RESEARCH ARTICLE

Daily-level simultaneous alcohol and marijuana use and its associations with alcohol use, marijuana use, and negative consequences in a young adult community sample

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Abstract

Background: Simultaneous alcohol and marijuana (SAM) use has been associated with greater alcohol use and consequences at the daily level, but limited research has examined SAM use in relation to marijuana use and its consequences. This study tested daily associations between SAM use and four outcomes: alcohol use (number of drinks), marijuana use (hours high), negative alcohol consequences, and negative marijuana consequences.

Methods: A community sample of young adults [ages 18–25, mean (SD) = 21.61 (2.17) years] with recent alcohol and SAM use was recruited (N = 409; 50.9% female; 48.2% non-Hispanic/Latinx White). Participants completed a baseline survey and six 2-week bursts of daily surveys (81.1% of morning surveys completed) and reported on substance use and negative substance-related consequences. Multilevel modeling was used to test the main aims and to explore each specific consequence.

Results: Among days with any alcohol use, SAM use days were associated with consuming more drinks and experiencing more total negative alcohol-related consequences than non-SAM use days. Among days with any marijuana use, SAM use days were associated with more hours being high than non-SAM use days. Exploratory models showed that SAM use was related to five specific alcohol-related consequences and two specific marijuana-related consequences.

Conclusions: These findings build upon prior research by showing that SAM use days are linked to consuming more drinks, reporting more hours being high from marijuana, and experiencing more total alcohol-related consequences even after controlling for the number of drinks, the number of hours high, any tobacco/nicotine use, and any other substance use. SAM use was also associated with a greater likelihood of experiencing some specific consequences related to alcohol and marijuana. The findings underscore the need for additional research on SAM use and marijuana-related outcomes.

KEYWORDS
alcohol, consequences, marijuana, SAM use, young adults

INTRODUCTION

The prevalence of young adult alcohol and marijuana use is highest relative to other substances. Recent national US data show that 28.5% of young adults reported marijuana use in the past month, and 66.3% reported alcohol use in the past month with 32.0% consuming 5+ drinks in a row within the last 2 weeks (Patrick, Schulenberg, et al., 2022). Moreover, young adults who use both alcohol and marijuana often engage in simultaneous alcohol and marijuana (SAM) use, defined as using these substances such that their effects overlap (Lee et al., 2022). Research suggests that approximately 75% of young adults who use marijuana and 20%–25% of all young adults engage in SAM use (Patrick et al., 2019; Terry-McElrath & Patrick, 2018). A recent review found evidence for both substitution effects (one substance is used in place of the other) and complementary effects (both substances are used to enhance the effects) across a range of methodologies, including laboratory, survey, and ecological momentary assessment (Gunn et al., 2022). Previous daily-level research has documented positive associations for SAM use with alcohol consumption and/or negative alcohol consequences (Lee et al., 2020; Linden-Carmichael et al., 2020); however, some research has not identified daily-level associations between SAM use and consequences, such as Sokolovsky et al. (2020) where a variety of definitions of SAM use were tested. It is imperative that we continue this line of research as 22 states and the District of Columbia have legalized nonmedical marijuana use for adults ages 21 and older, coupled with high prevalence rates of alcohol and marijuana use (Patrick, Kloska, et al., 2021). Specifically, there is a need to determine whether days young adults engage in SAM use are associated with more alcohol use (drinks consumed) and negative alcohol consequences as well as extend this research to test whether SAM use days are associated with more marijuana use (hours high) and negative marijuana consequences.

Links among SAM use and consequences

Cross-sectional and longitudinal research has demonstrated that individuals who engage in SAM use are more likely to experience consequences than individuals who report alcohol use alone (Jackson et al., 2021; Patrick et al., 2019; Thompson et al., 2021). Germane to the current study, prior daily-level research has tested associations between SAM use and negative alcohol consequences, showing that SAM use has been linked to experiencing more negative alcohol-related consequences relative to days when using only alcohol (Egan et al., 2019; Lee et al., 2020; Linden-Carmichael et al., 2020). Additionally, in our own work, we have found that SAM use is linked at the daily level to increased odds of impaired driving or riding with an impaired driver (Patrick, Graupensperger, et al., 2021) and to increased mental health symptoms for those who endorse coping motives (Patrick, Ramirez, et al., 2022). Using two bursts, a subset of the daily-level data from this study, Lee et al. (2020) compared SAM use days to alcohol-only days among a sample of young adults who reported past month alcohol use and SAM use at screening. Relative to alcohol-only days, SAM use days were associated with more alcohol use (number of drinks) and more negative alcohol consequences, but the association between SAM use and negative alcohol consequences was not significant after controlling for number of drinks. Among the few studies examining SAM use and marijuana days, Linden-Carmichael et al. (2020) reported that SAM use days had more negative substance-use related consequences (i.e., not specific to alcohol or marijuana) relative to marijuana days, controlling for number of hits, cigarette/vaping use, and other substance use. However, number of hits was not significantly associated with negative substance-use-related consequences. Notably, Linden-Carmichael and colleagues adapted a daily-level alcohol consequence measure to refer generally to alcohol or other substance use. Thus, the field would benefit from understanding SAM use in relation to marijuana-specific consequences. In this study, the marijuana consequences measure included consequences that may pertain to marijuana (but not alcohol) use, and consequences were assessed separately for alcohol and marijuana.

This study tested whether engaging in SAM use at the daily level was associated with drinks consumed and negative alcohol consequences compared with non-SAM use days, including both alcohol-only and same-day co-use days. This approach differs from a previous study by extending our work in Lee et al. (2020) that compared SAM use days to alcohol-only days. Here, same-day co-use days are days on which young adults reported both alcohol and marijuana use but did not report using so that effects overlapped. Moreover, this study expands this body of literature in two important ways. First, in addition to testing SAM use and alcohol outcomes, this study tests whether at the daily-level SAM use days were associated with hours high from marijuana and total negative marijuana consequences compared with non-SAM use days, including both marijuana-only and same-day co-use days. Second, unlike much of the previous literature, when testing associations between SAM use and consequences, we controlled for amount of use for both alcohol and marijuana as well as any tobacco/nicotine use and other substance use in order to determine the unique effect of SAM use above and beyond these covariates.

Although the risks associated with SAM use are becoming clearer as the evidence mounts (Lee et al., 2022), there remains much to be learned about *for whom* SAM use presents higher risk of negative consequences. Limited studies to date have examined for whom SAM use days may confer greater risk of negative consequences (e.g., biological sex in Linden-Carmichael et al., 2020). Of interest in this study, individuals with a background of hazardous alcohol or marijuana use may have a general predisposition to experience more use or consequences, potentially reinforcing the daily link between SAM use and substance use outcomes. Furthermore, although available evidence is limited, a study with veterans found that the daily association between heavy drinking and marijuana use may be especially pronounced in veterans with both alcohol and marijuana use disorders as well as veterans with an alcohol use disorder, but less so for veterans with only a marijuana use disorder

(Metrik et al., 2018). Thus, this study aims to explore the extent to which a background substance use characteristic, namely hazardous use based on Alcohol Use Disorders Identification Test (AUDIT) and Cannabis Use Disorders Identification Test (CUDIT) cutoffs, may moderate daily associations between SAM use and substance use outcomes among young adults.

The current study

This study examined daily-level SAM use in association with alcohol use, marijuana use, and negative alcohol- and marijuana-related consequences in a community sample of young adults. *Aim 1* examined whether SAM use days, as compared to non-SAM use days, were associated with consuming more drinks on days with any alcohol use and reporting more hours high on days with any marijuana use. *Aim 2* examined whether SAM use days were associated with experiencing more total negative alcohol consequences and more total negative marijuana consequences as compared to non-SAM use days. Models predicting alcohol- and marijuana-related consequences controlled for number of drinks, number of hours high, any tobacco/nicotine use, and any other substance use. Based on previous research testing SAM use and consequences (e.g., Lee et al., 2020; Linden-Carmichael et al., 2020), we expected that SAM use days would be associated with consuming more drinks, reporting more hours high, and experiencing more negative alcohol and marijuana consequences.

Two sets of exploratory analyses were conducted. The first set examined daily-level associations between SAM use and 15 specific negative alcohol-related consequences and 10 specific negative marijuana-related consequences. The second set examined hazardous use as a person-level moderator, which was indicated by baseline AUDIT scores of 8+ in alcohol models and baseline CUDIT-R scores of 13+ in marijuana models. We explored for whom effects of the daily-level associations between SAM use and outcomes, as specified in Aims 1 and 2, may be stronger. Analyses tested (a) whether the daily associations between SAM use and number of drinks consumed and consequences were moderated by hazardous alcohol use (baseline AUDIT scores of 8+) and (b) whether the daily associations between SAM use and hours high from marijuana and consequences were moderated by hazardous marijuana use (baseline CUDIT-R scores of 13+).

MATERIALS AND METHODS

Participants

A community sample of young adults was recruited in the greater Seattle, Washington area, for a longitudinal daily study examining SAM use and health behaviors (*N*=409; Fairlie et al., 2021; Graupensperger et al., 2022; Lee et al., 2020). Study eligibility criteria included being 18–25 years old; reporting SAM use at least once in the past month; reporting drinking alcohol three or more times in the past month; living within 60 miles of the study office; being willing to complete online daily surveys; being willing to receive study-related text messages; and attending an in-person session for consent, identity/age verification, and an online baseline survey. Daily procedures consisted of online surveys (2×/day; morning and afternoon) in six 14-day bursts across 2 years. These analyses use baseline covariates (described below) and daily data from all six bursts, noting that some participants (*n*=130; 31.8%) completed some or all of the final burst during the COVID-19 pandemic.

Half (50.9%) of the sample (*N*=409) reported biological sex as female. Almost half (48.2%) of the sample identified as non-Hispanic/Latinx White, 15.9% Hispanic/Latinx, 15.9% non-Hispanic/Latinx Asian or South Asian, and 20.0% non-Hispanic/Latinx other (i.e., non-Hispanic/Latinx Black or African American and multiracial). Mean age at baseline was 21.61 (SD=2.17). At baseline, 36.4% of the sample reported not being a student, 48.9% were 4-year college or university students, 6.6% were 2-year, community college, or trade/vocational school students, 7.1% were graduate or professional students, and the remaining 1.0% were high school students or in a GED program.

Procedures

A variety of recruitment methods were used, including advertisements on social media and Craigslist, advertisements in community and college newspapers, flyering, and outreach at community colleges and other local events. Interested individuals were instructed to call the study office or go to our website for details and a link to a confidential eligibility survey. The eligibility survey began with an information statement that included all necessary elements for consent. After completing the survey, individuals who met eligibility criteria were invited to come to the study office for an in-person session where their identity and age were verified with photo identification, informed consent was obtained for the longitudinal study, and a 30-min training was provided on the daily survey protocol. After the training session, participants completed an online baseline survey while still at the study office and received a $40 Amazon gift card upon completion.

The day after the training session participants began their first 14-day burst of daily online surveys (2×/day). Current analyses use data from morning surveys only. Participants had a 3-h window each morning, during which they could complete their online surveys. In Burst 1, the morning survey window was from 9 a.m. to 12 p.m. In Bursts 2–6, the survey windows had flexibility that allowed participants to specify a morning start of 8 a.m., 9 a.m., or 10 a.m. Every 4 months for 2 years, participants completed a 2-week burst (totaling six bursts). At the start of every survey window, participants received an email and text message containing the current survey link. Reminder texts were sent 30 min prior to the close of the survey window if the participant had not yet completed the survey. Participants could opt-in to receive additional reminders. Each survey took approximately 5 to

10min. Participants could earn $2.50 for each completed survey and a bonus of $10 for each burst if at least 25 of 28 surveys were completed (possible total of $80 paid in Amazon e-gift cards). The University IRB approved this study and no adverse events were reported.

Across all morning surveys in the six bursts analyzed here, 81.1% were completed either in whole (78.6%) or in part (2.5%). Alcohol use was reported on 36.1% ($n = 9893$) of all morning surveys, and negative alcohol consequences were reported on 28.0% of drinking days. Marijuana use was reported on 35.8% ($n = 9761$) of all morning surveys, and negative marijuana consequences were reported on 56.4% of marijuana days. Both alcohol and marijuana use were reported on 15.0% ($n = 4099$) of the morning surveys.

Measures

Daily measures

Substance use behaviors
Every morning participants were asked about their alcohol, marijuana, and SAM use for the previous day.

Every morning, participants were asked "Did you drink any alcohol yesterday?" (yes/no). On alcohol use days, participants were asked "How many total drinks did you have yesterday?" ($1 = 1$ *drink* through $25 = 25$ *or more drinks*). The NIAAA definition of a standard drink was provided with a corresponding figure: 12 fl. oz. of regular beer, 8 to 9 fl. oz. of malt liquor, 5 fl. oz. of table wine, and 1.5 fl. oz. shot of distilled spirits.

Every morning, participants were asked "Did you use marijuana yesterday?" (yes/no). On marijuana use days, participants were asked "How many total hours were you high yesterday?" ($0 = $ *less than an hour* to $23 = 23$–24h). Hours high applies across various modes of use, where an alternative like number of hits would only apply to certain methods (e.g., smoking marijuana), and previous research indicates that hours high serves as a parsimonious proxy across various modes of use (Calhoun et al., 2022).

A single item assessed SAM use on days when participants reported using both alcohol and marijuana: "Yesterday, did you use alcohol and marijuana at the same time—that is, so that their effects overlapped?" (yes/no). Days on which an individual responded affirmatively were coded as "1" to indicate a SAM use day, and otherwise days were coded as "0" to indicate no SAM use.

Every morning, participants were asked: "Did you use any of the following yesterday? Check all that apply." Participants were presented with the following list: tobacco/nicotine, prescription stimulants, prescription opioids, prescription sedatives, prescription sleep medication, prescription antidepressant medication, and other substances. Two binary variables were created to indicate days with "any tobacco/nicotine use" and "any other substance use."

Negative alcohol consequences
On alcohol use days, participants reported which of 15 negative alcohol-related consequences they had experienced as a result of their drinking yesterday ($0 = $ no, $1 = $ yes; Lee et al., 2020). Sum scores were created for the total number (up to 15) of negative alcohol-related consequences experienced each day (e.g., had a hangover, felt nauseated or vomited, passed out or fainted suddenly, and felt confused). For the full list of consequences, see Table S1a–c.

Negative marijuana consequences
On marijuana use days, participants were asked which of 10 negative marijuana-related consequences they had experienced as a result of their marijuana use yesterday ($0 = $ no, $1 = $ yes; Calhoun et al., 2022; Fairlie et al., 2021). Negative marijuana consequences included felt anxious or worried, had low motivation, and felt lethargic or sedated. Sum scores were created for total number of negative consequences experienced. For the full list of consequences, see Table S2a–b.

Baseline covariates/moderators

Age and biological sex
Demographic information included age (in years) and biological sex ($0 = $ female, $1 = $ male) as covariates.

Race and ethnicity
Race and ethnicity were included as covariates with non-Hispanic/Latinx White used as the reference group and three dummy codes to reflect Hispanic/Latinx, non-Hispanic/Latinx Asian or South Asian, and all remaining non-Hispanic/Latinx individuals.

Hazardous alcohol use
The 10-item AUDIT (Babor et al., 2001) assessed hazardous alcohol use. Each item is scored from 0 to 4; however, response options vary across items. The 10 items were summed, and a binary indicator was created to compare scores from 0 to 7 (coded "0" for nonhazardous alcohol use) to scores of 8+ (coded "1" for hazardous alcohol use).

Hazardous marijuana use
The CUDIT-Revised (CUDIT-R; Adamson et al., 2010) assessed hazardous marijuana use with eight items that were scored from 0 to 4; however, response options vary across items. The eight items were summed, and a binary indicator was created to compare scores from 0 to 12 (coded "0" for nonhazardous marijuana use) to scores of 13+ (coded "1" for hazardous marijuana use).

Data analysis plan

Aim 1 tested daily-level associations between SAM use and alcohol use (number of drinks) and marijuana use (number of hours high). *Aim 2* tested daily-level associations between SAM use and total number of alcohol consequences and also marijuana consequences, while controlling for number of drinks, number of hours high, any tobacco/nicotine use, and any other substance use. Exploratory analyses tested daily-level associations between SAM use and the probability

of reporting specific negative alcohol-related and marijuana-related consequences as well as whether hazardous use of alcohol or marijuana moderated the four daily-level associations tested in Aims 1 and 2. The analytic sample for all models predicting alcohol outcomes was limited to alcohol use days. Therefore, models examining alcohol outcomes used all days when alcohol was used, and we tested differences between SAM use and non-SAM use days, which included alcohol-only and same-day co-use days (i.e., reported alcohol and marijuana use but not so that effects overlapped). The analytic sample for all models predicting marijuana outcomes was limited to marijuana use days. Therefore, models examining marijuana outcomes tested differences between SAM use days and non-SAM use marijuana days, which included marijuana-only and same-day co-use days.

Poisson multilevel models were used for all analyses (a truncated Poisson model was used for the model predicting number of drinks because there were no zeros in the distribution of number of drinks on alcohol use days). Models were estimated using maximum likelihood estimation based on the Laplace Approximation in the *glmmTMB* package (Brooks et al., 2017) in R 4.2.2. Daily-level (Level 1) predictors included SAM use, number of drinks, number of hours high, any tobacco/nicotine use, any other substance use, burst number, day number within burst, and whether substance use occurred on a weekend (1 = Friday/Saturday vs. 0 = Sunday through Thursday). Given that data collection for Burst 6 occurred during the COVID-19 pandemic, a binary indicator variable representing days on or after March 1, 2020 (coded 1) versus days prior to March 1, 2020 (coded 0) was included as a daily-level predictor to account for any potential changes in substance use behaviors that may have been associated with the onset of the COVID-19 pandemic. Person-level (Level 2) predictors included the proportion of each person's sampled days that were SAM use days, person-means of the level of use variables (drinks/hours high), the proportion of each person's sampled days that were tobacco/nicotine days and other substance use days, biological sex, age at baseline, and race/ethnicity.

Two steps were taken to fully disentangle the pure within- and between-person associations at the daily (Level 1) and person (Level 2) levels. First, all daily-level predictors other than burst number and day number within burst were person-mean centered (Bolger & Laurenceau, 2013; Hamaker & Muthén, 2020). Second, the inclusion of burst number and day number within burst, which were centered at their midpoints, accounted for any trends over time in predictor or outcome variables, thereby improving the accuracy of person-mean-centering (Wang & Maxwell, 2015). All person-level predictors were grand-mean centered. Daily-level associations were specified as random, and thereby were allowed to vary across individuals, to the extent that doing so improved model fit, as indicated by likelihood ratio tests. Overdispersion was accounted for, as necessary, by adding a daily-level random effect. All models assumed data were missing at random after accounting for covariates.

RESULTS

Descriptive statistics

Descriptive statistics are presented in Table 1. The analytic sample used to test the alcohol outcomes included 9893 alcohol use days contributed by 404 participants. Of these participants, 62.6% met the AUDIT 8+ cutoff. At the day-level, SAM use was reported on 25.1% of alcohol use days and by 81.7% of participants who reported using alcohol during the study period. Across all alcohol use days (ignoring nesting within individuals), the mean number of drinks consumed was 3.59 (SD = 2.74) and the mean number of hours high was 1.31 (SD = 2.24). Marijuana use was reported on 41.9% of alcohol use days. Across all alcohol use days (ignoring nesting within individuals), the median number of negative alcohol consequences participants experienced was 0 (M = 0.61, SD = 1.32, range = 0–14). At least one negative alcohol consequence was reported on 28.0% of alcohol use days.

The analytic sample used to test the marijuana outcomes included 9761 marijuana use days contributed by 381 participants. Of these participants, 43.3% met the CUDIT 13+ cutoff. At the day-level, SAM use was reported on 25.2% of marijuana use days and by 86.6% of participants who reported using marijuana during the study period. Across all marijuana use days (ignoring nesting within individuals), the mean number of hours high was 3.18 (SD = 2.47), and the mean number of drinks consumed was 1.51 (SD = 2.50). Alcohol use was reported on 42.0% of marijuana use days. Across all marijuana use days (ignoring nesting within individuals), the median number of negative marijuana consequences participants experienced was 1 (M = 1.21, SD = 1.54, range = 0–10). At least one negative marijuana consequence was reported on 29.1% of marijuana use days.

Aim 1: Is SAM use associated with greater alcohol and marijuana use?

Table 2 shows results of the truncated Poisson multilevel model testing the daily-level association between SAM use and number of drinks consumed on alcohol use days (Model 1). At the daily level, on SAM use days, participants consumed 37% more drinks, on average, compared with non-SAM use days. The model-predicted number of drinks consumed by the average participant was 2.47 (95% CI = [2.34, 2.61]) on the average non-SAM use day and 3.37 (95% CI = [3.18, 3.57]) on the average SAM use day. At the person level, the proportion of alcohol use days that participants engaged in SAM use was not significantly associated with their average number of drinks.

Table 2 also shows the results of the Poisson multilevel model testing the daily-level association between SAM use and number of hours high on marijuana use days (Model 2). At the daily level, on SAM use days, participants reported being high for 10% more hours,

TABLE 1 Descriptive statistics.

Variable	N (no. person-days or no. persons)	M (SD) or percentage	Range
Alcohol use days (N = 9893 days within 404 participants)			
Person-level variables			
Biological sex (percentage male)	404	49.0	0–1
Age at baseline	404	21.63 (2.17)	18–26
Race/Ethnicity			
Asian NH	64	15.8	0–1
Hispanic	64	15.8	0–1
Other NH	81	20.0	0–1
White NH	195	48.3	0–1
AUDIT baseline (percentage at or above 8+ cutoff)	404	62.6	0–1
Daily-level variables			
SAM use (vs. alcohol-only or same-day co-use)	9735	25.1	0–1
Number of drinks	9880	3.59 (2.74)	1–25
Number of hours high	9764	1.31 (2.24)	0–21
Negative alcohol consequences sum	9783	0.61 (1.32)	0–14
Any tobacco/nicotine use	9678	0.24 (0.43)	0–1
Any other substance use	9021	0.19 (0.39)	0–1
Weekend days	9893	38.1	0–1
Marijuana use days (N = 9761 days within 381 participants)			
Person-level variables			
Biological sex (percentage male)	381	49.6	0–1
Age at baseline	381	21.62 (2.15)	18–26
Race/Ethnicity			
Asian NH	57	15.0	0–1
Hispanic	64	16.8	0–1
Other NH	77	20.2	0–1
White NH	183	48.0	0–1
CUDIT baseline (percentage at or above 13+ cutoff)	381	43.3	0–1
Daily-level variables			
SAM use (vs. marijuana-only or same-day co-use)	9714	25.2	0–1
Number of hours high	9702	3.18 (2.47)	0–23
Number of drinks	9761	1.51 (2.50)	0–25
Negative marijuana consequences sum	9675	1.21 (1.54)	0–10
Any tobacco/nicotine use	9597	0.28 (0.45)	0–1
Any other substance use	8925	0.21 (0.41)	0–1
Weekend days	9761	30.8	0–1

Abbreviations: AUDIT, alcohol use disorder identification test; CUDIT, cannabis use disorder identification test.

on average, compared with non-SAM use days. The model-predicted number of hours high for the average participant was 2.21 (95% CI = [2.09, 2.34]) on the average non-SAM use day and 2.43 (95% CI = [2.28, 2.59]) on the average SAM use day. At the person level, the proportion of marijuana use days that participants engaged in SAM use was not significantly associated with their average number of hours high.

Aim 2: Is SAM use associated with more negative alcohol and marijuana consequences?

Table 3 shows results of the Poisson multilevel model testing the daily-level association between SAM use and total number of negative alcohol consequences on alcohol use days (Model 3). At the daily level, on SAM use days, participants experienced 43%

TABLE 2 Poisson multilevel models testing daily-level associations between SAM use and level of alcohol and marijuana use.

Fixed effects	Model 1: Number of drinks		Model 2: Number of hours high	
	$N_{Days}=9019$		$N_{Days}=8887$	
	$N_{Persons}=403$		$N_{Persons}=374$	
	RR	95% CI	RR	95% CI
Level 2, Between-person				
Intercept	2.67***	2.54, 2.80	2.27***	2.15, 2.40
Male biological sex (vs. female)	1.24***	1.13, 1.37	1.33***	1.19, 1.48
Age	0.95***	0.93, 0.98	0.99	0.96, 1.01
Race/ethnicity (Ref.: White NH)				
Asian NH	0.96	0.83, 1.10	0.86	0.73, 1.01
Hispanic	1.13	0.99, 1.29	0.96	0.83, 1.12
Other NH	0.85*	0.75, 0.97	1.03	0.90, 1.19
Proportion of days that were SAM use days	0.94	0.76, 1.15	0.89	0.70, 1.15
Proportion of days tobacco/ nicotine was used	1.41***	1.23, 1.62	1.07	0.92, 1.25
Proportion of days other substances were used	0.86	0.73, 1.02	1.19	1.00, 1.42
Level 1, Within-person				
Burst number	0.99	0.97, 1.00	1.00	0.99, 1.02
Day number within burst	1.00	1.00, 1.01	1.00	0.99, 1.00
Weekend (Friday/ Saturday vs. other days)	1.39**	1.33, 1.45	1.10***	1.06, 1.14
COVID-19 days (days after vs. before March 1, 2020)	0.88*	0.78, 0.99	1.08*	1.01, 1.16
SAM days (vs. days with any alcohol use)	1.37***	1.29, 1.44	1.10***	1.05, 1.15
Tobacco/nicotine use days	1.21***	1.12, 1.31	1.01	0.93, 1.09
Other substance use days	1.05	0.99, 1.12	1.08	1.00, 1.16

Random effects	Model 1 SD	Model 2 SD
Intercept	0.44	0.47
Burst number	0.08	0.08
Weekend (Friday/Saturday vs. other days)	0.25	0.12
COVID-19 days (days after vs. before March 1, 2020)	0.34	–

TABLE 2 (Continued)

Random effects	Model 1 SD	Model 2 SD
SAM days (vs. days with any alcohol use)	0.27	0.11
Tobacco/nicotine use days	0.25	0.21
Other substance use days	–	0.18
Dispersion parameter	0.32	–

Abbreviations: NH, non-Hispanic; RR, rate ratio; SAM, simultaneous alcohol and marijuana.
*$p<0.05$.; **$p<0.01$.; ***$p<0.001$.

more negative alcohol consequences, on average, compared with non-SAM use days. The model-predicted number of negative alcohol consequences experienced by the average participant was 0.21 (95% CI = [0.18, 0.23]) on the average non-SAM use day and 0.30 (95% CI = [0.26, 0.34]) on the average SAM use day. The number of drinks participants consumed was positively associated with the total number of negative alcohol consequences participants experienced, such that each additional drink was associated with experiencing 48% more consequences. In contrast, the number of hours high participants reported on days with any alcohol use was negatively associated with the total number of negative alcohol consequences, such that each additional hour participants reported being high was associated with experiencing 4% fewer negative alcohol consequences. Findings were similar at the person level. Both the proportion of alcohol use days that participants engaged in SAM use and the average number of drinks they consumed were positively associated with the average number of total negative alcohol consequences they experienced. In contrast, the average number of hours high participants reported on alcohol use days was negatively associated with the average number of total negative alcohol consequences they experienced.

Table 3 also shows results of the Poisson multilevel model testing the daily-level association between SAM use and total number of negative marijuana consequences on marijuana use days (Model 4). At the daily level, there was no statistically significant association between SAM use and total number of negative marijuana consequences. The number of hours high was positively associated with the total number of negative marijuana consequences participants experienced, such that each additional hour high was associated with experiencing 14% more consequences. In contrast, the number of drinks participants consumed on days with any marijuana use was negatively associated with the total number of negative marijuana consequences they experienced, such that each additional drink consumed was associated with experiencing 3% fewer negative marijuana consequences. At the person level, the proportion of marijuana use days that participants engaged in SAM use, the average number of hours high they reported, and the average number of drinks they consumed were all not significantly associated with the average number of total negative marijuana consequences they experienced.

TABLE 3 Poisson multilevel models testing daily-level associations between SAM use and negative alcohol and marijuana consequences.

	Model 3: Number of negative alcohol consequences		Model 4: Number of negative marijuana consequences	
	$N_{Days} = 8993$		$N_{Days} = 8874$	
	$N_{Persons} = 403$		$N_{Persons} = 374$	
Fixed effects	**RR**	**95% CI**	**RR**	**95% CI**
Level 2, between-person				
Intercept	0.23***	0.20, 0.25	0.90*	0.83, 0.99
Male biological sex (vs. female)	0.59***	0.48, 0.72	0.87	0.73, 1.03
Age	0.91***	0.86, 0.95	0.97	0.93, 1.01
Race/ethnicity (Ref.: white NH)				
Asian NH	1.47**	1.11, 1.96	1.26	0.98, 1.63
Hispanic	0.91	0.69, 1.21	0.92	0.72, 1.17
Other NH	1.03	0.79, 1.34	0.85	0.68, 1.07
Person-mean number of drinks	1.20***	1.11, 1.30	0.94	0.87, 1.02
Person-mean number of hours high	0.90*	0.81, 1.00	0.97	0.91, 1.03
Proportion of days that were SAM use days	2.34*	1.17, 4.69	1.58	0.91, 2.75
Proportion of days tobacco/nicotine was used	1.00	0.75, 1.35	0.98	0.76, 1.25
Proportion of days other substances were used	1.82***	1.30, 2.53	1.43*	1.08, 1.89
Level 1, within-person				
Burst number	0.94**	0.91, 0.98	0.98	0.95, 1.01
Day number within burst	0.99*	0.98, 1.00	0.98***	0.97, 0.98
Weekend (Friday/Saturday vs. other days)	1.02	0.94, 1.11	0.95*	0.90, 1.00
COVID-19 days (days after vs. before March 1, 2020)	0.95	0.74, 1.23	0.93	0.76, 1.14
Number of drinks	1.48***	1.44, 1.52	0.97***	0.96, 0.98
Number of hours high	0.96**	0.93, 0.99	1.14***	1.12, 1.17
SAM days (vs. days with any alcohol use)	1.43***	1.27, 1.62	1.05	0.98, 1.12
Tobacco/nicotine use days	1.09	0.94, 1.27	1.03	0.91, 1.17
Other substance use days	1.03	0.88, 1.20	1.05	0.97, 1.14
Random effects	**Model 3 SD**			**Model 4 SD**
Intercept	0.89			0.75
Burst number	0.15			0.18
COVID-19 days (days after vs. before March 1, 2020)	–			0.61
Number of drinks	0.15			–
Number of hours high	–			0.09
SAM days (vs. days with any alcohol use)	–			–
Tobacco/nicotine use days	–			0.11
Dispersion parameter	0.76			0.07

Abbreviations: NH, non-Hispanic; RR, rate ratio; SAM, simultaneous alcohol and marijuana.

*$p < 0.05$.; **$p < 0.01$.; ***$p < 0.001$.

Exploratory analyses: Was SAM use associated with specific negative alcohol and marijuana consequences?

Exploratory models tested daily-level associations between SAM use and 15 specific alcohol-related consequences on alcohol use days (Table S1a–c). These models used the same set of predictor variables as Model 3, which tested the daily-level association between SAM use and total number of negative alcohol consequences. At the daily level, on SAM use days participants had 1.76 times greater odds of doing something embarrassing, 2.09 times greater odds of feeling clumsy, 1.56 times greater odds of having
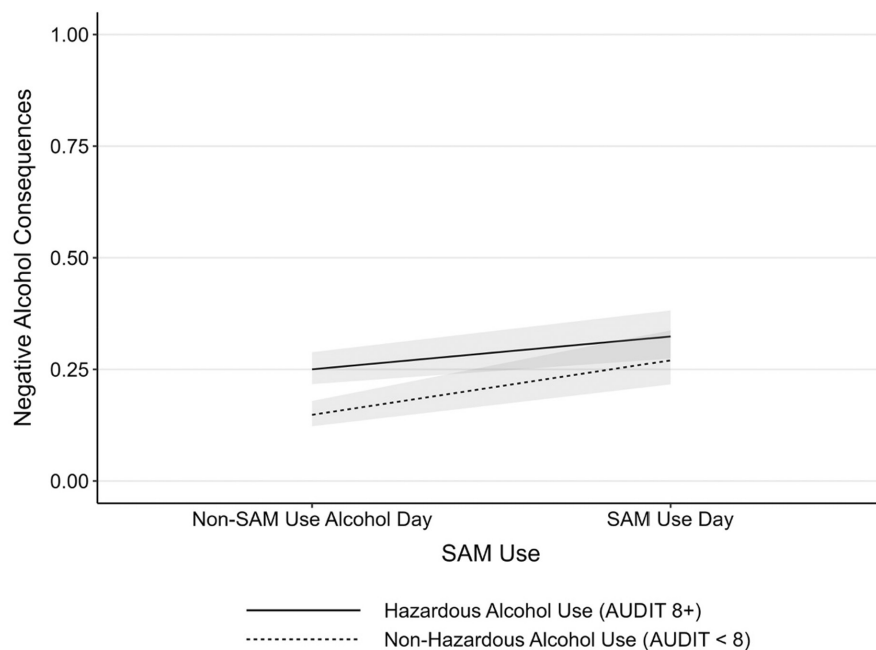
FIGURE 1 Moderation of the daily-level association between simultaneous alcohol and marijuana (SAM) use and total number of negative alcohol consequences by hazardous alcohol use (AUDIT scores <8 vs. 8 or higher). Gray bands are 95% confidence intervals.

difficulty concentrating, 2.41 times greater odds of feeling confused, and 1.78 times greater odds of feeling dizzy, compared to non-SAM use days; SAM use was not significantly associated with the remaining 10 specific alcohol consequences. At the person level, participants who engaged in SAM use on a greater proportion of drinking days reported feeling nauseated or vomiting, having difficulty concentrating, and feeling dizzy more often on drinking days throughout the study period.

Exploratory models tested daily-level associations between SAM use and 10 specific marijuana-related consequences on marijuana use days (Table S2a,b). These models used the same set of predictor variables as Model 4, which tested the daily-level association between SAM use and total number of negative marijuana consequences. At the daily level, on SAM use days, participants had 1.68 times greater odds of feeling clumsy and 2.64 times greater odds of feeling dizzy, compared with non-SAM use days; SAM use was not significantly associated with the remaining eight specific marijuana consequences. At the person level, participants who engaged in SAM use on a greater proportion of marijuana use days reported feeling lethargic or sedated more often on marijuana days throughout the study period.

Exploratory analyses: Were daily-level associations between SAM use and alcohol and marijuana outcomes moderated by hazardous use at baseline?

Exploratory models tested whether hazardous use, as reported at baseline, moderated the daily-level associations between SAM use and substance use outcomes tested in Aims 1 and 2. Moderation

models (not shown in a table) used the same model specifications as those estimated for Aims 1 and 2 with the exception of adding a binary indicator at the person level for hazardous use (either AUDIT 8+ or CUDIT-R 13+ at baseline) and a cross-level interaction between the hazardous use indicator and the daily-level SAM use variable. Hazardous alcohol use (AUDIT 8+ at baseline) did not moderate the daily-level association between SAM use and number of drinks consumed on alcohol use days (RR=0.98, 95% CI=[0.87, 1.10], p=0.76), but hazardous alcohol use was positively associated with number of drinks at the person level (RR=1.60, 95% CI=[1.46, 1.75], p<0.001). Similarly, hazardous marijuana use (CUDIT-R 13+ at baseline) did not moderate the daily-level association between SAM use and number of hours high on marijuana use days (RR=1.00, 95% CI=[0.93, 1.08], p=1.00), but hazardous marijuana use was positively associated with number of hours high at the person level (RR=1.47, 95% CI=[1.33, 1.62], p<0.001).

For the model predicting total number of negative alcohol consequences, hazardous alcohol use (AUDIT 8+ at baseline) moderated the daily-level association between SAM use and number of negative alcohol consequences on alcohol use days (RR=0.71, 95% CI=[0.56, 0.88], p<0.01). Simple slopes analysis indicated that there was a positive daily-level association between SAM use and negative alcohol consequences for both non-hazardous use (AUDIT <8 at baseline; RR=1.82, 95% CI=[1.50, 2.22], p<0.01) and for hazardous use (AUDIT 8+ at baseline; RR=1.30, 95% CI=[1.13, 1.49], p<0.01; Figure 1). For individuals who reported nonhazardous alcohol use at baseline, SAM use days were associated with experiencing 82% more negative consequences compared to non-SAM use alcohol days. In contrast, for individuals who reported hazardous alcohol use at baseline, SAM use was

associated with experiencing 30% more negative consequences compared to non-SAM use alcohol days.

For the model predicting total number of negative marijuana consequences, hazardous marijuana use (CUDIT-R 13+ at baseline) did not moderate the daily-level association between SAM use and number of marijuana consequences on marijuana use days (RR = 0.99, 95% CI = [0.89, 1.12], p = 0.93), and hazardous marijuana use was not significantly associated with number of marijuana consequences at the person level (RR = 1.08, 95% CI = [0.90, 1.30], p = 0.40).

DISCUSSION

The current study examined day-level associations between SAM use and number of drinks, hours high, and alcohol- and marijuana-related consequences in a community sample of young adults who reported recent alcohol and SAM use. The current findings showed, across all alcohol use days, SAM use days were associated with consuming more drinks as compared to alcohol use days where SAM use did not occur; across all marijuana use days, SAM use days were associated with reporting more hours high as compared to marijuana use days where SAM use did not occur. Furthermore, SAM use days were associated with experiencing more total negative alcohol consequences as well as experiencing five specific consequences as a result of drinking (doing something embarrassing, feeling clumsy, difficulty concentrating, feeling confused, and feeling dizzy). In contrast, SAM use days were not significantly associated with total marijuana consequences, but SAM use days were associated with feeling clumsy and feeling dizzy as a result of marijuana use (both of which were also significant in the corresponding alcohol models).

This study contributes to the literature by examining both alcohol and marijuana outcomes, while controlling for level of alcohol and marijuana and other substance use, and by using a young adult sample including young adults not in college. Daily-level findings between SAM use and an increased risk of alcohol consumption and consequences corroborate previous work (Lee et al., 2022). Furthermore, our findings are in contrast to Linden-Carmichael et al. (2020) that showed SAM use days were associated with negative substance-use related consequences on marijuana days. Here, SAM use days were not significantly associated with total negative marijuana consequences compared to non-SAM use days, after controlling for drinks consumed, hours high, and other substance use. Of note, present findings showed more hours high was associated with more total negative marijuana consequences, while Linden-Carmichael et al. (2020) did not find a significant association between number of hits and negative substance-use related consequences. Two notably different aspects of the current study are the use of hours high (rather than number of hits) and the use of a marijuana-specific consequences measure. Although the current study did not find a significant association between SAM use days and total marijuana consequences, exploratory analyses showed that SAM use was associated with greater odds of two specific marijuana consequences (i.e., feeling clumsy and feeling dizzy). Taken

together, the current findings provide evidence supporting the links between SAM use with hours high from marijuana and specific marijuana consequences. Given recent national estimates in the United States that 10.8% of young adults report daily marijuana use (20+ occasions in the past 30 days; Patrick, Schulenberg, et al., 2022), the current findings highlight the need to further investigate SAM use and negative marijuana consequences.

There was very limited evidence that hazardous alcohol or marijuana use served as a person-level moderator of the daily-level associations. The only significant moderation effect indicated that those *without* hazardous alcohol use (baseline AUDIT scores below 8) reported greater average increases in negative alcohol consequences on SAM use days relative to non-SAM use days than did those with hazardous alcohol use, as shown in Figure 1. Although individuals with hazardous alcohol use reported less pronounced average increases in negative consequences on SAM use days relative to non-SAM use days, their average level of consequences was higher than that of those with nonhazardous alcohol use on both SAM use and non-SAM use days. This reflects that those with baseline hazardous drinking typically experience elevated consequences, regardless of their SAM use.

Limitations

The advantages of the current study include use of a community sample and relatively high completion rates for daily surveys across six bursts (up to 84 sampled days per person) that spanned 2 years. Several limitations should be noted. First, the current sample was recruited based on their substance use. As a result, there is a substantial number of individuals who met the cutoffs for hazardous use at baseline (62.6% met for AUDIT 8+ and 43.3% met CUDIT-R 13+). The current findings may not generalize to other more general populations of young adults or other age groups. Second, young adults were recruited from a region where nonmedical marijuana use is legal. As such, results may not generalize to those living in different policy contexts. Third, for some participants, the sixth burst of data collection occurred during the early months of the COVID-19 pandemic. Although the multilevel nature of the data overcomes concerns relating to within-person changes, it should be noted that young adults faced numerous stressors during this time and some may have changed their substance use behaviors (Graupensperger, Cadigan, et al., 2021; Graupensperger, Fleming, et al., 2021). Finally, substance use and consequences were self-reported and may be affected by a person's tolerance and/or expectancies about the consequences of their use.

Clinical implications and future directions

The most salient clinical implication of the current findings is that SAM use confers elevated risks above and beyond the risks of non-SAM use days, even when adjusting for number of drinks, hours high,

and the presence of other substance use. This finding should be integrated into psychoeducational programs highlighting the risk of combining alcohol and marijuana. A more nuanced harm-reduction tact could also encourage young adults to closely monitor and limit the amount of each substance being used if they choose to combine substances. Specific to the exploratory moderation findings, young adults who are lighter drinkers (i.e., nonhazardous alcohol use) may be advised to take caution on days they use both alcohol and marijuana as they are at heightened risk for negative consequences on that day, despite generally lower risk overall. Taken together, the current findings provide the strongest evidence to date that SAM use is a high-risk behavior that should be the focus of ongoing prevention efforts.

To build on the strong evidence provided herein, several future directions are warranted. As it pertains to categorizing different substance use days (e.g., SAM vs. alcohol-only), there are discrepancies in the existing literature regarding how to handle same-day co-use days that do not entail overlapping effects (Sokolovsky et al., 2020). A deeper examination of the potential unique risks of same-day co-use (days alcohol and marijuana are used but without overlapping effects) would provide the field with guidance for how to categorize same-day co-use days. Regarding measurement of consequences, it is prudent to investigate which types of consequences (e.g., physical consequences like passing out versus social consequences like getting in a serious fight) are more likely on SAM use days relative to single-substance-use days Moreover, the negative consequences measured presently are not exhaustive; for example, previous studies from these data show that SAM use may have adverse effects on sleep health the night following use (Graupensperger, Fairlie, et al., 2021) and both intoxicated driving and riding with intoxicated drivers (Patrick, Graupensperger, et al., 2021). Relatedly, long-term risks of SAM use remain relatively unexplored and would provide better understanding of potentially unique risks of SAM use.

CONCLUSIONS

Results extend prior research showing that SAM use days are linked to consuming more drinks and to experiencing more total alcohol consequences even after controlling for number of drinks, hours high, and the presence of other substance use. In addition, SAM use days were associated with hours high, but not total number of marijuana consequences, after controlling for number of drinks, hours high, and the presence of other substance use. Exploratory models showed SAM use was associated with experiencing some of the specific alcohol and marijuana consequences examined here. This provides some evidence that SAM use is also a risk for marijuana outcomes.

CONFLICT OF INTEREST STATEMENT

We have no known conflicts of interest to disclose.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.