Longitudinal patterns of cannabis and tobacco co-administration and concurrent use among young adult college students

Daniel S. Kreitzberg, **Keryn E. Pasch**[*],
Alexandra Loukas

Department of Kinesiology and Health Education, The University of Texas at Austin, 2109 San Jacinto Blvd, Austin, TX 78712, USA

Abstract

Introduction: Co-use, including concurrent use or co-administration, of cannabis and tobacco is most prevalent in young adulthood and associated with worse health outcomes than use of either substance alone. This study examined latent classes of tobacco and cannabis concurrent use and co-administration, and transitions between classes from 2016 to 2019, among a sample of young adult college students in Texas.

Methods: Participants included 4,448 young adults (64.2% female, 64.7% non-white, mean age = 20.5) in a longitudinal cohort study. Measures included past 30-day use of cigarettes. hookah, cigars, ENDS, cannabis, and cannabis and tobacco co-administration. Latent Markov models were used to estimate latent class membership and transitions between classes from 2016 to 2017 and 2017 to 2019.

Results: Four latent classes emerged: non-use (58% of students) characterized by low/no probability of any use; general use (19%) characterized by some level of use of all behaviors; blunt and cannabis use class (13%) characterized by high probabilities of cannabis use and co-administration with blunts; and concurrent and co-administration use (10%) with high probabilities of cigarette, cannabis, blunt, and spliff use. Most students remained in the same latent class from 2016 to 2019.

Conclusions: While most students reported low/no tobacco and cannabis co-use, those who used cannabis and/or tobacco remained in their use classes over the course of the study (2016

to 2019). Public health advocates on college campuses should consider prevention and cessation programs that incorporate the constellation of behaviors related to cannabis and tobacco co-use and educate students about the health consequences of co-use.

1. Introduction

The prevalence of cigarette, little cigars/cigarillo (LCC), smokeless tobacco, and hookah use among young adults has decreased in recent years, while the prevalence of electronic nicotine delivery system (ENDS) and cannabis use has either increased (Romm et al., 2023; Schulenberg et al., 2020) or remained stable. (Seaman et al., 2019) Use of cannabis and tobacco have each been associated with negative health effects and the use of both products, or co-use, has been found to exacerbate some of these negative health effects, including poor lung functioning (Correa et al., 2020; Taylor et al., 2002) and increased dependence on nicotine. (Patton et al., 2005; Seaman et al., 2020) Co-use of cannabis and tobacco can be defined in different ways such as the use of both products during the same period, referred to as concurrent use, (Berg et al., 2015) or use of cannabis in or with a tobacco product, referred to as co-administration (e.g., cannabis in a blunt wrap). (Pedersen et al., 2020; Tucker et al., 2019).

Prevalence of co-use varies by the type of co-use, concurrent or co-administration. Studies indicate approximately 30–60% of college students who use cannabis also report concurrent tobacco product use. (Berg et al., 2015; Tucker et al., 2019; Jones et al., 2016) Tucker and colleagues (2019) found 17.4% of past-year marijuana users reported both sequential (use of one product after the other) and co-administration use while 14% reported only sequential use and 10% reported co-administration. (Tucker et al., 2019) Further, among a sample of past-year tobacco/nicotine users, 36.1% reported concurrent use only, 20.1% reported sequential and co-administration use, 16.7% reported sequential use only, and 9.6% reported only co-administration use. (Tucker et al., 2019) Another study of young adults from 11 colleges in North Carolina and Virginia, found 9.3% of participants reported concurrent past 30-day use of cannabis and tobacco and co-users were most likely to use ENDS and blunts and to use more cannabis than their peers who only use cannabis. (Reboussin et al., 2021) Data from the nationally representative Population Assessment of Tobacco and Health (PATH) study have shown slightly higher rates among young adults with between 20 and 33% of participants reporting concurrent past 30-day use of cannabis and tobacco (Seaman et al., 2020; Cohn et al., 2019) and 42% reporting ever co-administering cannabis in a tobacco product. (Seaman et al., 2020) Among past 30-day cannabis users, 96.4% reported ever use of tobacco while 51.3% of participants who reported ever using nicotine had also used cannabis. (Blair et al., 2022) A longitudinal study by Berg et al. (2020) found early marijuana use, before the age of 18 years, was associated with four different tobacco use trajectories, with marijuana use before 18 predicting increased odds of being in the three tobacco user classes (adult users, college users, teenage users) as compared the abstainer/dabblers trajectory. (Berg et al., 2020) Together, these studies make clear that a meaningful proportion of young adults are reporting co-use of tobacco and cannabis. Beyond estimating prevalence, more complex modeling can elucidate patterns of cannabis and tobacco concurrent use and co-administration to discover more nuanced and possibly common patterns of co-use.

Latent class analysis and latent transition analysis (LCA and LTA, respectively) (Lanza et al., 2012) have been used to identify patterns, or classes, of concurrent use of cannabis and tobacco, and transitions between classes over time. Studies have found latent classes with high probabilities of concurrent cannabis and tobacco use among about 10% (Haardörfer et al., 2016) and 18% (Evans-Polce et al., 2016) of young adult college students. Research by Cho et al. (2015) (Bin et al., 2015) found classes with concurrent tobacco and cannabis use that included over 40% of the college student sample. Additionally, 7% of college students in the Cho et al. study transitioned from the low or no use class to the alcohol, tobacco, and cannabis use class from fall to spring semester, while 2.6% transitioned from a use class to the low/no-use class. These studies demonstrate the usefulness of LCA and LTA for estimating patterns of concurrent cannabis and tobacco use, however, none measured co-administration. It is unclear if college students commonly engage in both co-administration and concurrent use or if these are distinct use behaviors. These studies also included measures of alcohol use and other substances when estimating latent classes, this may obscure patterns of cannabis and tobacco co-administration and concurrent use which might be useful for interventionists to target.

While previous studies that examined tobacco and cannabis concurrent use have found common patterns, our study aims to build upon this work by including measures of co-administration and expanding the length of time used to examine transitions over three years. If the current study finds similar high stability in class membership as previous studies (Bin et al., 2015), early prevention efforts may be key to preventing concurrent use or co-administration as young adults are likely to continue these behaviors once they start. Therefore, the purpose of this study is two-fold 1) determine latent classes of concurrent use and co-administration of cannabis and tobacco and 2) analyze transitions between latent classes of concurrent use and co-administration of cannabis and tobacco products across three years, from 2016 to 2019, among young adult college students.

2. Methods

2.1. Study design and population

The Marketing and Promotions Across Colleges in Texas (M–PACT) project was a rapid-response surveillance study that measured tobacco and nicotine product use, correlates of use, and trajectories of use among young adult college students in Texas from 2014 to 2019. (Loukas et al., 2016; Loukas et al., 2022) Students were eligible for participation in M–PACT if they were enrolled full- or part-time in vocational training/certificate programs at 12 2-year colleges or undergraduate degree-seeking students at 12 4-year colleges. Potential participants were contacted via an e-mail that outlined the purpose of the study and included an eligibility survey. A total of 13,714 students were contacted via e-mail and 40% were eligible, provided consent, and completed the survey. M–PACT participants included 5,478 students from 24 colleges located within five counties and the four largest metropolitan areas of Texas. Project M–PACT wave four was chosen as the baseline for this study as it was the first wave of M–PACT to include measures of past 6-month co-administration. Data for this study was drawn from waves four (spring 2016; considered baseline for the present study), six (spring 2017), and eight (spring 2019) with a retention rate that ranged from 75%

to 81% (n = 3,797–4,448) between waves. (Loukas et al., 2022; Clendennen et al., 2019) Thus, we examined tobacco and cannabis use behaviors at baseline in 2016, one year later in 2017, and two years after the one-year follow-up in 2019. There was a two-year gap between 2017 and 2019 because the 2018 questionnaire was an abridged version that did not measure co-administration behaviors. The analysis for this study included 4,448 students who had complete data at wave four.

2.2. Measures

Current separate use measures.—Past 30-day use of cigarettes, hookah, cigar, smokeless tobacco, ENDS, and marijuana were each measured with a single question, (e.g., "On how many of the past 30 days have you smoked a cigarette?"). Possible responses included 0 to all 30 days for each question and responses were dichotomized to either zero days (0) or at least one day (1).

Cannabis and Tobacco co-administration.—Four separate measures were used to assess past 6-month co-administration of cannabis and four different tobacco products including use in a hand-rolled cigarette (e.g., 'spliff'), in an ENDS, in a large cigar, cigarillo, or 'blunt', and in a hookah or water pipe. Each of the four separate measures were assess with a similar question, "In the past 6 months (e.g., since the last survey you took) have you smoked marijuana in a [hookah]?" Responses were either "yes" (1) or "no" (0). ENDS co-administration was measured differently at the three-year follow up in this study with three separate questions: "In the past 6 months, have you smoked marijuana in a: "juul/pod vape", "disposable e-cigarette or an e-cigarette with a disposable cartridge (not a juul/pod vape)", and "vape pen, personal vaporizer, mod, or any other similar device". Response options to these three questions were "yes" (1) or "no" (0) and a "yes" to any of the three questions was coded as "yes" (1) for ENDS co-administration and "no" on all three was coded (0).

2.3. Analytic approach

Latent Markov models were used to address the two purposes of the study; to estimate latent class membership during waves four (spring 2016), six (spring 2017), and eight (spring 2019) and transitions class membership over one year, from spring 2016 (referred to as baseline) to 2017, and over two years, from 2017 (referred to as one-year follow-up) to 2019 (referred to as three-year follow-up). Latent Markov models allow for modeling time-constant and varying latent classes between two or more categorical variables. In this study, 10 binary indicator variables were used: 5 past 30-day tobacco use indicators, a past 30-day cannabis use item, and 4 co-administration measures. The number of latent classes was determined via multiple model fit criteria including 1) lower values of Akaike information criterion (AIC) (Akaike, 1973) and Bayesian information criterion (BIC) (Schwarz, 1978), 2) visual inspection of AIC and BIC values by number of latent classes (scree plots), 3) bootstrapped likelihood ratio test (BLRT) results, where significant results indicate the model with k classes fits the data better than a model with k-1 classes, and 4) no latent class with<10% membership among the sample. To select the most parsimonious model, models with one through 35 latent classes were compared. These criteria have been used in previous studies to select an appropriate number of latent classes. (Bin et al., 2015;

Clendennen et al., 2019) Analyses were conducted with R (version 4.0.3) (R: A language and environment for statistical computing. Published online, 2021) including descriptive statistics, chi-square tests between sex and race/ethnicity groups within each latent class and transitions between classes, and the latent Markov model with package LMest. (Bartolucci et al., 2017) LMest handles missing data using the expectation–maximization algorithm. P-values were considered statistically significant at < 0.007 due to multiple comparisons.

3. Results

Of the 4,448 participants that were included in this study, 64.2% were female, with an average age of 20.5 years (SD = 2.33), and 35.3% were non-Hispanic white, 31.1% Hispanic, 18.3% Asian, 7.8% African American/Black, and 7.5% other/multiracial (see Table 1). Cigarettes were the most used tobacco product across each measurement occasion followed by, ENDS, hookah, cigars, and smokeless (see Table 1). For each tobacco product, except ENDS, the prevalence of use decreased from baseline to the one-year follow-up and from the one- to the three-year follow-up. Current ENDS use dropped from baseline to the one-year follow-up but increased to nearly the baseline prevalence at the three-year follow-up. Prevalence of past 30-day Cannabis use was highest at baseline and dropped at the three-year follow-up. Of the co-administration measures, past 6-month blunt use had the highest prevalence at baseline but was exceeded by cannabis use in ENDS at the three-year follow up. Further, of the four types of co-administration, cannabis use in ENDS was the only type of co-administration to increase from baseline to the three-year follow up. Spliff use followed by cannabis use in hookah were the least endorsed of the co-administration measures (see Table 1).

3.1. Latent class characteristics at baseline

The latent Markov model with the best model fit indices, statistically significant BLRT, and sufficient class membership included four latent classes (see Table 2). Participants in the first class, termed "non-use" (57.8% of the sample), had very low or no probability of any of the use items (see Table 3). The second class, termed "general use" (18.9% of the sample), had low probabilities of tobacco product use, ranging from smokeless (0.06) to cigarettes (0.42), cannabis (0.12), and co-administration, from blunts (0.02) to cannabis in ENDS (0.12) (see Table 3). The third class, termed "blunt and cannabis use" (13.2% of the sample), had high probability of past 30-day cannabis use (0.82) and past 6-month blunt use (0.57). The fourth class, termed "concurrent and co-administration use" (10.1% of the sample) had high probabilities of concurrent past 30-day cannabis and cigarette use, and past 6-month blunt and spliff use (0.92 to 0.65; see Table 3). Female students made up a statistically significantly larger proportion of membership in each class compare with males, except for the concurrent and coadministration use class (χ^2 = 22.9 – 628.5, p-values < 0.001; see Supplemental Table 1). Further, there were statistically significant differences in proportions of racial/ethnic groups within each of the four latent classes (χ^2 = 184.9 – 792.7, p-values < 0.001).

3.2. Stability of class membership and transition probabilities

In general, there was a high probability of participants remaining in the same latent class from baseline to the one-year follow-up (see Table 4). However, 5% of students in the "non-use" class transitioned to the "blunt and cannabis use" class and 3% of students in the "blunt and cannabis use" and 7% of students within the "general use" class transitioned to the "concurrent and co-administration use" class. Further, 8% of students in the "concurrent and co-administration use" class transitioned to the "blunt and cannabis use" class while 17% transitioned to the "general use" class. Of participants in the "blunt and cannabis use" class at baseline, 14% transitioned to the "non-use" class at the one-year follow-up, indicating these individuals decreased their use behavior. Among students in the "general use" class, 13% transitioned to the "non-use" class and 3% transitioned to the "blunt and cannabis use" class (see Table 4).

Transition patterns from the one- to three-year follow-up were similar to the transitions from baseline to the one-year follow up with a few exceptions (see Table 4). Specifically, 21% of students in the "blunt and cannabis use" class and 4% of students in the "general use" class transitioned to the "non-use" class from the one- to three-year follow-up. The percentage of students who remained in the "non-use" class decreased slightly from 95% to 91%, across the two transitions because a greater proportion of students in the "non-use" class transitioned to the "general use" classes between transitions (see Table 4).

From baseline to three-year follow-up, a small number of students transitioned from the non-use to the general use class (2%) and the blunt and cannabis use (7%) groups while no students transitioned to the concurrent and co-administration use class (see Table 4). Of students in the general use class at baseline, 11% transitioned to the non-use class, 4% to the blunt and cannabis use class, and 7% to the concurrent and co-administration use class. Nearly a quarter of students in the blunt and cannabis use class transitioned to the non-use class while 1% transitioned to the general use class and 3% to the concurrent and co-administration use class. Of students in the concurrent and co-administration class at baseline, 22% transitioned to the general use class, 8% transitioned to the blunt and cannabis use class, and 1% transitioned to the non-use class.

Of students who transitioned to the non-use class, a greater proportion were females compared to males, including from baseline to one-year follow-up, one-year to three-year follow-up, and from baseline to three-year follow-up (see supplemental Table 2; $\chi^2 =$ 16.20–39.03, p-values < 0.001). Further, a larger proportion of students who transferred to the blunt and cannabis use class were female from baseline to one-year follow-up ($\chi^2 =$ 21.89, p-value < 0.001) and from baseline to three-year follow-up ($\chi^2 = 19.59$, p-value < 0.001) but there was not a statistically significant difference in proportions from one-year to three-year follow-up. Omnibus tests found statistically significant differences in proportions of racial/ethnic groups transitioning to each of the four use classes from baseline to one-year follow-up, one-year to three-year follow-up, and from baseline to three-year follow-up (see supplemental Table 2; $\chi^2 = 34.77$–36.83, p-values < 0.001) with the exception of transitions to the concurrent and co-administration class from one-year to three-year follow-up.

3.3. General changes in use behaviors

Students were categorized into five groups based on their changes in use behavior throughout the study: 1) students with "no change," did not change their tobacco use behavior, 2) students who "decreased," transitioned from a higher use class to a lower use class (e.g. transitioned from the general use to non-use class), 3) students who "increased," transitioned from a lower to a higher use class (e.g. transitioned from the non-use to the blunt and cannabis class), 4) students who "experimented," transitioned from non-use to a use class from baseline to one-year follow up but transitioned back to the non-use class during the three-year follow up, and 5) students who were "varied," a group that captured students who transitioned between use classes without a clear increase or decrease (e.g. transitioned between the general use and blunt and cannabis use classes). Most students did not change their use behavior during the study (82.5%, n = 3,671) while 8.5% (n = 380) decreased use, 7.8% (n = 348) increased use, 0.7% (n = 32) were experimenters, and 0.4% (n = 17) varied or transitioned between the general use and blunt and cannabis use classes.

4. Discussion

This is one of the largest studies with the longest time frame to examine patterns of concurrent cannabis and tobacco use and the only such study to include measures of cannabis and tobacco co-administration among young adult college students. Our study built upon previous work by including measures of concurrent and co-administration of cannabis and tobacco at three occasions, over the course of three years, independent of alcohol or other substance use, which allowed for the estimation of transition probabilities between latent classes of cannabis and tobacco use. We identified four latent classes, which included non-use, general use, blunt and cannabis use, and concurrent and co-administration use classes. Further, we found that 82.5% of students remained in the same use class from baseline to the three-year follow-up while 8.5% decreased their use behavior, 7.8% increased, 0.7% experimented (e.g., transitioned from non-use to general or blunt and cannabis use classes and then transitioned back to non-use).

Of the four latent classes identified, the non-use class included the most students. The percentage of students in the non-use class in this study was similar to previous studies that found about 60% of college students were classified as either low or non-use. (Evans-Polce et al., 2016; Bin et al., 2015) Haardörfer et al. (2016) (Haardörfer et al., 2016) found between 20.8% and 28.8% of participants to be in a class characterized as non-use, however, their study included alcohol use as a class indicator and the researchers found one class characterized by only alcohol use that included between 35.5% and 37.9% of students. It is likely that if alcohol use was not included as an indicator, these students would have been classified into the non-use class making their findings similar to our study. In our study we also found a small percentage of students transitioned from the non-use to either the cannabis use or general use classes but not to the concurrent and co-administration use class. These transitions may indicate a general pattern of increasing use behavior from non-use to blunt and cannabis use or to separate cannabis and tobacco use (general use class). Findings from our study and the three previous studies consistently find that most college students

do not report any current tobacco or cannabis use but a substantial percentage of college students (around 40%) report use of cannabis, tobacco, or both.

The "general use" class included between 17.1% (one-year follow-up) and 18.9% (baseline) of students. Students in this class did not have a high probability of use of any one tobacco product, cannabis, or co-administration indicating that this class was made up students representing a mixture of use behaviors. This class is similar to a latent class found by Haardörfer and colleagues (2016) (Haardörfer et al., 2016) characterized by low probabilities of past 30-day cigarette, cigar, ENDS, hookah, and cannabis use that included 15.5% of college students. While 10% of students in the general use class in our study transitioned to another use class at each transition occasion, which may indicate an increase in use behavior, 13% of students in this class transitioned to the non-use class from baseline to one-year and 4% from one- to three-year follow up indicating a decrease in use behavior. Additionally, 11% of students who were in the general use class at baseline transitioned to non-use at the three-year follow-up. Students who transitioned to the non-use class from the general use class may have been experimenters. More research, including qualitative work, is needed to understand characteristics of students within this general use class, such as frequency of use, reasons for use, context of use, and nicotine or cannabis dependence, to tailor interventions aimed at preventing escalation of use and promoting cessation.

The present study found a latent class of college students characterized by high probability of past 30-day cannabis use and past 6-month blunt use, which ranged from 13.2% of students at baseline to 15.0% at the one-year follow-up. Previous research has not found a latent class characterized by past 30-day cannabis use and co-administration of cannabis in tobacco products. Haardörfer et al., (2016) (Haardörfer et al., 2016) found a class with high probabilities of LCC, hookah, and cannabis concurrent use separate from latent classes characterized by polytobacco use. However, they did not measure blunt use and it is probable that a proportion of students within the LCC, hookah, and cannabis latent class were blunt users. The latent class of blunt and cannabis users in our study may reflect an increase in social acceptance of cannabis use associated with increased legalization. (Kerr et al., 2017; Parnes et al., 2018; Wen et al., 2019) Interestingly, 14% and 21% of college students in the present study within this blunt and cannabis use class transitioned to the non-use class from baseline to one-year and from one-year to three-year follow-ups, suggesting decreases in use behavior. Additionally, 24% of students in the blunt and cannabis use class at baseline transitioned to non-use at the three-year follow-up. Students who transitioned from the blunt and cannabis only to the non-use class may represent experimental users or occasional users who may use cannabis in the context of a social gathering. A recent study found college students who do not use daily were more likely to use cannabis in a social context. (Phillips et al., 2018) More research should focus on students who remained in the blunt and cannabis use class, to determine, for example, what proportion of these students meet the criteria for a DSM-IV cannabis dependence diagnosis as well as the long-term health outcomes tied to separate cannabis use and co-administration.

The "concurrent and co-administration use" class was the smallest of the four classes (8.9% three-year follow up to 10.1% at baseline). This class had a high probability of concurrent past 30-day cannabis and cigarette use as well as past 6-month co-administration

of blunts and spliffs. These findings build on previous research that shows high probabilities of concurrent use and extend this research by showing that co-administration often co-occurs with tobacco use. (Haardörfer et al., 2016; Evans-Polce et al., 2016; Bin et al., 2015) Compared to their peers who may be experimenting, students who remained in the concurrent and co-administration class throughout the three years of this study represent the most at-risk for negative health outcomes. Concurrent cigarette and cannabis use has been associated with short-term health issues such as poor lung functioning (Correa et al., 2020; Taylor et al., 2002) and increased dependence on nicotine (Patton et al., 2005; Seaman et al., 2020) but more research is needed to examine long term health outcomes such as cancer, stroke, and heart disease that has been linked with individual use of cigarettes and cannabis. (Rumalla et al., 2016; Franz and Frishman, 2016; CDC's Office on Smoking and Health. Smoking and Tobacco Use; Health Effects. Published, 2018) Further, we found 3% of students within the blunt and cannabis use class transitioned to this class during both transition occasions and from baseline to three-year follow-up. This transition pattern may be explained by the fact that blunt users, which students in the cannabis use class had a high probability of being, are exposed to nicotine (Peters et al., 2016) and thus may be more likely to transition to using spliffs or cigarettes compared to their peers. Past research has found early exposure to cannabis is associated with tobacco use in college and adulthood. (Reboussin et al., 2021) Further research is needed to better understand the role of blunt use in predicting transitions to tobacco from cannabis use among young adult college students. Public health interventionists on college campuses could then tailor interventions to those who are at greater risk of tobacco use based on how they use cannabis.

An important finding of our study was the consistency of class membership, indicating college student cannabis and tobacco use patterns are stable, not only from one semester to the next (Bin et al., 2015) but across three years. Previous studies of substance use, other than cannabis and tobacco, among young adult college students similarly have found stable use patterns over time. For example, research by Cleveland et al., (2012) (Cleveland et al., 2012) found high stability of heavy alcohol use from the summer prior to beginning college and the fall semester of college. Similarly, Lanza and colleagues (2010) (Lanza et al., 2010) found high stability of membership in both binge drinking and binge drinking and cannabis use latent classes among first-year college students from the fall of 2007 to spring of 2008. Considering previous research and our findings together, most college students will be non-users of tobacco or cannabis products, but for those that do use, the use behaviors tend to be consistent over time, suggesting the need for early intervention prior to the establishment of use.

4.1. Limitations

While this study offers meaningful insights into cannabis and tobacco co-use among young adult college students, it is not without limitations. This study used a convenience sample of participants from colleges and universities within the state of Texas and the findings may not be generalizable to students from other states, particularly states with legal recreational cannabis. Despite this limitation, our study is the first to examine latent classes with measures of both concurrent and co-administration. More research is needed on concurrent use and co-administration of cannabis with tobacco among young adults in states with legal

cannabis as a wider variety of cannabis products may be available and used differently in these states. Another limitation is the measurements of current marijuana and tobacco product use within the past 30-days while the co-administration questions asked students to recall their use within the past 6-months. It is possible that measuring co-administration within the past 30-days rather than 6-months could change the latent classes discovered as the number of individuals engaging in co-administration use behaviors would likely decrease. Additionally, previous studies have used measures of past 30-day use (Reboussin et al., 2021; Cohn et al., 2019) which may make comparisons of findings less meaningful. Despite these limitations, the general findings of a low or no use and a high use class, with classes characterized by a mixture of use in between, correspond with previous research and expand these findings with the additional finding of a class characterized by concurrent and co-administration of cannabis and tobacco.

4.2. Summary and implications

This study builds upon prior research by examining latent classes with a unique combination of past 6-month co-administration and separate past 30-day use of cannabis and tobacco over three years. We found four distinct classes of use behavior among college students including a non-use class, a class with low probabilities of any specific tobacco product, cannabis, or co-administration method, a class with high probability of cannabis and blunt use, and a class with high probability of cigarette, cannabis, blunt, and spliff use. It is important to note that classes with high probability of past 30-day cannabis use had high probabilities of co-administration supporting previous findings that many college students who use cannabis are exposed to nicotine through co-administration of cannabis with tobacco products. Class membership was stable across the three years indicating a need for cannabis and tobacco prevention programs to target individuals as they enter or prior to college, as suggested by previous researchers. (Bin et al., 2015) Public health advocates on college campuses should consider cannabis and tobacco use as a constellation of use behaviors and educate their students of the health consequences of co-use.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Funding

Data availability

Data will be made available on request.

References

Romm K, Wang Y, Duan Z, et al. Psychosocial predictors of longitudinal changes in tobacco and cannabis use among young adults. Elsevier. Accessed August 20, 2023. https://www.sciencedirect.com/science/article/pii/S0306460322000302.

Schulenberg JE, Johnston LD, O'Malley PM, Bachman JG, Miech RA, Patrick ME. Monitoring the Future National Survey Results on Drug Use, 1975–2019: Volume II, College Students and Adults Ages 19–60.; 2020. http://www.monitoringthefuture.org/pubs/monographs/mtf-vol2_2019.pdf.

Seaman EL, Green KM, Wang MQ, Quinn SC, & Fryer CS (2019). Examining prevalence and correlates of cigarette and marijuana co-use among young adults using ten years of NHANES data. Addictive Behaviors, 96, 140–147. 10.1016/j.addbeh.2019.04.014 [PubMed: 31078741]

Correa JB, Myers MG, Tully LK, & Doran N (2020). Co-occurring Use of Cannabis and Tobacco and the Presence of Acute Respiratory Symptoms among Young Adult Light and Intermittent Smokers. Substance Use & Misuse, 1–9. 10.1080/10826084.2020.1793366. Published online.

Taylor DR, Fergusson DM, Milne BJ, et al. (2002). A longitudinal study of the effects of tobacco and cannabis exposure on lung function in young adults. Addiction, 97(8), 1055–1061. 10.1046/j.1360-0443.2002.00169.x [PubMed: 12144608]

Patton GC, Coffey C, Carlin JB, Sawyer SM, & Lynskey M (2005). Reverse gateways? Frequent cannabis use as a predictor of tobacco initiation and nicotine dependence. Addiction, 100(10), 1518–1525. 10.1111/j.1360-0443.2005.01220.x [PubMed: 16185213]

Seaman EL, Stanton CA, Edwards KC, & Halenar MJ (2020). Use of tobacco products/devices for marijuana consumption and association with substance use problems among U.S. young adults (2015–2016). Addictive Behaviors, 102. 10.1016/j.addbeh.2019.106133

Berg CJ, Stratton E, Schauer GL, et al. (2015). Perceived Harm, Addictiveness, and Social Acceptability of Tobacco Products and Marijuana Among Young Adults: Marijuana, Hookah, and Electronic Cigarettes Win. Substance Use & Misuse, 50(1), 79–89. 10.3109/10826084.2014.958857 [PubMed: 25268294]

Pedersen ER, Tucker JS, Davis JP, et al. (2020). Tobacco/Nicotine and Marijuana Co-Use Motives in Young Adults: Associations With Substance Use Behaviors One Year Later. Psychology of Addictive Behaviors. 10.1037/adb0000638. Published online.

Tucker JS, Pedersen ER, Seelam R, Dunbar MS, Shih RA, & D'Amico EJ (2019). Types of Cannabis and Tobacco/Nicotine Co-Use and Associated Outcomes in Young Adulthood. Psychology of Addictive Behaviors, 33(4), 401. 10.1037/adb0000464 [PubMed: 30985164]

Jones CB, Hill ML, Pardini DA, & Meier MH (2016). Prevalence and correlates of vaping cannabis in a sample of young adults. Psychology of Addictive Behaviors, 30 (8), 915–921. 10.1037/adb0000217 [PubMed: 27631612]

Reboussin BA, Wagoner KG, Ross JC, Suerken CK, & Sutfin EL (2021). Tobacco and marijuana co-use in a cohort of young adults: Patterns, correlates and reasons for co-use. Drug and Alcohol Dependence, 227. 10.1016/j.drugalcdep.2021.109000

Cohn AM, Abudayyeh H, Perreras L, & Peters EN (2019). Patterns and correlates of the co-use of marijuana with any tobacco and individual tobacco products in young adults from Wave 2 of the PATH Study. Addictive Behaviors, 92, 122–127. 10.1016/j.addbeh.2018.12.025 [PubMed: 30623805]

Blair LM, Ickes M, McCubbin A, & Ashford K (2022). PATH to understanding cannabis and nicotine initiation and co-use among emerging adults. Public Health Nursing, 39(5), 973–981. 10.1111/PHN.13094 [PubMed: 35609183]

Berg CJ, Haardörfer R, Lanier A, et al. (2020). Tobacco Use Trajectories in Young Adults: Analyses of Predictors Across Systems Levels. Nicotine & Tobacco Research, 22 (11), 2075–2084. 10.1093/NTR/NTAA048 [PubMed: 32170324]

Lanza ST, Bray BC, & Collins LM (2012). An Introduction to Latent Class and Latent Transition Analysis. In Handbook of Psychology (Second Edition). John Wiley & Sons, Inc. 10.1002/9781118133880.hop202024

Haardörfer R, Berg CJ, Lewis M, et al. (2016). Polytobacco, marijuana, and alcohol use patterns in college students: A latent class analysis. Addictive Behaviors, 59, 58–64. 10.1016/j.addbeh.2016.03.034 [PubMed: 27074202]

Evans-Polce R, Lanza S, & Maggs J (2016). Heterogeneity of alcohol, tobacco, and other substance use behaviors in US college students: A latent class analysis. Addictive Behaviors, 53, 80–85. https://www.sciencedirect.com/science/article/pii/S0306460315300393. [PubMed: 26476004]

Bin CS, Llaneza DC, Adkins AE, et al. (2015). Patterns of substance use across the first year of college and associated risk factors. Front Psychiatry, 6(OCT). 10.3389/fpsyt.2015.00152

Loukas A, Chow S, Pasch KE, et al. (2016). College Students' Polytobacco Use, Cigarette Cessation, and Dependence. American Journal of Health Behavior, 40(4), 514–522. 10.5993/AJHB.40.4.13 [PubMed: 27338998]

Loukas A, Marti CN, Pasch KE, Harrell MB, Wilkinson AV, & Perry CL (2022). Rising vape pod popularity disrupted declining use of electronic nicotine delivery systems among young adults in Texas, USA from 2014 to 2019. Addiction, 117(1), 216–223. 10.1111/ADD.15616 [PubMed: 34159679]

Clendennen SL, Loukas A, Creamer MLR, Pasch KE, & Perry CL (2019). Longitudinal Patterns of Multiple Tobacco and Nicotine Product Use Among Texas College Students: A Latent Transition Analysis. Prevention Science, 20(7), 1031–1042. 10.1007/s11121-019-01031-3 [PubMed: 31302841]

Akaike H Information Theory and an Extension of the Maximum Likelihood Principle. In: In Petrov BN, Csaki F (Eds.), Second International Symposium on Information Theory. Akademiai Kiado; 1973:267–281. doi:10.1007/978-1-4612-0919-5_37.

Schwarz G (1978). Estimating the Dimension of a Model. The Annals of Statistics, 6(2), 461–464. 10.1214/aos/1176344136

R: A language and environment for statistical computing. Published online 2021. https://www.r-project.org/.

Bartolucci F, Pandolfi S, & Pennoni F (2017). Lmest: An R package for latent Markov models for longitudinal categorical data. Journal of Statistical Software, 81. 10.18637/jss.v081.i04

Kerr DCR, Bae H, Phibbs S, & Kern AC (2017). Changes in undergraduates' marijuana, heavy alcohol and cigarette use following legalization of recreational marijuana use in Oregon. Addiction, 112(11), 1992–2001. 10.1111/add.13906 [PubMed: 28613454]

Parnes JE, Smith JK, & Conner BT (2018). Reefer madness or much ado about nothing? Cannabis legalization outcomes among young adults in the United States. The International Journal on Drug Policy, 56, 116–120. 10.1016/j.drugpo.2018.03.011 [PubMed: 29626630]

Wen H, Hockenberry JM, & Druss BG (2019). The Effect of Medical Marijuana Laws on Marijuana-Related Attitude and Perception Among US Adolescents and Young Adults. Springer., 20(2), 215–223. 10.1007/s11121-018-0903-8

Phillips KT, Phillips MM, Lalonde TL, & Prince MA (2018). Does social context matter? An ecological momentary assessment study of marijuana use among college students. Addictive Behaviors, 83, 154–159. 10.1016/J.ADDBEH.2018.01.004 [PubMed: 29329753]

Rumalla K, Reddy AY, & Mittal MK (2016). Recreational marijuana use and acute ischemic stroke: A population-based analysis of hospitalized patients in the United States. Journal of the Neurological Sciences, 364, 191–196. 10.1016/j.jns.2016.01.066 [PubMed: 26874461]

Franz CA, & Frishman WH (2016). Marijuana Use and Cardiovascular Disease. Cardiology in Review, 24(4), 158–162. 10.1097/CRD.0000000000000103 [PubMed: 26886465]

CDC's Office on Smoking and Health. Smoking and Tobacco Use; Health Effects. Published 2018. Accessed January 19, 2019. https://www.cdc.gov/tobacco/basic_information/health_effects/index.htm.

Peters EN, Schauer GL, Rosenberry ZR, & Pickworth WB (2016). Does marijuana "blunt" smoking contribute to nicotine exposure?: Preliminary product testing of nicotine content in wrappers of cigars commonly used for blunt smoking. Drug and Alcohol Dependence, 168, 119–122. 10.1016/j.drugalcdep.2016.09.007 [PubMed: 27639129]

Cleveland MJ, Lanza ST, Ray AE, Turrisi R, & Mallett KA (2012). Transitions in First-Year College Student Drinking Behaviors: Does Pre-College Drinking Moderate the Effects of Parent- and

Peer-Based Intervention Components? Psychology of Addictive Behaviors, 26(3), 440. 10.1037/ A0026130 [PubMed: 22061340]

Lanza ST, Patrick ME, Maggs JL. Latent Transition Analysis: Benefits of a Latent Variable Approach to Modeling Transitions in Substance Use. J Drug Issues. 2010;40(1):93. Accessed August 9, 2021. [PubMed: 20672019]

Table 1

Demographic characteristics and prevalence of tobacco, marijuana, and co-administration among young adult college students in Texas (n = 4,448).

Characteristic	n (%) or Mean (SD)		
Male	1,590 (35.7)		
Female	2,856 (64.2)		
Age (years)	20.5 (2.3)		
White	1,570 (35.3)		
Hispanic	1,383 (31.1)		
African American	350 (7.8)		
Asian American	812 (18.3)		
Other/Multiracial	333 (7.5)		
Use Item	**Baseline n (%)**	**One-year Follow Up n (%)**	**Three-year Follow Up n (%)**
Current Cigarettes	758 (17.0)	662 (14.9)	559 (12.6)
Current ENDS	480 (10.8)	363 (8.2)	473 (10.6)
Current Cigars	266 (6.0)	207 (4.7)	198 (4.5)
Current Smokeless	103 (2.3)	95 (2.1)	74 (1.7)
Current Hookah	493 (11.1)	374 (8.4)	305 (6.9)
Past 6-Months Spliffs	563 (12.7)	481 (10.8)	446 (10.0)
Past 6-Months Cannabis in ENDS	463 (10.4)	419 (9.4)	727 (16.3)
Past 6-Months Blunts	707 (15.9)	614 (13.8)	570 (12.8)
Past 6-Months Cannabis in Hookah	323 (7.3)	202 (4.5)	157 (3.5)
Current Cannabis	1,050 (23.6)	963 (21.7)	899 (20.2)

Note: Counts and prevalence of each category is among participants with complete data for at least one use item measured during baseline (n = 4,448). Current use refers to use of each product at least once in past 30 days and past 6-months is any use in past 6-months. The baseline measurement occasion occurred in spring of 2016, one-year follow up in spring of 2017, and three-year follow up in spring of 2019.

There were two individuals who were missing sex.

Table 2

Summary of model fit indices for selecting number of latent classes of college student marijuana and tobacco use and co-administration (baseline, one-year, and three-year follow up; n = 4,448).

Number of latent classes	Class with<10%	Log-likelihood	Degrees of freedom	AIC	BIC	BLRT p-value
1	No	−78483.26	20	157006.50	157134.50	NA
2	No	−33502.07	45	67094.14	67382.15	<0.01
3	No	−32199.73	74	64547.45	65021.07	<0.01
4	No	−31413.08	67	62960.16	63388.97	<0.01
5	Yes	−30990.38	144	62268.77	63190.40	<0.01

AIC = Akaike information criterion; BIC = Bayesian information criterion; BLRT = bootstrapped likelihood ratio test.

Table 3

Initial class membership probabilities by cannabis and tobacco use behaviors, estimated during wave two of project M–PACT, among young adult college students in Texas (n = 4,448).

	Non-use (57.8%; n = 2,572)	General use (18.9%; n = 840)	Blunt and Cannabis use (13.2%; n = 585)	Concurrent and Co-administration use (10.1%; n = 451)
Use items				
Cigarettes	0	0.42	0.07	0.74
ENDS	0	0.27	0.09	0.44
Cigar	0.01	0.11	0.04	0.26
Smokeless	0	0.06	0	0.11
Hookah	0.01	0.24	0.09	0.34
Spliff	0	0.08	0.30	0.65
Cannabis & ENDS	0.01	0.12	0.37	0.52
Blunts	0.01	0.02	0.57	0.68
Cannabis & Hookah	0.01	0.11	0.09	0.21
Cannabis	0.02	0.12	0.82	0.92

Note: There were two students who had missing information for sex, one student in the non-use and another in the marijuana use group. Latent class categories were named based on the distribution of probabilities by use items to best characterize each latent class.

Table 4

Latent class transition probabilities from baseline to one-year follow-up, one-year follow up to three-year follow-up, and baseline to three-year follow-up among young adult college students in Texas (n = 4,448).

		One-Year Follow Up			
		Non-use (58.5%; n = 2,602)	General use (17.1%; n = 762)	Blunt and Cannabis use (15.0%; n = 665)	Concurrent and Co-administration use (9.4%; n = 419)
Baseline	Non-use (57.8%; N = 2,572)	0.95	0	0.05	0
	General use (18.9%; N = 840)	0.13	0.77	0.03	0.07
	Blunt and Cannabis use (13.2%; N = 585)	0.14	0.03	0.80	0.03
	Concurrent and Co-administration use (10.1%; N = 451)	0	0.17	0.08	0.74

		Three-Year Follow Up			
		Non-use (57.9%; n = 2,575)	General use (18.3%; n = 815)	Blunt and Cannabis use (14.9%; n = 662)	Concurrent and Co-administration use (8.9%; n = 396)
One-Year Follow Up	Non-use (58.5%; N = 2,602)	0.91	0.04	0.05	0
	General use (17.1%; N = 762)	0.04	0.85	0.05	0.05
	Blunt and Cannabis use (15.0%; N = 665)	0.21	0	0.77	0.03
	Concurrent and Co-administration use (9.4%; N = 419)	0	0.15	0.08	0.78

		Three-Year Follow Up			
		Non-use (57.9%; n = 2,575)	General use (18.3%; n = 815)	Blunt and Cannabis use (14.9%; n = 662)	Concurrent and Co-administration use (8.9%; n = 396)
Baseline	Non-use (57.8%; N = 2,572)	0.91	0.02	0.07	0
	General use (18.9%; N = 840)	0.11	0.78	0.04	0.07
	Blunt and Cannabis use (13.2%; N = 585)	0.24	0.01	0.72	0.03
	Concurrent and Co-administration use (10.1%; N = 451)	0.01	0.22	0.08	0.69

The one-year follow up measurement occasion occurred in the spring of 2017 and the three-year follow up in the spring of 2019.