Types of Cannabis and Tobacco/Nicotine Co-Use and Associated Outcomes in Young Adulthood

Joan S. Tucker[1], **Eric R. Pedersen**[1], **Rachana Seelam**[1], **Michael S. Dunbar**[2], **Regina A. Shih**[3], and **Elizabeth J. D'Amico**[1]

[1]RAND Corporation, Santa Monica, CA

[2]RAND Corporation, Pittsburgh, PA

[3]RAND Corporation, Arlington, VA

Abstract

Objectives: Cannabis and tobacco/nicotine use are highly comorbid. Given expanding access to cannabis through legalization for recreational use, it is important to understand how patterns of cannabis and tobacco/nicotine co-use are associated with young adult outcomes.

Methods: A predominantly California-based sample of 2,429 young adults (mean age=20.7) completed an online survey. Based on past-year reports of cannabis and tobacco/nicotine use, we defined five mutually exclusive groups: (1) single-product use; (2) concurrent use only (using both products, but only on separate occasions); (3) sequential use only (using both products on the same occasion, one right after the other, but not mixing them together); co-administration only (using both products on the same occasion by mixing them in the same delivery device); and both sequential use and co-administration. We examined group differences in use patterns, dependence, consequences of marijuana use, and psychosocial functioning.

Results: Fifty percent of respondents reported cannabis use, 43% tobacco/nicotine use, and 37% co-use of both substances. The most prevalent method of co-use involved smoking combustible products. Overall, individuals who co-used reported heavier marijuana and tobacco/nicotine use and greater problematic behaviors than those who did not co-use. However, differences in physical, mental and social functioning varied by co-use category, with sequential use (especially among those that also engaged in co-administration) typically associated with worse functioning overall compared to using each substance separately.

Conclusions: Findings illuminate both prevalence and risks associated with co-use of cannabis and tobacco/nicotine products, and can inform policies for states considering regulation of cannabis and tobacco/nicotine products.

Keywords

marijuana; cannabis; tobacco; nicotine; co-use; young adult

Correspondence concerning this article should be addressed to: Joan Tucker, RAND Corporation, 1776 Main Street, Santa Monica, CA 90407-2138; Phone: 310-393-0411; Fax: 310-393-8175; jtucker@rand.org. .

Introduction

In recent years, both cannabis and tobacco/nicotine products have become much more widely available to young adults. Stores that sell tobacco/nicotine products are ubiquitous. It is estimated that 375,000 U.S. retailers sell conventional tobacco products (e.g., combustible cigarettes), with 300,000 of these retailers also selling electronic nicotine delivery systems (ENDS) (Center for Public Health Systems Science, 2016). In addition, there has been a proliferation of both cannabis dispensaries and specialty vape shops (i.e., stores that sell only ENDS, but not other tobacco products) in states that have legalized cannabis for recreational sale and possession. For example, specialty vape shops in the United States listed on yelp.com increased from slightly less than 5,000 in 2002 to almost 10,000 in 2012 (Groskopf, 2016), and researchers have found that the number of vape shops near college campuses nearly tripled over a two-year period from 2013 to 2015 (Dai & Hao, 2016). Given this increasing availability, it is perhaps not surprising that there has been an overall upward trend in recent years in the co-use of cannabis and tobacco/nicotine products among adults in the U.S. (Schauer et al., 2015).

Prior to the proliferation of different types of cannabis and tobacco/nicotine products and methods of use, co-use of these products was generally limited to combustible methods. This could include smoking each type of product separately or after mixing them in some way (e.g., spliffs, blunts). Studies indicate that use of one of these drugs increases the likelihood of using the other. For example, combustible tobacco use has been shown to lead to subsequent initiation of and increases in marijuana use (Agrawal, Budney, & Lynskey, 2012; Agrawal, Lynskey, Bucholz, Madden, & Heath, 2007; Lai, Lai, Page, & McCoy, 2000), and young adults who initiate marijuana use have been found to subsequently report more combustible tobacco use (Agrawal et al., 2012; Agrawal, Madden, Bucholz, Heath, & Lynskey, 2008; Behrendt, Wittchen, Höfler, Lieb, & Beesdo, 2009; Timberlake et al., 2007; Tullis, Dupont, Frost-Pineda, & Gold, 2003). Further, studies of young people have found that marijuana use can impede their efforts to quit cigarette smoking (Amos, Wiltshire, Bostock, Haw, & McNeill, 2004; Ramo et al., 2013; Tullis et al., 2003).

In recent years, much attention has focused on the dramatic rise in the popularity of ENDS products (US Department of Health and Human Services, 2016). ENDS are typically marketed as being used to vape e-liquids (which often contain nicotine), but can also be used to consume cannabis (Morean, Kong, Camenga, Cavallo, & Krishnan-Sarin, 2015; Prieur, 2018). Multiple studies indicate that over half of the people that report using ENDS also report using cannabis (Berg et al., 2015; Saddleson et al., 2015; US Department of Health and Human Services, 2016). In a large nationally representative sample of 18 to 24 year olds, those who used ENDS in the past 30 days were three times more likely to also report use of cannabis during that same period compared to young adults who did not use ENDS (Cohn et al., 2015). Further, available studies show that greater use of cannabis is related to greater use of ENDS to vape cannabis (Cranford, Bohnert, Perron, Bourque, & Ilgen, 2016; Frohe et al., 2018; Jones, Hill, Pardini, & Meier, 2016). The use of ENDS to vape cannabis (with or without nicotine) by young adults is also concerning because the short-term and long-term health consequences are largely unknown (Cranford et al., 2016; Giroud et al., 2015; Ramo, Liu, & Prochaska, 2012).

Although a research base on cannabis and tobacco/nicotine co-use is emerging, both in the U.S. and in other countries (Schauer, Rosenberry, & Peters, 2017), existing work on cannabis and tobacco/nicotine co-use has been limited in several key respects. First, most studies were conducted at a time when these substances were almost exclusively smoked and therefore do not reflect the recent proliferation in product types and methods of use (Russell, Rueda, Room, Tyndall, & Fischer, 2018). Understanding young adults' preferred methods of combining cannabis and tobacco/nicotine products is important because certain methods of co-use (e.g., combustible) may pose greater health risks than others (e.g., vaping). Second, studies have often assessed co-use in terms of whether the individual reported using both products during a specified period such as the past year or past month, ignoring whether these products were used together in some way – for example, using both products on the same occasion, one right after the other, but not mixing them together in the same delivery device (sequential use; e.g., smoking a joint and then smoking a cigarette), or mixing them in the same delivery device (coadministration; e.g., smoking a spliff that contains tobacco rolled in with marijuana). These distinctions have important implications for both the quantity consumed and the health effects of use, although research in this area is sparse and with methodological limitations (Meier & Hatsukami, 2016). For example, one study found that using products on the same occasion or mixing the products in the same delivery device are both associated with increased symptoms of cannabis dependence (Ream, Benoit, Johnson, & Dunlap, 2008). In addition, co-administration, or mixing the products together, can significantly increase the amount of THC inhaled per gram of cannabis (Rabin & George, 2015). Further, individuals who use both cannabis and tobacco/nicotine are at elevated risk of poorer psychosocial functioning such as worse mental health, lower life satisfaction, more legal problems, and poor academic achievement in college (Georgiades & Boyle, 2007; Hernandez-Serrano, Gras, & Font-Mayolas, 2018; Moore & Budney, 2001; Suris, Akre, Berchtold, Jeannin, & Michaud, 2007). However, it is important to better understand whether certain types of co-use (e.g., sequential co-use, co-administration) may elevate risk for poorer young adult outcomes.

The Present Study

This study examined different types of co-use as a first step in understanding more detailed patterns of cannabis and tobacco/nicotine use among young adults, an age group that has the highest rates of both cannabis and tobacco/nicotine use (Ahrnsbrak, Bose, Hedden, Lipari, & Park-Lee, 2017; Azofeifa, 2016; Centers for Disease Control and Prevention, 2017; Hasin et al., 2016; Hasin et al., 2015; Schauer, Berg, Kegler, Donovan, & Windle, 2015), as well as co-use of these products (Centers for Disease Control and Prevention, 2017; Schauer et al., 2015). We surveyed a diverse and predominantly California sample of 2,429 young adults in 2017–2018 about their use of cannabis and tobacco/nicotine products in the past year. We first describe the prevalence and most common methods of co-use (i.e., unique combinations of products). We categorized participants into one of five mutually exclusive groups: (1) single-product use (cannabis only; tobacco/nicotine only); (2) concurrent use only (using both products at some point, but only on separate occasions); (3) sequential use only (using both products on the same occasion, one right after the other, but not mixing them); co-administration only (using both products by mixing them in the same delivery device); and both sequential use and administration. These co-use groups were then compared on their

frequency and heaviness of use, marijuana misuse, cigarette and e-cigarette dependence, as well as indicators of psychosocial functioning. We hypothesized that young adults who engaged in any type of co-use (concurrent, sequential, or co-administration) would report worse functioning compared to those who reported cannabis only or tobacco/nicotine only use. Little research is available to help form hypotheses for specific co-use groups; however, we hypothesized that those who used cannabis and tobacco/nicotine products together in some way (i.e., sequential use, co-administration, or both) would report poorer outcomes than those who reported use of both substances but on separate occasions only (i.e., concurrent use only).

Method

Sample and Procedures

Participants originated from two cohorts of 6th and 7th grade students who were initially recruited in 2008 from 16 middle schools in southern California as part of a substance use prevention program, CHOICE (D'Amico et al., 2012). All students in the two cohorts who were followed to wave 10 consented to the study (N=6,509), and all procedures were approved by the institution's review board. Participants completed wave 1 (Fall 2008) through wave 5 (Spring 2011) during physical education classes. Follow-up rates ranged from 74% to 90% during this time period, excluding new youth that could have come in at a subsequent wave. Adolescents transitioned from the 16 middle schools to over 200 high schools following wave 5, and were subsequently re-contacted and re-consented to complete annual web-based surveys, for which they were compensated. At wave 6 (Spring 2013-Spring 2014), 61% of the sample participated in the follow-up survey. At the subsequent annual assessments, we retained 80% of the sample from waves 6–7, 91% of the sample from waves 7–8, 89% of the sample from waves 8–9, and 90% of the sample from waves 9–10. Demographics (e.g., gender, race/ethnicity, employment) and substance use at the prior wave (e.g., alcohol, cigarettes, marijuana) did not predict attrition at Wave 10, similar to what we have found at earlier waves (e.g., D'Amico et al., 2016).

The present analyses utilize Wave 10 data, which occurred between July 2017 and June 2018, which is the first wave we added items assessing different types of co-use. The full sample at wave 10 consists of 2,429 respondents, with an average age of 20.67 years (*SD*=0.70). The sample is 45.62% male, 20.13% non-Hispanic White, 45.20% Hispanic, 20.75% Asian, 10.13% Multi-ethnic, 2.31% Black, and 1.48% Other races/ethnicities. The majority were still residing in California (93%) and were currently in college or trade school (80.28%). Within the full wave 10 sample, 1,222 respondents reported past year cannabis use and 1,036 reported past year tobacco/nicotine use (as defined below). These two groups are the main focus of analyses, and their characteristics are presented in Table 1.

Measures

Past year cannabis and tobacco/nicotine use.—Separate items asked how often participants used each of eight cannabis products or devices in the past year: joint to smoke marijuana; blunt (cigar shell) that contains only marijuana (no tobacco), handpipe (bowl) to smoke marijuana, bong (waterpipe) to smoke marijuana, dabs (wax, shatter, budder, hash

oil), edibles (e.g., brownies or candy), electronic cigarette or e-cigarette to smoke/vaporize marijuana, and personal vaporizer filled with hash oil, THC wax, dried buds, or other type of marijuana product. Separate items also asked how often participants had used each of the following seven tobacco/nicotine products or devices in the past year: cigarette, smokeless tobacco, hand pipe, hookah, large cigar/little cigar/cigarillo, e-cigarette (not for the purposes of using marijuana), and personal vaporizer filled with nicotine e-liquid or other type of tobacco product. Items were rated on a scale from 1=*none* to 6=*more than 20 times.* These items were used to identify participants who had used a single type of product (cannabis or tobacco/nicotine) vs. both cannabis and tobacco/nicotine products in the past year.

Past year cannabis and tobacco/nicotine co-use.—Participants who reported use of both cannabis and tobacco/nicotine rated how often in the past year they had "used both of these products/devices, one right after the other" (1=*none* to 6=*more than 20 times)* as an indicator of sequential use. In addition, participants completed ten items on how often they had "mixed tobacco and marijuana together" in different ways (cigarette dipped in hash oil; cigarette, joint, blunt, bong, hookah, hand pipe/bowl, or any other method that contained both tobacco and marijuana; e-cigarette or personal vaporizer that contained both nicotine e-liquid and marijuana) (1=*never* to 6=*7 or more times*) as an indicator of co-administration. We then calculated the percent of participants who reported each type of sequential use and each type of co-administration. Given the strong correlation between e-cigarette and personal vaporizer use ($r = .60$ for any use; $r = .70$ for frequency), and potential for some participants to not differentiate between these terms for ENDS devices (Coleman, Johnson, Alexander, & Williams, 2018), we combined reported use of e-cigarettes or personal vaporizer into a single ENDS category. From this information we created five mutually exclusive groups based on reports of whether they had engaged in the following types of cannabis and tobacco/nicotine use in the past year (yes/no): (1) single-product use (cannabis only; tobacco/nicotine only); (2) concurrent use only (using both products, but only on separate occasions); (3) sequential use only (using both products at the same time, but not mixing them); co-administration only (using both products by mixing them in the same delivery device); and both sequential use and co-administration.

Frequency of marijuana, cigarette, and e-cigarette use.—Measures of marijuana, cigarette, and e-cigarette use were based on items from Monitoring the Future asking how often they had used or tried each of these products in the past year (1=*none* to 6=*20 or more times*). Response options were recoded to reflect the mid-point of number of times (e.g., 11–20 times=15.5) using an established approach (National Institute on Alcohol Abuse and Alcoholism, 2003; Osilla et al., 2014) to yield a continuous score ranging from 0–20 so model estimates could be interpreted as number of times a respondent used each substance/device in the past year.

Quantity of marijuana, cigarette, and e-cigarette use.—For marijuana, this was assessed by first asking how many times they used marijuana on the days they used and, for those who reported at least 1 time, asking: "On the days you use marijuana, on a typical use day, how much marijuana flower/bud do you personally consume (don't include amount you may have shared)? (Kilmer et al., 2013). Response options ranged from 1=*< 0.25 grams* to

10=*more than 5 grams*. Response options were recoded to reflect the mid-point number of grams to yield a continuous score ranging from 0.25–5.0 grams. Those who reported using marijuana zero times in the past year were coded as 0. To encourage accurate responses, we provided pictures of 0.5 gram, 1.0 gram, and 3.5 grams (eighth ounce) of marijuana flower/bud (Kilmer et al., 2013). We assessed quantity of cigarette and e-cigarette use, respectively, by asking: "On the days you smoke cigarettes, how many do you usually smoke" (response options were capped at 20 or more cigarettes per day) and "On the days that you use your e-cigarette, how many times per day do you usually use it? Assume that one "time" consists of around 15 puffs or lasts around 10 minutes" (response options were capped at 99 times). Those who reported smoking zero cigarettes in the past year or using e-cigarettes 0 times were coded as 0 for these quantity items.

Cannabis misuse and cigarette/e-cigarette dependence.—We assessed cannabis misuse with the 3-item Cannabis Use Disorder Identification Test Short-Form (CUDIT-SF; Bonn-Miller, Heinz, Smith, Bruno, & Adamson, 2016). Participants who reported past month marijuana use rated how often during the past six months they found that they were not able to stop using marijuana/cannabis once they had started; devoted a great deal of their time to getting, using, or recovering from marijuana/cannabis; and had problems with their memory or concentration after using marijuana/cannabis. Items were rated on a scale from 0=*never* to 4=*daily or almost daily* and then summed (α=0.70; note that all reported alphas are based on full wave 10 sample). Among those reporting past month cigarette use, we used latency to first cigarette ("How soon after waking do you smoke your first cigarette?") as an indicator of *cigarette dependence* (Baker et al., 2007). Similarly, among for past month e-cigarette use, we used latency to first e-cigarette ("On days that you use your electronic cigarette freely, how soon after waking do you first use your electronic cigarette") as an indicator of *e-cigarette dependence* (Foulds et al., 2014). Both items were rated on a 4-point scale: 1=*within 5 minutes*, 2=*6–30 minutes*, 3=*31–60 minutes*, and 4=*after 60 minutes*.

Marijuana consequences and problems.—Negative consequences due to marijuana use in the past year were assessed with a 10-item measure based on items from the RAND Adolescent/Young Adult Panel Study (Ellickson, D'Amico, Collins, & Klein, 2005) and the Marijuana Consequences Questionnaire (Simons, Dvorak, Merrill, & Read, 2012). Respondents were asked how many times various things had happened to them in the past year because of using marijuana (sample items: missed school, work, or other obligations; got into trouble; did something you later felt sorry for). Each item was rated from 1=*none* to 7=*20 or more times* and summed (α=0.91). Using the same response scale, participants were also asked how often in the past year they engaged in two marijuana problematic behaviors: selling marijuana or driving a car after using marijuana.

Delinquency.—Participants were asked about frequency of past year engagement in non-alcohol and drug delinquency, such as fighting, skipping school, getting fired from a job, and getting in trouble with the police. Items were modified from the RAND Adolescent/Young Adult Panel Study (Tucker, Orlando, & Ellickson, 2003) and were rated on a scale from 1=*none* to 6=*20 or more times* and summed (α=0.86).

Mental health.—Mental health was assessed with two measures. The Patient Health Questionnaire – 8 item (PHQ-8; Kroenke et al., 2009) assessed eight symptoms of depression such as feeling down, depressed, or hopeless and having little interest or pleasure in doing things (α=0.92). The Generalized Anxiety Disorder 7-item (GAD-7; Spitzer, Kroenke, Williams, & Lowe, 2006) assessed seven symptoms of anxiety such as feeling nervous, anxious, or on edge and not being able to stop or control worrying (α=0.94). Both measures assessed symptoms in the past two weeks on a scale from 0=*not at all* to 3=*nearly every day*.

Physical health.—Physical ailments in the past four weeks were assessed with four items from the Patient Health Questionnaire – 15 item (PHQ-15; Kroenke, Spitzer, & Williams, 2002) asking how much participants were bothered by stomach pain, headaches, feeling tired or having low energy, and trouble sleeping (0=*not bothered at all* to 2=*bothered a lot*). Each item was dichotomized such that 0=*not bothered at all* and 1=*bothered a little/bothered a lot*, and the four items were summed to create an overall physical ailment score (α=0.75). Physical health was assessed with a combination of subjective overall health (1=*excellent* to 5=*poor*) and two items from the *Patient-Reported Outcomes Measurement Information System (PROMIS;* DeWitt et al., 2011) for ability to physically engage in activities that one enjoys and ability to participate in sports/ activities similar to their peers (1=*with no trouble* to 5=*not able to do).* Items were reverse scored and summed, with higher scores indicating better physical health (α = 0.80). Lastly, *social functioning* was assessed with eight PROMIS peer relationship items (Dewalt et al., 2013) rated from 0=*Never* to 4=*Always.* Items included "I was able to count on my friends," "I felt accepted by other people my age," and "I was good at making friends" (α=0.96).

Socio-demographics and race/ethnicity.—Variables included age, gender, current attendance in college/trade school, and race/ethnicity. Participants were classified into one of six racial/ethnic groups: Hispanic and five non-Hispanic groups: White (reference group), Black, Asian, Multi-racial (more than one race), and Other (e.g., Native American, Native Hawaiian).

Analytic Approach

Analyses describing the prevalence of different types of sequential use (Table 2) and administration (Table 3) within the full sample, and among those who reported using both cannabis and tobacco/nicotine in the past year, were primarily descriptive. A secondary analysis explored differences by gender and race/ethnicity, within the full sample, in any sequential use (yes/no) and any co-administration (yes/no). Analysis of covariance tests and follow-up Tukey post-hoc tests were conducted to compare the five mutually exclusive groups: single substance use; concurrent use only (no sequential use or co-administration); co-administration only (no sequential use); sequential use only (no co-administration); and those who reported both sequential use and co-administration. Separate analyses were conducted to compare the cannabis only use group to each co-use group (Table 4), and to compare the tobacco/nicotine only use group to each co-use group (Table 5). These group comparisons controlled for socio-demographic covariates described above.

Results

Prevalence and methods of marijuana and tobacco/nicotine co-use

In the full sample (N=2,429), 50.31% (n=1,222) of respondents reported past year use of <u>any</u> cannabis product, 42.65% (n=1,036) reported past year use of <u>any</u> tobacco/nicotine product, and 37.18% (n=903) reported past year use of both cannabis and tobacco/nicotine products. Sequential use of cannabis and tobacco/nicotine (using both products at the same time, one right after another, but not mixing them) was reported by 401 respondents, which was 16.51% of the full sample and 44.41% of those who used both products in the past year. Co-administration of cannabis and tobacco/nicotine (using both at the same time by mixing them in the same delivery device) was reported by 342 respondents, which was 14.08% of the full sample and 35.87% of those who used both products in the past year.

Secondary analyses exploring racial/ethnic differences found an overall difference in both sequential use [$F_{(5, 2423)} = 3.45, p = .004$] and co-administration [$F_{(5, 2423)} = 15,13, p < .001$] within the full sample. Tukey post-hoc comparisons found that sequential use was more common among non-Hispanic Whites than Hispanics (21.88% vs. 14.12%, $p < .05$). Co-administration was more likely among non-Hispanic Whites (24.74%) than Hispanics (9.93%), Asians (10.71%), and those in the Other group (5.56%), and more prevalent in the Multiethnic group than among Hispanics (18.29% vs. 9.93%) ($ps < .05$). In addition, males were more likely than females to engage in both sequential use (22.20% vs. 11.73%; $t = 6.84$, $p < .0001$) and co-administration (18.68% vs. 10.22%; $t = 5.89$, $p < .0001$).

As shown in Table 2, the most prevalent forms of sequential use, or using one product right after the other, were cigarette and joint (7.41% of full sample), ENDS and joint (6.46%), ENDS and e-cigarette/vaporizer for marijuana (6.46%), cigarette and blunt (6.21%), ENDS and bong (6.09%), cigarette and bong (5.84%), ENDS and blunt (5.56%), and ENDS and hand pipe (5.02%). All other combinations were mentioned by less than 5% of the full sample. Table 3 contains the 10 forms of co-administration listed in order of prevalence. The most common forms of co-administration, or mixing of products, were joints (10.03% of the total sample), bongs (7.89%), and blunts (7.76%) that contained both marijuana and tobacco. All other forms of co-administration were mentioned by less than 5% of the full sample.

Comparing cannabis only group to the four co-use groups

Table 4 contains means and standard errors for each outcome by subgroup, as well as the overall analysis of covariance test statistic and significant findings between subgroups.

Marijuana use and misuse.—As hypothesized, we found overall group differences on marijuana use and dependence based on the use group. The three co-use groups that used cannabis and tobacco/nicotine products <u>on the same occasion</u> in some way (co-administration, sequential, or both) reported more days of marijuana use than the cannabis only group; however, there was not a significant difference in heaviness of use between the group that had used both products in the past year, but never on the same occasion (concurrent only), and the cannabis only group. Further, the two groups that reported co-administration of products reported more frequent marijuana use than the sequential only

and concurrent only groups, and the sequential only group reported more frequent marijuana use than the concurrent only group.

In terms of marijuana quantity, the three co-use groups that used both products on the same occasion reported consuming more grams of marijuana on a typical day of use compared to either the cannabis only group or the concurrent only group. For example, the sequential + co-administration group reported using about a gram of marijuana when they used, which is a little larger than a bottle cap, compared to about ½ a gram for the cannabis only and concurrent only groups. On the CUDIT-SF, the sequential + co-administration group reported a mean CUDIT-SF score that was higher than the cutoff score of 2 which is indicative of cannabis use disorder; the score for this group was significantly higher than for any of the other four groups.

Marijuana problems.—A comparison of the five mutually exclusive cannabis groups found overall differences on each outcome. For marijuana-related consequences, the three co-use groups that used cannabis and tobacco/nicotine products on the same occasion reported greater consequences than the cannabis only group; however, there was not a significant difference in consequences between the group that had used both products in the past year, but never on the same occasion (concurrent use only), and the cannabis only group. The sequential + co-administration group reported more consequences than the sequential only, co-administration only, and concurrent only groups. In turn, the sequential only and co-administration only groups reported more consequences than the concurrent only group. For selling marijuana, the three co-use groups that used both products on the same occasion were more likely to sell the drug compared to the cannabis only group and the concurrent only group. Considering the means, about 20% of those in the sequential + co-administration group reported selling marijuana compared to only 4% in the cannabis only group and 10% in the concurrent only group. Lastly, for driving after marijuana use, the three co-use groups that used both products on the same occasion were more likely to drive after using marijuana compared to the cannabis only group and the concurrent only group. The sequential + co-administration group was also more likely to drive after using marijuana than the sequential only group. Compared to 15% of the cannabis only use group, 47% of the co-administration only group and 55% of the sequential + co-administration group reported driving after use.

Physical health, mental health and delinquency.—We found overall group differences on delinquency, physical ailments, physical health, anxiety and depression. For delinquency, those in the sequential + co-administration group reported greater past year delinquency compared to all other groups. In addition, the sequential only group reported greater delinquency than the cannabis only group. Regarding physical ailments and health, the sample overall reported good physical health; however, the sequential + co-administration group reported more physical ailments and poorer health than the concurrent only group, and the sequential only group reported poorer health than the concurrent only group. For anxiety, those in the sequential + co-administration group reported greater anxiety symptoms than the concurrent only group. For depression, those in the sequential + co-administration group reported greater depression symptoms than the cannabis only and

concurrent only groups, and the sequential only group reported greater depression symptoms than the concurrent only group. Means across the groups were generally mild to moderate, as scores of 10 on the GAD-7 and the PHQ-8 indicate positive screens for anxiety and depression, respectively. There were no significant differences between groups for social functioning.

Comparing the tobacco/nicotine only group and the four co-use groups

Table 5 contains means and standard deviations for each outcome by co-use subgroup, as well as the overall analysis of covariance test statistic and significant subgroup differences.

Tobacco/nicotine use and dependence.—A comparison of the five mutually exclusive tobacco/nicotine groups found overall group differences on tobacco/nicotine use and dependence. The sequential + co-administration group reported significantly more frequent cigarette use and e-cigarette use in the past year compared to the tobacco/nicotine only group and the other three co-use groups. In addition, the sequential only group reported more frequent cigarette use and e-cigarette use than the concurrent only and tobacco/nicotine only groups. Finally, the co-administration only group reported more frequent cigarette and e-cigarette use than the tobacco/nicotine only group, and more frequent cigarette use compared to the concurrent only group. In terms of quantity of use, the sequential + co-administration group reported higher quantity of both cigarette and e-cigarette use compared to the tobacco/nicotine only group and concurrent only group, and higher quantity of cigarette use compared to the sequential only group. In addition, the sequential only group reported a higher quantity of both cigarette and e- cigarette use compared to the concurrent only group, and a higher quantity of e-cigarette use compared to the tobacco/nicotine only group. Even though there was an overall effect between groups, post-hoc tests revealed there were no mean differences between groups on the indicators of cigarette or e-cigarette dependence.

Physical health, mental health, and delinquency.—Similar to comparisons for the cannabis only use group, we found overall group differences on delinquency, physical ailments, physical health, anxiety and depression. For delinquency, those in the sequential + co-administration group reported greater past year delinquency than all other groups. The sequential only group also reported greater delinquency than the tobacco/nicotine only group. For physical ailments, the sequential + co-administration group reported more physical ailments than the concurrent only group. Regarding physical health, the sequential + co-administration group and the sequential only group reported poorer health than the tobacco/nicotine only group and the concurrent only group. For both anxiety and depression, the sequential + co-administration group reported greater symptoms than the concurrent only group. There were no significant differences between groups for social functioning.

Discussion

Studies have shown that cannabis and tobacco/nicotine use are highly comorbid in young adulthood (Schauer et al., 2015); however, little research has provided detailed information on how these substances are used together. This study is among the first to examine unique

combinations of cannabis and tobacco/nicotine use and different types of co-use behaviors in a diverse sample of young adults. We found that the most popular forms of both sequential use (using one product right after another) and co-administration (mixing the products) involved smoking combustible products (i.e., cigarettes, joints, bongs, blunts). Vaping methods for co-use of cannabis and tobacco/nicotine were somewhat less prevalent, as noted in prior work (Meier & Hatsukami, 2016), but may grow in popularity over time given the recent alarming increase in vaping among high school students (Cullen et al., 2018). Combustible cigarette use has declined substantially over the past 50 years (Lauterstein et al., 2014; National Center for Chronic Disease Prevention and Health Promotion Office on Smoking and Health, 2014). However, our study shows that despite these declining rates, the highest rates of cannabis and tobacco/nicotine co-use are through combustible methods. Though the long-term health effects of vaping nicotine (with or without cannabis) are still being actively studied without firm conclusions (Budney, Sargent, & Lee, 2015; Giroud et al., 2015; Pisinger & Døssing, 2014), vaping is almost certainly a less harmful variant of substance use than smoking combustible products (National Academies of Sciences & Medicine, 2018). Findings emphasize the continued need for early education programs to address the dangers of smoking combustible products, and interventions for those that have already begun smoking to prevent adverse health effects.

Mixing cannabis and tobacco is prevalent in several countries, but has generally been considered to be rare in the U.S. (Winstock, Barratt, Ferris, & Maier, 2017). Thus, another interesting finding from this study is that the majority of young adults who co-use cannabis and tobacco/nicotine products use them together in some way. Among those who reported using both cannabis and tobacco/nicotine products in the past year, nearly one-half had used the two products one after the other on the same occasion (sequential use) and about one-third mixed them in the same delivery device (co-administration). The heterogeneity within the population is important to consider, as some co-use subgroups had higher risk profiles than others. For example, young adults who co-used cannabis and tobacco/nicotine on the same occasion, or mixed the products in the same device, tended to report higher frequency and quantity of marijuana or tobacco/nicotine use compared to those who used only one product. Of note, we did not see these same increases among young adults who used cannabis and tobacco/nicotine on separate occasions only. We did not find that cigarette or e-cigarette dependence was higher among any of the co-use subgroups compared to the tobacco/nicotine only group; however, consistent with other work (Peters, Budney, & Carroll, 2012), cannabis use disorder scores were significantly higher in the sequential + co-administration group compared to the cannabis only group. We found a similar pattern for marijuana consequences, marijuana problems (selling the drug, driving after using it), and most domains of young adult functioning. Overall, youth who reported co-administration and sequential use, either alone or in combination, also reported poorer outcomes compared to youth using only one product or using both products independently. There is some literature on psychosocial and physical health correlates of co-use in young adults (Masters, Haardörfer, Windle, & Berg, 2018; Ramo et al., 2012); however, further longitudinal research is needed to examine how outcomes may differ across types of co-use over time and to identify mechanisms underlying these differences. For example, differences across types of co-use may be due to the manner in which cannabis and tobacco/nicotine are co-

used, characteristics of the person who chooses to co-use in a particular way, or other factors. Additional research on co-use is also needed to inform various stakeholder groups, including policy makers and public health officials, and to guide both tobacco and cannabis regulatory science (Schlienz & Lee, 2018).

It is clear from this study and others (Agrawal et al., 2012; Meier & Hatsukami, 2016; Ramo et al., 2012) that any research study assessing the effects of cannabis or tobacco/nicotine use (e.g., whether use contributes to poor physical and mental health) should also account for co-use of these products given the prevalence of this behavior among young adults. Given the changing legal landscape of cannabis (D'Amico, Tucker, Pedersen, & Shih, 2017), and the fact that co-use is associated with more frequent and problematic use, poorer mental and physical health, and delinquent behaviors such as getting fired from a job or getting in trouble with the police, it will be important for programming to include content and discussions geared toward co-use of both products, and how co-use may also lead to problems.

Limitations

Data were collected in a state where medical cannabis had been legal for about 20 years, mostly (but not exclusively) prior to the retail sale of recreational cannabis going into effect in January 2018. The use of this predominantly California-based sample limits generalizability of findings; however, the use of such a sample allowed us to have a diverse sample of young adults (74% of youth who reported cannabis use were non-White), and offered some standardization of both cannabis and tobacco state policies applied to all participants in the study. Though this study represents the most detailed effort to collect information on specific types of co-use products, our online survey methods relied on self-report data from one time-point. With the recent opening of recreational marijuana dispensaries in California and other states, the proliferation of specialty vape shops, and the ubiquitous availability of tobacco/nicotine products, it is essential to create well-designed longitudinal studies that can address important policy questions, such as whether legalizing marijuana for recreational sale and possession has an unintended impact on increasing tobacco use among young adults. We also were not able to assess the relative quantity of cannabis vs. tobacco/nicotine within the co-administration device. This study was meant to provide an overview of the extent of co-use among young adults. There is a need for more detailed data on recent and regular use (e.g., past week), and specifically at the daily level, perhaps using ecological momentary assessment to disentangle order of product use and better understand quantities of use for both drugs.

Conclusions

This study represents an important first step toward understanding cannabis and tobacco/nicotine co-use behavior among young adults. We detailed the most popular forms of sequential use and co-administration, finding that young adults who engage in certain types of co-use are at high risk for more frequent use of both drugs, more frequent consequences, and poorer psychosocial functioning than other co-use groups and single product use groups. Longitudinal research and data collection methods are needed that gather more nuanced details, such as the order of product use on sequential occasions and predictors of co-

administration and sequential use which were the highest risk groups for negative consequences. Overall, these descriptive findings emphasize the need for prevention and intervention efforts to target both cannabis and tobacco/nicotine use (including sequential use and co-administration) in the effort to address long term health problems and problematic behaviors related to both drugs.

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Table 1.

Sample characteristics

	Past year cannabis use group (N = 1,222)		Past year tobacco/nicotine use group (N=1,036)	
	N/Mean	%/SD	N/Mean	%/SD
Demographics				
Age	20.65	0.69	20.68	0.71
Race/ethnicity				
Hispanic	516	42.23%	444	42.86%
Non-Hispanic				
White	319	26.10%	261	25.19%
Asian	209	17.10%	185	17.86%
Black	30	2.45%	18	1.74%
Multi-racial	134	10.97%	115	11.10%
Other	14	1.15%	13	1.25%
Male	577	47.22%	531	51.25%
In College/Trade School	984	80.52%	819	79.05%
Co-Use Status				
No co-use	344	28.15%	182	17.57%
Concurrent use only	374	30.61%	374	36.10%
Co-administration use only [a]	122	9.98%	99	9.56%
Sequential use only [a]	170	13.91%	173	16.70%
Sequential + co-administration use [a]	212	17.35%	208	20.08%

Note.

[a]Differences in sample sizes across the cannabis use and tobacco/nicotine use samples for co-administration and sequential use are due to inconsistent reporting (e.g., endorsing a form of co-use, but not the individual cannabis and tobacco/nicotine items that comprise the co-use).

Table 2.

Past year sequential co-use of cannabis and tobacco/nicotine in full sample and among past year cannabis and tobacco/nicotine co-use groups (combinations with 10% prevalence among co-use are shown)

	% among full sample	% among co-use
Any type of sequential co-use (n=401)	16.51%	44.41%
Cigarette + joint to smoke marijuana (*n*=179)	7.41%	19.93%
ENDS [a] + joint to smoke marijuana (*n*=157)	6.46%	17.39%
ENDS [a] + e-cigarette/vaporizer to use marijuana (*n*=157)	6.46%	17.39%
Cigarette + blunt (cigar shell) that contains only marijuana (*n*=150)	6.21%	16.76%
ENDS [a] + bong (waterpipe) to smoke marijuana (*n*=148)	6.09%	16.39%
Cigarette + bong (waterpipe) to smoke marijuana (*n*=141)	5.84%	15.75%
ENDS [a] + blunt (cigar shell) that contains only marijuana (*n*=135)	5.56%	14.95%
ENDS [a] + hand pipe (bowl) to smoke marijuana (*n*=122)	5.02%	13.51%
Cigarette + hand pipe (bowl) to smoke marijuana (*n*=117)	4.84%	13.01%
Cigarette + e-cigarette/vaporizer to use marijuana (*n*=111)	4.57%	12.29%
ENDS [a] + dabs (wax, shatter, budder, hash oil) (*n*=104)	4.28%	11.52%
ENDS [a] + edible (e.g., brownies or candy) (*n*=102)	4.20%	11.30%

Note. *N* = 2,429 for full sample and *N* = 903 for co-use sample. Tobacco/nicotine product is listed first, followed by cannabis product.

[a] Indicates endorsement of the item on using e-cigarettes (not for the purpose of using marijuana) and/or the item on use of personal vaporizer filled with nicotine e-liquid or other type of tobacco/nicotine product.

Table 3.

Past year co-administration of cannabis and tobacco/nicotine in full sample and among past year cannabis and tobacco/nicotine co-use groups

	% among full sample	% among co-use
Any type of co-administration (n=342)	14.08%	35.87%
Joint that contains both tobacco and marijuana (*n*=243)	10.03%	27.00%
Bong that contains both tobacco and marijuana (*n*=191)	7.89%	21.27%
Blunt that contains both tobacco and marijuana (*n*=188)	7.76%	20.89%
Cigarette that contains both tobacco and marijuana (*n*=104)	4.29%	11.56%
Hand pipe or bowl that contains both tobacco and marijuana (*n*=92)	3.80%	10.22%
ENDS that contains both nicotine e-liquid and marijuana (such as hash oil, THC wax, dried buds) (*n*=79)	3.25%	8.75%
Any other way of using both tobacco and marijuana through the same delivery device (*n*=58)	2.40%	6.45%
Hookah that contains both tobacco and marijuana (*n*=49)	2.02%	5.44%
Cigarette dipped in hash oil (*n*=48)	1.98%	5.33%

Note. $N = 2,429$ for full sample and $N = 903$ for co-use sample.

Table 4.

Comparing cannabis only use groups to concurrent co-use, sequential co-use, and co-administrator use groups

	Group 1 Cannabis use only	Group 2 Concurrent use only	Group 3 Co-admin. only	Group 4 Sequential use only	Group 5 Sequential + co-admin.	Overall ANCOVA	Group differences [a]
	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	$F (df=8)$	--
Frequency of marijuana use	8.55 (0.40)	9.94 (0.38)	15.05 (0.67)	12.60 (0.57)	17.30 (0.51)	32.82[‡]	1/3, 2/3, 1/4, 2/4, 3/4, 1/5, 2/5, 4/5
Quantity of marijuana use	0.58 (0.05)	0.53 (0.05)	0.90 (0.08)	0.94 (0.07)	1.04 (0.06)	17.67[‡]	1/3, 2/3, 1/4, 2/4, 1/5, 2/5
CUD [b]	1.02 (0.19)	1.21 (0.17)	1.83 (0.26)	1.54 (0.22)	2.81 (0.18)	12.15[‡]	1/5, 2/5, 3/5, 4/5
Marijuana consequences	13.11 (0.46)	14.12 (0.44)	18.30 (0.77)	16.64 (0.65)	22.29 (0.59)	28.32[‡]	1/3, 2/3, 1/4, 2/4 1/5, 2/5, 3/5, 4/5
Marijuana selling	0.04 (0.02)	0.05 (0.02)	0.15 (0.03)	0.16 (0.02)	0.23 (0.02)	14.76[‡]	1/3, 2/3, 1/4, 2/4 1/5, 2/5
Marijuana-impaired driving	0.15 (0.02)	0.21 (0.02)	0.47 (0.04)	0.38 (0.03)	0.55 (0.03)	21.62[‡]	1/3, 2/3, 1/4, 2/4, 1/5, 2/5, 4/5
Delinquency	6.41 (0.15)	6.56 (0.14)	6.67 (0.25)	7.13 (0.21)	8.53 (0.19)	15.68[‡]	1/4, 1/5, 2/5, 3/5, 4/5
Physical ailments	2.09 (0.07)	1.92 (0.07)	2.21 (0.12)	2.13 (0.11)	2.40 (0.10)	6.94[‡]	2/5
Physical health	12.21 (0.13)	12.43 (0.12)	12.29 (0.21)	11.68 (0.18)	11.76 (0.16)	6.34[‡]	2/4, 2/5
Social functioning	42.66 (0.41)	43.18 (0.39)	43.99 (0.69)	42.41 (0.58)	43.17 (0.52)	3.97[‡]	--
Anxiety	5.73 (0.29)	4.74 (0.28)	5.31 (0.50)	5.88 (0.42)	6.67 (0.38)	4.44[‡]	2/5
Depression	5.71 (0.31)	5.42 (0.29)	5.83 (0.51)	6.90 (0.43)	7.57 (0.39)	5.79[‡]	1/5, 2/4, 2/5
N	344	374	122	170	212		

Note.

[a] Group differences significant at $p < .05$ from pairwise comparisons.

[b] past month marijuana use only (n=738). Adjusted means and SEs after controlling for age, gender, race/ethnicity, and college status are shown.

[‡] $p < .001$.

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CUD = cannabis use disorder.

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Table 5.

Comparing tobacco/nicotine only use group to concurrent use, sequential use, and co-administrator use groups

	Group 1 Tobacco use only	Group 2 Concurrent use only	Group 3 Co-admin. only	Group 4 Sequential use only	Group 5 Sequential + co-admin.	Overall ANCOVA	Group differences [a]
	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	F (df=8)	--
Frequency of cigarette use	3.58 (0.51)	3.74 (0.36)	6.97 (0.70)	5.77 (0.52)	11.01 (0.48)	27.36‡	1/3, 2/3, 1/4, 2/4, 1/5, 2/5, 3/5, 4/5
Frequency of e-cigarette use	2.66 (0.53)	3.36 (0.37)	5.33 (0.72)	5.76 (0.54)	9.51 (0.49)	23.67‡	1/3, 1/4, 2/4, 1/5, 2/5, 3/5, 4/5
Quantity of cigarette use	0.50 (0.17)	0.39 (0.12)	1.02 (0.23)	0.96 (0.17)	1.71 (0.16)	9.00‡	2/4, 1/5, 2/5, 4/5
Quantity of e-cigarette use	1.66 (0.91)	1.97 (0.65)	3.20 (1.27)	5.86 (0.94)	7.24 (0.86)	5.58‡	1/4, 2/4, 1/5, 2/5
Time to first cigarette [b]	3.79 (0.12)	3.62 (0.09)	3.57 (0.14)	3.47 (0.10)	3.69 (0.07)	2.14*	--
Time to first e-cigarette [c]	3.47 (0.12)	3.39 (0.07)	3.31 (0.13)	3.22 (0.09)	3.31 (0.08)	1.98*	--
Delinquency	6.31 (0.22)	6.59 (0.15)	6.70 (0.30)	7.22 (0.22)	8.58 (0.20)	12.65‡	1/4, 1/5, 2/5, 3/5, 4/5
Physical ailments	2.05 (0.10)	1.89 (0.07)	2.15 (0.14)	2.14 (0.10)	2.40 (0.10)	8.79‡	2/5
Physical health	12.54 (0.17)	12.43 (0.12)	12.30 (0.24)	11.70 (0.18)	11.76 (0.16)	6.61‡	1/4, 2/4, 1/5, 2/5
Social functioning	42.67 (0.56)	43.22 (0.439)	43.87 (0.76)	42.49 (0.57)	43.07 (0.53)	3.70‡	--
Anxiety	6.00 (0.41)	4.69 (0.29)	5.19 (0.56)	5.77 (0.42)	6.66 (0.38)	4.80‡	2/5
Depression	6.16 (0.43)	5.41 (0.30)	5.95 (0.58)	6.77 (0.44)	7.58 (0.40)	5.74‡	2/5
N	182	374	99	173	208		

Note.

[a] Group differences significant at $p < .05$ from pairwise comparisons.

[b] past month cigarette use only (n=375).

[c] past month e-cigarette use only (n=1,015). Adjusted means and SEs after controlling for age, gender, race/ethnicity, and college status are shown.

*
$p < .05.$

†
$p < .001.$