retail dispensaries, often located close to schools, sell cannabis products or feature advertisements that appeal to youth, and have been demonstrated to make sales without requiring age verification (Cao et al., 2020). Thus, it is possible that obtaining cannabis from medical dispensaries, or through other means that offer a greater variety of products, might be associated with differential cannabis products and use patterns, given that youth may use products with greater potency or may have selected specific products that suit their preferences. However, there is little evidence addressing these questions, particularly among adolescent populations.

Additionally, some sources of procuring cannabis may allow for more consistent access to cannabis products which may be associated with more frequent cannabis use. In a cross-sectional study of young adult cannabis users, obtaining cannabis from a recreational retailer and from family or friends were the most prevalent sources of cannabis, while accessing cannabis from a medical dispensary or dealer were less common, though still of appreciable prevalence (D'Amico et al., 2020). Those who obtained cannabis from dispensaries and retailers (vs. those obtaining it from friends or family) reported using greater amounts of cannabis, more product types (e.g., dabs, pipes, vape), and other consequences (e.g., missing school/work, getting into trouble)

due to their cannabis use (D'Amico et al., 2020). Accessing cannabis through medical dispensaries and purchasing cannabis from someone may allow youth to purchase cannabis and have ongoing access to cannabis products, compared to youth who rely on seeing friends or family on an infrequent basis to obtain cannabis. Furthermore, obtaining cannabis from sources other than getting it for free from peers or family members reflects self-initiated use and would appear to be related to progression to heavier or riskier patterns of consumption (D'Amico et al., 2020).The extent to which adolescents obtain cannabis from dispensaries through legal or illegal (e.g. use of counterfeit medical cards) means and whether obtaining cannabis from such sources increases risk for future non-medical cannabis use is unknown.

In this prospective, longitudinal cohort study of adolescent cannabis users, we estimated associations of how cannabis was obtained with subsequent continuation and frequency of cannabis use for non-medical purposes. The study took place in Los Angeles, CA, USA, during 2016-2017, a context in which medical cannabis had been legal for 20 years, cannabis dispensaries densely populated the region (Wong and Wilens, 2017), and virtual online dispensaries were emerging that have since become increasingly numerous (DeWitt, 2020).

2. METHODS

2.1. Participants, Procedures, and Design

This study analyzes data from the Happiness and Health Study (Leventhal et al., 2015), a prospective, longitudinal cohort of adolescents who reported on their mental health and substance use. Initially, approximately 40 public high schools in the greater Los Angeles area were invited to participate in this study due to their diverse demographic characteristics. A total of 10 high schools agreed to participate in the longitudinal study. Nineth graders were approached to participate in the study and were enrolled in the study when written or verbal assent and parental consent were obtained. Participants were surveyed once every 6 months from 9^{th} – 12^{th} grade during 2013-2017. A total of 4100 students were eligible to participate in the study, and 3396 (82.8%) students were enrolled in the cohort. Paper surveys were completed on site for students

in attendance. Students not in attendance were provided abbreviated web or phone surveys that omitted the cannabis source items.

Because source of cannabis was not measured until Spring 2016 (11th grade), this study includes data obtained at three time points: Spring 11th grade (labeled wave 1 for the purposes of this study), Fall 12th grade (wave 2), and the final high school survey that was administered during Spring 12th grade in 2017 (wave 3). Because of infrequent exposures to accessing certain cannabis sources, a time-lagged repeated measures design was used, which included time-varying exposure data at both waves 1 and 2 and outcome data during waves 2 and 3 that were collected 6-months after the respective exposure assessments. Individual students could contribute either one or two exposure-outcome wave pairings for these analyses: the wave 1 exposure-wave 2 outcome pair and/or the wave 2 exposure-wave 3 outcome pair. The analytic sample included students who reported: (a) past 6-month use of any cannabis product and identified at least one cannabis supply source at either exposure wave; and (b) completed cannabis use outcome measures at the subsequent corresponding outcome wave. A total of 1243 exposure-outcome wave pair observations were included in the current analyses, representing 835 unique students (See Figure 1).

2.2. Ethics Statement

This study was approved by the University of Southern California Institutional Review Board. Written or verbal parental consent and written student assent was obtained prior to data collection.

2.3. Measures

2.3.1. Cannabis Product Supply Sources

At each data collection wave, participants completed a survey item asking, "Where do you usually get marijuana?," and responses were made on a checklist of seven different sources with instructions to check all that apply (self-grown, free/from a friend, bought from someone, bought at a store with a real medical marijuana card, bought at a store with a fake card, online dispensary, other). Responses were coded as seven separate dichotomous cannabis source exposure variables (yes/no). Number of cannabis sources was also calculated as a dichotomous variable (1 source vs. ≥2 sources).

2.3.2. Non-Medical Use of Cannabis Products

At each wave, participants self-reported non-medical use (described as use without a provider's prescription, or for the purpose of getting high) of 5 different cannabis products (combustible [smoking cannabis flower by itself], edible [THC-infused foods or beverages], vaporized [inhaling THC products in a vaporizer], blunts [smoking cannabis flower rolled in a tobacco cigar casing], or dabs [cannabis concentrates made with butane hash oil]) was assessed as in past work (Barrington-Trimis et al., 2020). For each cannabis product, participants completed past-6-month use status (any use; yes/no) and past-30-day use frequency (number of days used; range: 0-30) survey items, which served as dependent variables at outcome waves. Two 'any cannabis' composite variables were generated, serving as primary outcomes in this study. Any cannabis product use continuation was coded "yes" if youth reported "yes" to using any of the 5 cannabis products in the past 6 months (any use; yes/no). The past-30-day any cannabis frequency variable was coded based on the maximum number of days a participant reported using any one of the 5 cannabis products in the past 30 days (e.g., if a participant used combustibles on 5 days, edibles on 7 days, and no other products during the past 30 days, their any cannabis frequency variable was coded "7"). Responses to each 5 specific cannabis products were supplemental outcomes of interest.

2.3.3. Covariates

To distinguish associations from sociodemographic variation, we included time-invariant covariates of self-reported gender (male/female), race/ethnicity (Hispanic, Asian, white, other) and the time-varying covariates of eligibility for subsidized lunch (free lunch, reduced cost, no subsidized lunch, don't know or missing; a proxy for family socioeconomic status), number of friends using cannabis, (0-5+ friends, or missing), and school attended. We also included the time-varying covariate of exposure timepoint (wave 1 vs. 2) to account for historical or developmental variation.

2.4. Statistical Analysis

We first calculated descriptive statistics of sample characteristics and cannabis use outcomes stratified by positive vs. negative statuses for each of the 7 cannabis source binary exposure variables. The primary analysis used random-effect repeated-measures regression models to test associations of cannabis source at the

exposure wave (as a time-varying and time-lagged regressor) with cannabis use at the immediately subsequent 6-month outcome wave. For each of the five cannabis products and the any cannabis use composite variable outcomes, two model sets were run: models with past-6-month use status (yes/no; modeled with binary logit link distributions) as the dependent variable and models with past-30-day use frequency (number of days used; negative binomial count distribution) as the dependent variable. For each outcome, the 7 cannabis source variables were tested in separate models that included a single cannabis source binary exposure regressor variable. A supplemental analysis of number of cannabis sources (1 vs. ≥2 sources) was also examined as a dichotomous exposure variable. Models were adjusted for all covariates indicated above and included a random effect of participant ID. To examine prospective changes in cannabis use from the exposure waves to the outcome waves, a time-varying covariate for previous, specific product use was included in each model. For example, in the model predicting frequency of past 30-day edible use, we included a time-varying covariate for past 30-day edible use frequency at the exposure wave (measured 6 months before the respective outcome). Past 6 month use of cannabis in any form at the exposure waves was required for analytic sample inclusion (see above) and therefore not adjusted for. To determine the incremental predictive value of accessing cannabis through each of the different sources, each dependent variable was retested in an exploratory multivariable model that included all 7 cannabis source exposure variables as simultaneous regressors. Complete data were available for composite any cannabis use past-6 month (n=1243 observations) and past 30-day use (n=1241 observations). Missing data for specific cannabis product type outcomes were rare for past-6-month (ns=1217-1234) and past 30-day (ns=1208-1234) models and were managed with listwise deletion. Odds ratios (ORs) and rate ratios (RRs) with 95% confidence intervals (CIs) were calculated and reported. SAS 9.4 (Institute., 2017) was used to conduct analyses. Benjamini-Hochberg multiple testing corrections were applied to control for study-wide false-discovery rates at 0.05 (Benjamini and Hochberg, 1995).

3. RESULTS

3.1. Descriptive Analyses

A total of 835 participants contributed 1243 exposure-outcome observation pairs (observation M_{age}=17.33, SD=.43) to the analytic sample with 213 students providing only wave 1-wave 2 observations, 214 students providing only wave 2-wave 3 observation pairs, and 408 students providing data at both pairings. The sample was demographically diverse regarding gender (56.4% female), ethnicity (51.6% Hispanic, 18.4% Caucasian, 13.6% Asian, and 16.4% multiracial/other), and socioeconomic status (47.6% of observation pairs received free or reduced school lunches due to low family income and 31.0% reported highest parental education was a high school diploma or less; see Table 1). Among the students included in these analyses, a substantial majority reported previous use of alcohol (89.6%), tobacco (71.1%), and e-cigarettes (71.6%). Most observation pairs reported one or more friends who use cannabis (88.6%; see Table 1). Pooled across both exposure waves, participants reported the most common source of cannabis was getting it for free (72.1%); 50.9% of adolescents bought cannabis from someone and 15.9% reported acquiring cannabis with a valid medical card. The other sources had prevalences $\leq$ %3.9 in the sample (i.e., self-grown, bought at a store with a fake card, online dispensary, other). Table 2 reports wave-by-wave frequencies of cannabis supply sources.

3.2. Prospective associations between source of cannabis supply and subsequent non-medical cannabis use

3.2.1. Past-6-month Cannabis Use Status Outcomes

Figure 2 reports descriptive results of past 6-month cannabis use outcomes (percentage of observations reporting cannabis product use), by specific supply sources at exposure wave. Table 3 reports covariate-adjusted longitudinal regression modeling results. Youths who did (vs. did not) report buying cannabis from someone were at greater odds of any past-6-month use of any cannabis product 6 months later (83.3% vs. 76.2%, Adjusted-OR=1.46, 95% CI: 1.07-1.99, p=.02), and use of some specific cannabis products: combustible and vaporized cannabis (vaping), edibles, and blunts. Similarly, using a valid medical marijuana card was also significantly associated with greater odds of any past-6-month cannabis use (88.9% vs. 78.1%, Adjusted-OR=1.99, 95% CI: 1.20-3.31, p=.008) and with some specific cannabis products: combustible and vaporized cannabis, edibles, and dabs. Reporting other sources of cannabis acquisition was significantly associated with

greater odds of past-6-month use of vaporized cannabis (80.0% vs. 34.1%, Adjusted-OR=4.68, 95% CI: 1.83-11.99, p=.001). Conversely, obtaining cannabis from friends or for free was associated with significantly lower odds of any past-6-month use of dabs (26.6% vs. 40.0%, Adjusted-OR=0.64, 95% CI: 0.46-0.88, p=.006). When all sources of cannabis products were entered into the model simultaneously to adjust for the covariance between accessing multiple sources, these associations remained significant, except for the association between obtaining cannabis from friends/for free and reduced odds of dabbing (see Supplemental Table 1). Sources of cannabis products not associated with past 6-month cannabis use outcomes included self-growing cannabis, purchasing it with a counterfeit medical card, or buying cannabis from an online dispensary. Supplemental analyses of number of cannabis sources with past-6-month cannabis use are reported in Supplemental Table 3. Considering any cannabis product use, number of sources was associated with greater odds of use, such that reporting ≥2 sources (vs. 1 source) was associated with 1.73 (CI: 1.24-2.42, p=.001) times the odds of past-6-month cannabis use. Obtaining cannabis from more than one source was significantly associated with use of all cannabis products.

3.2.2. Frequency of Past-30-day Cannabis Use Outcomes

Figure 3 illustrates the descriptive results of past 30-day cannabis use frequency at the 6-month follow-up outcomes by cannabis supply sources. Table 4 reports regression modeling results, considering the dependent variables of past-30-day cannabis use. Buying cannabis from someone was significantly associated with a greater number of past-month days of using any cannabis product (mean: 7.6 [SE 0.4] vs 5.1 [SE 0.4]; RR=1.25, 95% CI=1.05-1.48, p=.01) and of specific products including combustible cannabis, blunts, and dabs. Additionally, youth who did vs. did not report self-growing cannabis reported 2.35 times greater number of days of edible cannabis use in the past 30 days, 6 months later (means: 6.0 [SE 1.5] vs 2.0 [SE 0.2]; RR=2.35, 95% CI=1.09-5.09, p=.03). Buying cannabis with a real medical marijuana card was associated with a greater number of past-30 days of using several specific cannabis products: vaping cannabis (mean: 4.4 [SE 0.6] vs 1.6 [SE 0.1]; RR=1.77, 95% CI=1.06-2.95, p=.03), edibles (mean: 4.7 [SE 0.6] vs 1.7 [SE 0.2]; RR=1.71, 95% CI=1.12-2.59, p=.01), and dabs (mean: 4.2 [SE 0.6] vs 1.1 [SE 0.1]; RR=2.89, 95% CI=1.67-5.01, p<.001). Obtaining cannabis from "other" sources was associated with a greater number of days of using dabs in the past

30 days (mean: 13.3 [SE 2.2] vs 6.2 [SE 0.3]; RR=4.49, 95% CI=1.45-13.92, p=.009). These associations all remained significant in the multivariable models including all 7 sources as simultaneous regressors except for the association between self-growing cannabis and greater number of days using edibles (see Supplemental Table 2). Among this sample of cannabis users, obtaining cannabis for free or from a friend was associated with lower odds of past 30-day use of vaporized or edible cannabis and dabs. Using a counterfeit medical card to purchase cannabis, and buying cannabis through an online dispensary were not associated with past-30-day cannabis use. Supplemental analyses of total number of cannabis sources with past-30-day cannabis use are reported in Supplemental Table 3. Considering any cannabis product use, obtaining cannabis through more than one source (vs. 1 source) was associated with a greater number of days of use (mean: 8.4 [SE 0.5] vs. 5.1 [SE 0.3]; RR=1.38, CI: 1.16-1.64, p=.003). Obtaining cannabis from more than one source was significantly associated with greater number of days of all cannabis product use.

4. DISCUSSION

In this prospective study of adolescents, youth obtained cannabis from a variety of sources. Where and how adolescents obtain cannabis was related to their patterns of non-medical cannabis use six months later. As the first prospective longitudinal study on this topic among adolescents, this study moves the field forward in several ways.

The current findings provide new evidence about the sources that teen cannabis users might access to obtain products. Acquiring cannabis for free, which likely reflected sharing with or receiving cannabis from peers, family members, or other free alternatives, was the most frequently reported source (72.5%), consistent with past research among young adults (D'Amico et al., 2020). Lower but appreciable percentages of youth reported buying cannabis from someone (50.9%), purchasing it from a dispensary with a valid medical cannabis authorization (15.9%; typically requiring caregiver permission and a physician's prescription for minors in many U.S. states; Pedersen et al., 2018), and growing their own cannabis (3.9%). This is the first study to examine adolescent use of online dispensaries and instances of youth obtaining cannabis at brick-and-mortar dispensaries using counterfeit medical cards, both of which were of low prevalence. Online-only dispensaries

are common in several U.S. states and Canadian providences, and the number and activity of virtual cannabis dispensaries and other online purchasing options appears to be increasing during the COVID-19 pandemic (Mahamad and Hammond, 2019; Matthay and Schmidt, 2020). Given the possibility that verification of age or caregiver permission and physician prescription might be less rigorous with online dispensaries, youth use of online dispensaries and counterfeit medical cards merit further surveillance.

There are a few considerations for why adolescents' cannabis source may be associated with cannabis use continuation and frequency of use. First, obtaining cannabis from some sources denotes self-initiated cannabis use, which appears to be related to progression to heavier or problematic patterns of consumption (D'Amico et al., 2020). Second, procuring cannabis in some settings (e.g., medical dispensary) may provide youth with a wider range of products (e.g., alternative cannabis products including edibles, concentrates, etc.) which affords the opportunity to identify preferred products and high-potency cannabis for on-going use (Borodovsky and Budney, 2017; Borodovsky et al., 2016). Third, some cannabis sources may allow for more frequent access to cannabis products (e.g., if they have procured larger amounts of cannabis for future use) rather than incidental use when in a peer settings.

The overall pattern of results in this study indicate that youth who bought cannabis (i.e., purchased from someone illicitly, used a medical card to buy) generally reported greater subsequent frequency and continuation of use. This observation supports and extends prior cross-sectional studies that found positive relationships between purchasing cannabis and greater frequency of use (D'Amico et al., 2020; King et al., 2016; Lankenau et al., 2019). Purchasing cannabis can be considered an important marker of increased likelihood of future cannabis use. Purchasing cannabis from sources rather than getting it for free from peers or family members reflects self-initiated use and investment that likely extends beyond occasional use (Akre et al., 2010). Furthermore, youth who obtain cannabis in these self-initiated ways may have more consistent access to cannabis products and access to a wider variety of products (e.g., alternative cannabis products including edibles, high potency and concentrate products) which affords the opportunity to identify preferred products for on-going use.

Self-growing as a source of cannabis was significantly associated with past 30-day frequency of edible cannabis in this study. However, our sample only included 49 observations of youth reporting self-growing at baseline, so this finding should be interpreted cautiously. Nonetheless, self-growing cannabis also reflects self-initiated use and may also serve as a marker for current or future cannabis use. Furthermore, if youth are growing cannabis at home, and assuming that they reside with caregivers, living with a caregiver who condones or ignores substance use could be associated with additional risk for future or current substance use problems (Schuler et al., 2019).

Other cannabis sources, such as purchasing cannabis from a medical dispensary, may afford youth access to a wider range of cannabis products. The current study provides the first prospective evidence that using a valid medical authorization card to purchase cannabis may be associated with increased risk for non-medical cannabis use persistence and escalation among adolescents. Past research in adult samples shows that having a medical card, purchasing cannabis from a medical dispensary, or even reporting use of cannabis for medical reasons is associated with more frequent consumption and use disorder (Boyd et al., 2015; D'Amico et al., 2020; Lankenau et al., 2019; Pedersen et al., 2019; Tucker et al., 2019; Wardell et al., 2021). Whether or not youth with medical authorization use cannabis for perceived therapeutic benefit, the great majority also use cannabis for non-medical purposes (Boyd et al., 2015; Tucker et al., 2019; Wardell et al., 2021). A recent longitudinal study of young adults observed that more frequent cannabis use predicted acquiring a medical card but having physical or mental health conditions did not (Pedersen et al., 2019). In concert with the current adolescent data, there is convergent evidence that seeking and purchasing cannabis using a medical cannabis card may be a risk factor for adverse cannabis use outcomes among young people.

There are several potential reasons why accessing cannabis using a medical authorization card might be associated with increased risk for subsequent cannabis use. Past work shows that medical cannabis laws generally, and medical cannabis dispensaries in particular, are associated with increased cannabis use and access to and use of alternative cannabis products including edibles and high potency (high dose THC) cannabis flower and concentrate products (i.e., dabs; Borodovsky and Budney, 2017; Borodovsky et al., 2016; Borodovsky et al., 2017; Shih et al., 2019; Spindle et al., 2019). Thus, it is possible that the current findings

indicate that cannabis dispensaries may provide adolescents access to a greater variety of these non-traditional or higher-potency products that might be particularly appealing and addictive to youth and therefore might increase risk of frequent and persistent cannabis use patterns. Because youth might perceive vaping to be a safer alternative to smoking (at least prior to the EVALI crisis; Manzione et al., 2020; Park et al., 2019), a more discreet way to use cannabis (Pokhrel et al., 2015), and a highly efficient method of THC delivery to the brain (Morean et al., 2015), vaping may increase use escalation. Edibles pose a unique risk because they can inadvertently lead to intake of dangerously high levels of THC because of their delayed onset of effects and their highly palatable delivery vehicles (i.e., cookies, sodas, chocolate bars, candy). This palatable method of use may also facilitate more persistent use patterns (Barrington-Trimis et al., 2020). Dabs (cannabis concentrates that are vaped or smoked) are the highest potency products available, and as such, confer increased risk for escalating use and high levels of intoxication, development of cannabis use disorder, and psychosis (Budney and Borodovsky, 2017; Loflin and Earleywine, 2014; Sideli et al., 2020). Purchasing at brick-and-mortar dispensaries and using a medical card to purchase were consistent predictors of both higher prevalence and frequency of dabbing, raising the possibility that youth access to cannabis concentrates at brick-and-mortar dispensaries may be detrimental to the pediatric population.

Supplemental analyses also considered whether obtaining cannabis from a greater diversity of sources is associated with different cannabis use patterns. Overall, our data indicate that obtaining cannabis from more than one source confers greater risk of cannabis use continuation and of frequency of use. Having multiple cannabis sources likely denotes a combination of self-initiated use, more consistent access to cannabis products, and access to a wider variety of products (e.g., alternative cannabis products including edibles, high potency and concentrate products) as described above, all of which likely confer risk of ongoing cannabis use.

Conversely, obtaining cannabis for free predicted lower probability of any past-6-month and frequency of past-30-day use of dabs, though was not statistically significantly associated with reduced odds of other cannabis products in adjusted models. This finding is somewhat consistent with a prior cross-sectional study that observed associations between getting cannabis from family or friends and reduced cannabis use severity among samples that are already using cannabis (D'Amico et al., 2020). That said, we caution against

considering this as a "safety factor" because it may identify youths who have yet to progress to more frequent risky patterns of use. As such, obtaining cannabis for free may provide a marker for alternative tailored prevention approaches that differ from prevention or intervention approaches designed for those who have begun to self-initiate cannabis procurement and use.

While there may indeed be a direct link between cannabis source and subsequent use, other explanations are possible because of the observational design. It is possible that risk factors for cannabis use (i.e., family history of substance use problems, low socioeconomic status, poor educational performance, peer use, other substance use externalizing symptoms, and conduct problems/delinquent behavior; Daniel et al., 2009; Defoe et al., 2019; Schuler et al., 2019) might also increase the propensity to seek out certain sources of cannabis. For instance, because socioeconomically disadvantaged neighborhoods might have less restrictive cannabis dispensary regulations (Morrison et al., 2014), it is possible that youth with lower socioeconomic status, which is an established risk factor for cannabis use (Daniel et al., 2009), might be more likely to access cannabis dispensaries. While we adjusted for demographic characteristics which could address some shared risk factors, a number of other unmeasured factors might contribute to the association. For associations with medical cannabis cards specifically, more frequent cannabis use proceeds acquisition of medical authorization (Pedersen et al., 2019) and it is possible that reverse causality explains some of the relations of purchasing cannabis from a dispensary with a medical card with subsequent cannabis use found in this study. However, the prospective longitudinal design and statistical adjustment of the presence and frequency of cannabis use at the time of exposure reduces the influence of reverse causal pathways on the current finding. The study methodology was designed to primarily identify statistical associations and is not well-suited to make rigorous causal inferences.

This study also had some limitations. First, data were self-reported and thus subjected to recall and social desirability biases. Additionally, while the sample was demographically diverse, it is not a representative sample, thus the findings should be generalized to other populations with caution. Future research aimed at extending these findings to different geographic regions and age ranges is warranted. Furthermore, youth reported on their substance use behaviors in a school-based data collection and thus may have underreported their use given the academic setting in which data were collected. We did not assess frequency with which

youth accessed cannabis from different sources, instead relying on a dichotomous (yes/no) predictor variable. Similarly, we did not have specific data on additional sources of cannabis, such as buying online/on an app that is not associated with an online dispensary. Future research should examine a wider range of cannabis sources and whether there are graded associations between the frequency with which youth access cannabis from a specific source and subsequent cannabis use. Finally, we did not assess adverse consequences of cannabis use or risks associated with use. Therefore, the current study does not provide insight regarding the impact of cannabis use sources on risk outcomes. Nonetheless, the current study expands and adds support to prior studies linking source of procurement and cannabis use frequency, and as such these observations should inform screening and prevention strategies and shape regulatory processes to better mitigate cannabis consumption among youth.

5. CONCLUSION

The results of this study highlight that an appreciable portion of adolescents who use cannabis for non-medical purposes accessed cannabis from medical dispensaries or purchased cannabis by other means. Adolescents who purchased cannabis, using a medical card or through other avenues, reported greater odds and frequency of subsequent cannabis use, including use of high-potency products. While these findings may not support strong causal inferences, they have implications worthy of consideration for policy. Namely, regulations might consider the potential for adverse effects of making certain cannabis products available to adolescents. For example, most U.S. states with legal medical cannabis laws stipulate a minimum age of only 18 years, in contrast to commercial cannabis laws that restrict purchase and possession to those 21 years and older and disregarding the well-accepted age safeguard commonly implemented to mitigate the potential developmental impact of cannabis use and misuse among youth and young adults (Jacobus et al., 2019; Volkow et al., 2014; Volkow et al., 2016). Designing a regulatory system that decreases adolescent access to cannabis products rather than making these products more available would seem prudent. Given the health risks associated with frequent cannabis use – and in particular to risky, high potency products – among adolescents (Arterberry et al., 2019; Hall and Degenhardt, 2009, 2014; Volkow et al., 2014), regulatory policies to limit adolescents' access to risky cannabis products may improve adolescent public health.

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Figure Titles and Legends

Figure 1. Participant Flow Chart

Figure 2. Prevalence of Past 6 Month Cannabis Use by Source of Cannabis Supply

Note. Graphs represent the percent of participants who reported past 6-month cannabis product use, by product. Columns indicate whether specific cannabis source was reported (gray= no; did not report obtaining cannabis using the specific source; black= yes; did report obtaining cannabis using the source indicated). Error bars denote standard error.

Figure 3. Mean Frequency of Past 30-Day Cannabis Use by Source of Cannabis Supply

Note. Graphs represent the mean number of days participants reported using cannabis products, by product, over the past 30 days. Columns indicate whether specific cannabis source was reported (gray= no; did not report obtaining cannabis using the specific source; black= yes; did report obtaining cannabis using the source indicated). Error bars denote standard error of the mean

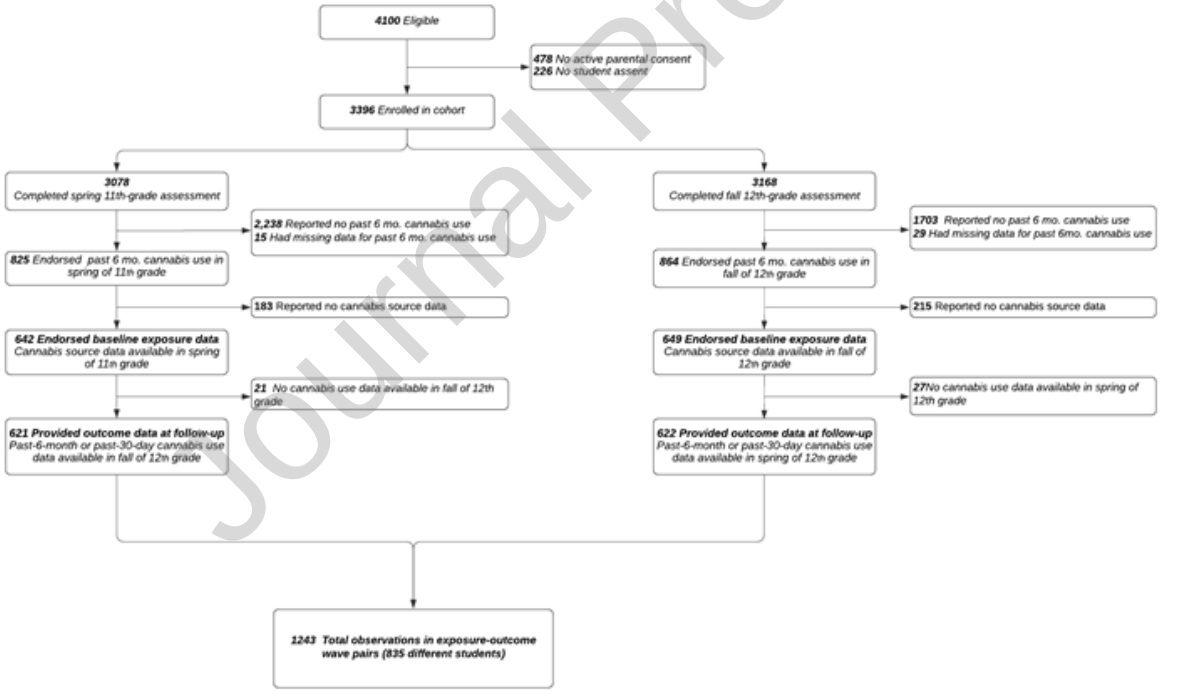

Fig 1

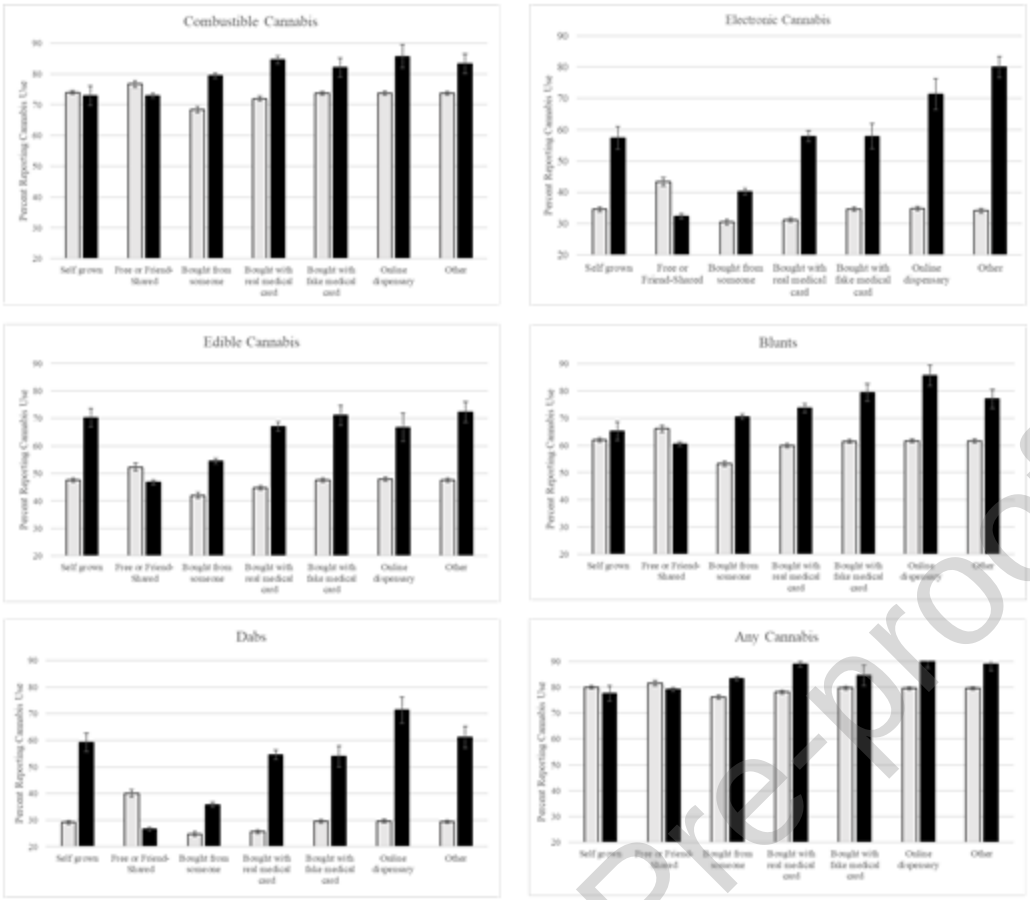

Fig 2

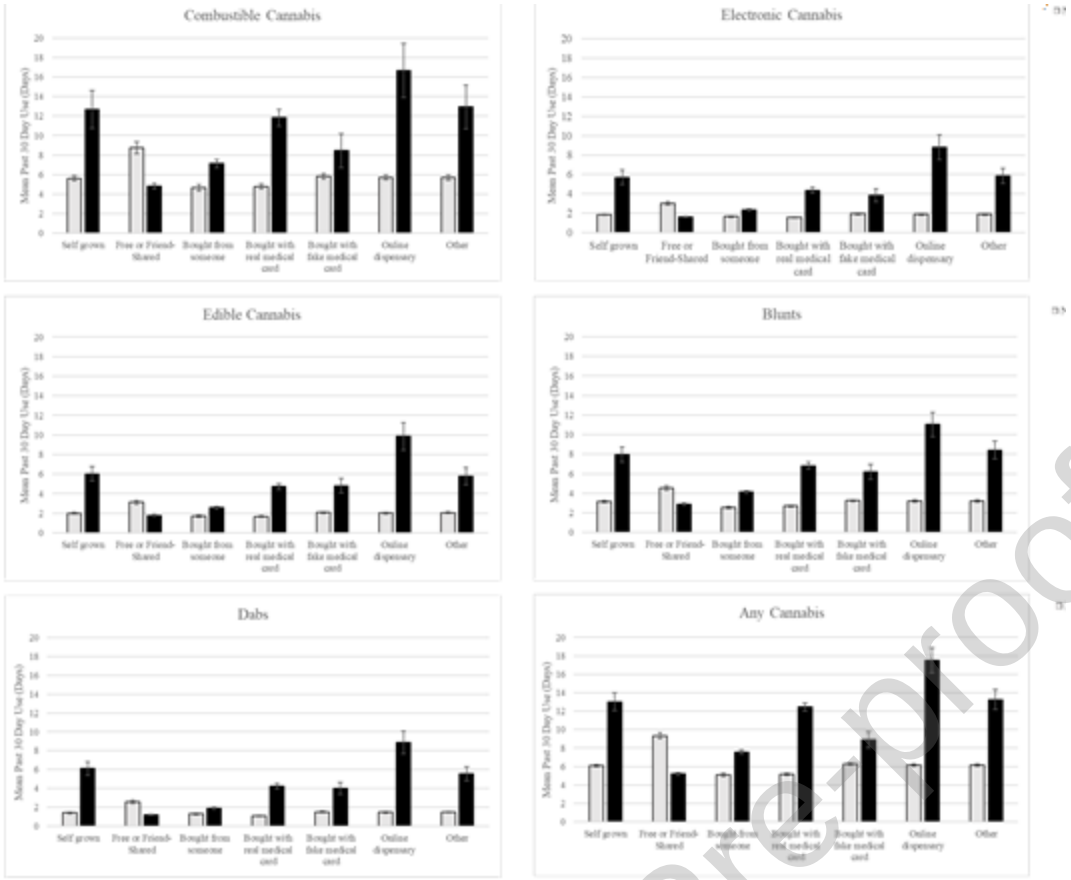

Fig 3

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Contributors
Ms. Kelleghan conceptualized the study, conducted the analyses, drafted the initial manuscript, and reviewed and revised the manuscript; Dr. Leventhal conceptualized and designed the study, acquired funding, coordinated and supervised data collection, and reviewed and revised the manuscript; Drs. Sofis and Budney provided important feedback regarding study conceptualization, drafted portions of the initial manuscript, and contributed to reviewing and revising the paper. Dr. Ceasar critically reviewed the manuscript for important intellectual content; all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Conflict of Interest
No conflict declared.

Table 1. Sample Demographics and Descriptive Statistics

Variable	Result n (%)	Available No.[a]
Time-invariant covariates & descriptive variables[b] (total students: n=835)		
Gender		828
Female	467 (56.4)	
Male	361 (43.6)	
Race and/or ethnicity		810
Hispanic	418 (51.6)	
White	149 (18.4)	
Asian	110 (13.6)	
Other/Multiracial	133 (16.4)	
Highest Parental Education		739
Some high school or less	99 (13.4)	
High school diploma	130 (17.6)	
Some college	164 (22.2)	
College diploma	234 (31.7)	
Advanced degree	112 (15.2)	
Other Substance Use at Baseline[c]		
Alcohol[d]	723 (89.6)	807
Tobacco[e]	576 (71.1)	810
Electronic cigarette with nicotine	577 (71.6)	806
Time-varying covariates at exposure wave[f] (total observations: n=1243)		
Subsidized Lunch		1243
No	574 (46.2)	
Reduced	111 (8.9)	
Free	481 (38.7)	
Don't know/missing	77 (6.2)	
Number of Friends Using Cannabis		1206
0 Friends	137 (11.4)	
1 Friend	119 (9.9)	
2 Friends	182 (15.1)	
3 Friends	215 (17.8)	
4 Friends	137 (11.4)	
5+ Friends	416 (34.5)	

[a] The number of observations with (nonmissing) data available for the respective variable and denominators for percentages reported for categorical variables.
[b] Time-invariant covariates measured at first wave of study participation.
[c] Refers to participants' report of ever consuming each substance in their lifetime, as reported at study baseline.
[d] Reported consumption of at least one full drink of alcohol (can of beer, glass of wine, wine cooler, or shot of liquor).
[e] Reported consumption of tobacco products (cigarettes, smokeless tobacco, big and little cigars, cigarillos, hookah), but not including e-cigarettes or blunts.
[f] Time-varying covariates measured at each exposure wave.

[g] Participants reported on where they get their cannabis products and were able to indicate any number of sources, thus percentages for these categories total more than 100, as each binary variable was non-exclusive.

Table 2. Prevalence of Cannabis Supply Source at Each Exposure Wave

Cannabis Source	Exposure Wave: Wave 1 (n=621) No. Students, %[a]	Exposure Wave: Wave 2 (n=622) No. Students, %[a]	Pooled across Waves 1 & 2 (N=1243) No. Observations, %[b]
Self-grown	27 (4.4)	22 (3.5)	49 (3.9)
Free/Shared by a friend	440 (70.9)	456 (73.3)	896 (72.1)
Bought from someone	312 (50.2)	321 (51.6)	633 (50.9)
Bought using a medical card	92 (14.8)	106 (17.0)	198 (15.9)
Bought using a fake card	22 (3.5)	17 (2.7)	39 (3.1)
Bought from an online dispensary	12 (1.9)	9 (1.5)	21 (1.7)
Other	18 (2.9)	18 (2.9)	36 (2.9)
Number of Sources			
1	400 (64.4)	376 (60.5)	776 (62.4)
≥2	221 (35.6)	246 (39.6)	467 (37.6)

Note: Students were instructed to select all cannabis supply sources that apply. Each cannabis source (row) is not mutually exclusive, except for the Number of Sources variable.

[a] Denominators for percent values reflect the total number of students at each respective wave; because students can report more than one supply source, percentages total >100% for the column.
[b] Denominator for percent values reflect the total number of exposure wave observations; because students can report more than one supply source, percentages total >100% for the column.

Table 3. Association between Source of Cannabis and Subsequent Past 6 Month Cannabis Use Status 6 months later[a]

	Association estimates, Odds Ratios (95% CI)					
	Combustible Cannabis	Vaporized Cannabis	Edible Cannabis	Blunts	Dabs	Any Cannabis Product[b,c]
Cannabis source (yes vs. no)						
Self-grown	0.85 (0.41-1.76)	1.48 (0.74-2.95)	1.79 (0.89-3.58)	0.80 (0.41-1.56)	1.31 (0.65-2.64)	0.83 (0.39-1.80)
Free/Shared by a friend	0.91 (0.66-1.26)	0.74 (0.55-1.00)	0.90 (0.68-1.19)	0.81 (0.60-1.09)	0.64 (0.46-0.88)[†]	0.88 (0.62-1.25)
Bought from someone	1.55 (1.16-2.07)[†]	1.47 (1.12-1.94)[†]	1.43 (1.11-1.85)[†]	1.68 (1.28-2.19)[†]	1.26 (0.94-1.70)	1.46 (1.07-1.99)
Bought using a medical card	1.64 (1.04-2.58)	2.15 (1.49-3.09)[†]	1.76 (1.23-2.53)[†]	1.33 (0.90-1.96)	1.88 (1.28-2.76)[†]	1.99 (1.20-3.31)[†]
Bought using a fake card	1.51 (0.61-3.73)	1.50 (0.71-3.17)	2.03 (0.92-4.45)	1.81 (0.75-4.34)	1.49 (0.68-3.26)	1.52 (0.58-4.02)

Bought from an online dispensary	1.86 (0.49-6.98)	2.36 (0.81-6.89)	1.35 (0.50-3.67)	3.42 (0.88-13.30)	2.24 (0.72-7.03)	2.47 (0.52-11.64)
Other	1.62 (0.62-4.25)	4.68 (1.83-11.99) †	2.43 (1.07-5.49)	1.84 (0.75-4.52)	2.17 (0.93-5.08)	2.30 (0.74-7.12)

[a.] Univariable-adjusted models predict any past-6-month cannabis product use from each cannabis source variable, including time –varying (i.e. eligibility for subsidized lunch, exposure wave, school attended, number of friends using cannabis, and cannabis use at the exposure wave) and time-invariant covariates (i.e., gender, race/ethnicity). Each variable representing a specific source of cannabis products was entered into individual models as a time-varying predictor.

[b.] Any Cannabis Product is coded dichotomously: 0= no reported past 6-month cannabis use, 1= reported use of 1 or more of the 5 cannabis product types in the past 6 months.

[c.] Considering the dependent variable any past-6-month cannabis use, use at exposure wave was not included as a covariate, as any past-6-month use at exposure wave was a study inclusion criterion for all observations.

† Statistically significant after Benjamini-Hochberg corrections for multiple testing to control the false-discovery rate at 0.05 for all estimates of cannabis source and product use.

Table 4. Association between Source of Cannabis and Subsequent Past 30-Day Cannabis Use Frequency 6-months later[a]

	Association estimates, Rate Ratios (95% CI)					
	Combustible Cannabis	Vaporized Cannabis	Edible Cannabis	Blunts	Dabs	Any Cannabis Product[b]
Cannabis source (yes vs. no)						
Self-grown	1.14 (0.73-1.79)	2.37 (0.90-6.24)	2.35 (1.09-5.09)	0.82 (0.46-1.47)	1.83 (0.68-4.94)	1.13 (0.74-1.72)
Free/Shared by a friend	0.95 (0.77-1.17)	0.63 (0.41-0.97)	0.68 (0.48-0.97)	0.95 (0.73-1.23)	0.61 (0.38-0.97)	0.90 (0.74-1.09)
Bought from someone	1.24 (1.03-1.50)	1.48 (0.98-2.24)	1.38 (0.99-1.92)	1.45 (1.14-1.85)	1.80 (1.16-2.98)	1.25 (1.05-1.48)
Bought using a medical card	1.15 (0.89-1.48)	1.77 (1.06-2.95)	1.71 (1.12-2.59)	0.95 (0.69-1.32)	2.89 (1.67-5.01) †	1.16 (0.91-1.46)
Bought using a fake medical card	1.12 (0.68-1.86)	1.30 (0.49-3.44)	1.30 (0.53-3.19)	0.79 (0.41-1.50)	2.00 (0.66-6.12)	1.01 (0.63-1.64)
Bought from an online dispensary	1.54 (0.78-3.03)	2.91 (0.73-11.61)	3.15 (0.98-10.11)	1.72 (0.74-4.02)	2.45 (0.57-10.50)	1.60 (0.86-2.98)
Other	1.13 (0.66-1.94)	1.87 (0.67-5.22)	1.82 (0.71-4.69)	1.76 (0.91-3.41)	4.49 (1.45-13.92)	1.15 (0.69-1.90)

a. Covariate-adjusted models predict past 30 day cannabis product use from each cannabis source variable including time –varying (i.e. eligibility for subsidized lunch, exposure wave, school attended, number of friends using cannabis, and cannabis use at the exposure wave) and time-invariant covariates (i.e., gender, race/ethnicity). Each variable representing a specific source of cannabis products was entered into individual models as a time-varying predictor.

b. Any Cannabis Product was coded 0-30 days based on the maximum number of days reported using one of the five product types (e.g., if a participant used combustibles on 5 days, edibles on 7 days, and no other products during the past 30 days, their any cannabis frequency variable was coded "7").

† Statistically significant after Benjamini-Hochberg corrections for multiple testing to control the false-discovery rate at 0.05 for all estimates of cannabis source and product use.

Highlights:

- Most youth using cannabis report receiving cannabis for free or buying from someone
- Using a valid medical card to buy cannabis confers greater odds of non-medical use
- Buying cannabis from someone confers greater odds of use and more frequent use