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Monthly simultaneous cannabis and alcohol use: effects on depression, anxiety, and stress in male and female college students

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Abstract

Background Alcohol and cannabis are two of the most commonly used and co-used substances by young adults, and simultaneous cannabis and alcohol (SCA) use has been linked to increased risk for negative consequences, including poor mental health. College students represent an important group to study given their high prevalence of co-use and rising rates of depression, anxiety, and stress. Further, sex-related differences have been observed in polysubstance use, and research is needed on how SCA use may be differentially related to mental health outcomes in male and female college students.

Methods This cross-sectional survey study on $N=367$ college students compared male and female sexes on the relationships between monthly SCA use (compared to less than monthly) and depression, anxiety, and stress. A multigroup path analysis was conducted to simultaneously regress mental health symptoms onto a dichotomously coded SCA group variable, while controlling for age, most recent cannabis use, and typical alcohol frequency, with sex as the grouping variable. A post-hoc Monte Carlo simulation was conducted to examine power and provide recommendations for sample sizes in future research.

Results Monthly SCA use significantly positively predicted depression in male ($\beta=0.322$) and female ($\beta=0.296$) college students, and the relation between SCA and depression was not different between sexes ($p=0.939$). While anxiety ($\beta=0.323$) and stress ($\beta=0.369$) were significantly positively predicted by monthly SCA use in males, but not females, the relations between SCA and anxiety, as well as stress, were not significantly different between the sexes.

Conclusions Across sexes, more frequent SCA use is positively associated with depression symptoms in college students. Although SCA use was also linked to higher anxiety and stress among males but not females, these sex differences were not significant. Studies with greater statistical power are warranted to investigate potential sex differences.

Keywords Polysubstance use, Frequency, Mental health, Sex differences, Young adults

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Background

From a nationally representative sample, 8.4% of U.S. adults aged 30 to 80 reported past-month co-use of alcohol and cannabis (Tucker et al. 2023). Among college students, the prevalence of non-disordered past-year co-use increased from approximately 1.8 million in 2002 to 2.6 million in 2018 (McCabe et al. 2021). Co-use is commonly categorized as either simultaneous (i.e., overlapping) co-use or concurrent (i.e., non-overlapping) co-use, based upon the temporal patterns of use. Simultaneous use of alcohol and cannabis (SCA) is defined as using both substances within the same timeframe, such that the intoxicating effects of each are experienced at the same time (Bravo et al. 2021; Cummings et al. 2019). SCA use occurs at the highest rate amongst young adults ages 19 to 22 (Terry-McElrath and Patrick 2018). Among college students who use both cannabis and alcohol, 79% reported past year SCA use with an average frequency of twice per month (White et al. 2019). Young adults often report engaging in SCA to experience overlapping effects, such as enhanced euphoria or relaxation (Jackson et al. 2020; Patrick et al. 2018, 2020).

SCA has been linked to a number of negative consequences when compared to non-overlapping alcohol and cannabis use, including increased consumption of both alcohol and cannabis (Cummings et al. 2019; Linden-Carmichael et al. 2019; Subbaraman and Kerr 2015) and greater odds of experiencing negative consequences including blackouts, impaired driving, physical injury, and acute psychological distress (Brière et al. 2011; Cummings et al. 2019; Haas et al. 2015; Jackson et al. 2020; Linden-Carmichael et al. 2019, 2020; White et al. 2019). High schoolers engaging in extreme binge drinking (i.e., more than 10 drinks in a row) and cannabis use are at elevated risk for engaging in SCA use, with frequency being a predicting factor (Patrick et al. 2017). Jackson and colleagues found that SCA use resulted in more severe negative consequences than non-overlapping use, even when accounting for frequency and quantity of use (Jackson et al. 2020), suggesting that the coinciding intoxication effects of SCA use may uniquely contribute to consequences (Subbaraman and Kerr 2015).

Mental health outcomes are significantly impacted by SCA use, particularly in adolescents and young adults. SCA use has been strongly correlated with increased depressive symptoms, lower grades, and a greater likelihood of psychosis and externalizing issues (Brière et al. 2011; Fleming et al. 2021; Patrick et al. 2022; Subbaraman and Kerr 2015; Thompson et al. 2021; Yurasek et al. 2017). Importantly, some longitudinal work has indicated that SCA predicts subsequent increases in depressive symptoms, substance-related harms, externalizing problems, and psychosis risk across time (Fleming et al. 2021; Thompson et al. 2021). Furthermore, SCA use

correlates with elevated incidence of mental health disorders and co-occurring substance use disorders (Subbaraman and Kerr 2015; Thompson et al. 2021; Yurasek et al. 2017). Prior work has categorized SCA frequency using a monthly cutoff (e.g., on the Alcohol and Cannabis Simultaneous Use Scale [ACSUS]; Kolp et al. 2024), and research indicates that reporting more frequent SCA is associated with elevated risk for substance-related consequences relative to less frequent co-use (Linden-Carmichael et al. 2019). Additionally, individuals endorsing monthly alcohol and/or cannabis use regularly demonstrate more pronounced mental health symptoms compared to individuals reporting less frequent use (Fleming et al. 2021; Karriker-Jaffe et al. 2018; Robinson et al. 2022; Sokolovsky et al. 2020; Subbaraman et al. 2019). These associations highlight the need to better understand the relationship between SCA use and mental health. This is particularly relevant for young adults and college students, who experience elevated rates of depression, anxiety, and stress (Beiter et al. 2015; Melchior et al. 2007; Ramón-Arbués et al. 2020) as well as high rates of SCA use (Terry-McElrath and Patrick 2018). Greater understanding of how SCA relates to mental health can offer clarity that may inform clinical interventions for young adults who co-use and are seeking mental health treatment. Further, because sex differences in internalizing disorders often begin to emerge in late childhood and adolescence (Hankin et al. 1998; Zahn-Waxler et al. 2008), it is also important to consider whether patterns of SCA use may interact with these developmental vulnerabilities.

Notably, prior research suggests that males and females may show different patterns of SCA use. Males may be more likely to engage in SCA and consume both alcohol and cannabis at higher quantities and frequencies than females (Erol and Karpyak 2015; Goodwin et al. 2022; Haberstick et al. 2014). On the other hand, females tend to experience similar subjective and objective effects when engaging in simultaneous use despite using significantly less cannabis than males (Wright et al. 2021). Understanding the differential associations of SCA with biological sex can offer valuable insights for clinical interventions aimed at reducing mental health symptoms in male and female college students who co-use these substances.

The present study aimed to explore whether SCA use at least once per month differently predicted scores on mental health variables (depression, anxiety, and stress) compared to individuals who engage in SCA less than once per month (including those who use alcohol and cannabis at non-overlapping times, but do not engage in SCA at all). Further, we aimed to examine whether relations between SCA use and depression, anxiety, and stress differed between males and females. Post-hoc

Table 1 Frequency of SCA use within SCA+ Group

Frequency of SCA Use	N (% Relative to SCA+ Group Total) N= 133
1 Day/Month	26 (19.5)
2 Days/Month	26 (19.5)
3 Days/Month	25 (18.8)
1 Day/Week	32 (24.1)
2 Days/Week	19 (14.3)
3 Days/Week	4 (3.0)
4 Days/Week	0 (0)
5 Days/Week	0 (0)
6 Days/Week	1 (0.8)
7 Days/Week	0 (0)

Note. SCA Simultaneous Cannabis and Alcohol Use. SCA+ indicates individuals reporting monthly simultaneous cannabis and alcohol use.

Table 2 Demographic characteristics of SCA+ and SCA- groups

	SCA+ (At least monthly) N= 133	SCA- (Less than monthly) N= 234
Age (SD)	19.09 (1.50)	19.11 (1.44)
Sex (%)		
Female	82 (61.7)	163 (69.7)
Male	51 (38.3)	71 (30.3)
Gender (%)		
Woman	66 (49.6)	134 (57.3)
Man	48 (36.1)	61 (26.1)
Androgynous	0 (0)	1 (0.4)
Gender Fluid	1 (0.8)	0 (0)
Gender Non-Binary	1 (0.8)	1 (0.4)
Another	1 (0.8)	1 (0.4)
Do Not Wish to Respond	15 (11.3)	36 (15.4)
Race (%)		
American Indian or Alaska Native	2 (1.5)	2 (0.9)
Asian	2 (1.5)	6 (2.6)
Black or African American	1 (0.8)	3 (1.3)
Native Hawaiian or Other Pacific Islander	2 (1.5)	1 (0.4)
White	119 (89.5)	196 (83.8)
Do Not Wish to Respond	7 (5.3)	26 (11.1)
Ethnicity (%)		
Hispanic or Latino	17 (12.8)	49 (20.9)
Not Hispanic or Latino	116 (87.2)	185 (79.1)

Note. SCA Simultaneous Cannabis and Alcohol Use.

Monte Carlo power simulations based on coefficient estimates from the current sample were examined to provide sample size recommendations for future studies and contextualize the present results.

Methods

Participants

The current study was a secondary data analysis of 367 participants from a University psychology student research pool. Participants were eligible for this study if they were enrolled as a college student at the University during the Fall 2022 semester, were between the ages of 18 and 25 years old and had not previously completed the study. Exclusion criteria included being under the

age of 18 or over the age of 25, previously completing the study, and not being enrolled as a college student at the University during the Fall 2022 Semester. After gaining informed consent, eligible participants completed an online survey (which took approximately one hour to complete) inquiring about substance use behaviors and mental health. Participants answered demographic questions, followed by questions on alcohol and cannabis use. If a participant indicated that they ever used alcohol and cannabis, a question regarding SCA use frequency was populated. All participants were asked questions about mental health symptoms. As compensation for completing the survey, participants received class credit. The study was approved by the University Institutional Review Board. Participant data was excluded if they failed to provide complete responses to questions about alcohol and cannabis use or mental health symptoms or they did not indicate SCA use.

Participants ($N_{\text{total}} = 367$) were split into two groups: those who engaged in *monthly or greater SCA use* (henceforth referred to as the SCA+ group; $N_{\text{SCA+}} = 133$) and those who engaged in *less than monthly SCA use* (henceforth referred to as the SCA- group; $N_{\text{SCA-}} = 234$). Frequency of participant SCA use within the SCA+ group is described in Table 1. Basic demographic characteristics of both SCA+ and SCA- groups can be found in Table 2.

Measures

The Alcohol Use Disorders Identification Test (AUDIT; (Saunders et al. 1993; World Health Organization, (World n.d.)) was used to measure participant alcohol consumption patterns and consequences. In 2004 Kokotailo and colleagues (Kokotailo et al. 2004) reported that the AUDIT had strong internal consistency (Cronbach's $\alpha = 0.89$) and was a reliable tool for identifying alcohol misuse and disorders in college student populations. Sample AUDIT items include: "How many standard drinks containing alcohol do you have on a typical day when drinking?" and "Have you or someone else been injured as a result of your drinking?" Typical alcohol frequency was ascertained from the first question of the AUDIT "How often do you have a drink containing alcohol?" with response options 0 = "Never", 1 = "Monthly or less", 2 = "2–4 times per month", 3 = "2–3 times per week", and 4 = "4 or more times per week".

The Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory (Cuttler and Spradlin 2017) was used to measure participant cannabis consumption, administration, and preferences. Sample items include: "Approximately how many days of the past month did you use cannabis?" with a free response answer. Participants were asked about their most recent cannabis use occasion with the item "Which of the following best captures when you last used cannabis?"

with response options including: 0 = “Over a year ago”, 1 = “9–12 months ago”, 2 = “6–9 months ago”, 3 = “3–6 months ago”, 4 = “1–3 months ago”, 5 = “Less than 1 month ago”, 6 = “Last week”, 7 = “This week”, 8 = “Yesterday”, 9 = “Today”, and 10 = “I am currently high”.

SCA use frequency was examined by asking only participants who reported previous cannabis and alcohol use “How often do you use cannabis and drink alcohol at the same time? (Use one while feeling the effect from the other)”. Response options included 0 = “Less than once per month”, 1 = “One day a month”, 2 = “Two days a month”, 3 = “Three days a month”, 4 = “One day a week”, 5 = “Two days a week”, 6 = “Three days a week”, 7 = “Four days a week”, 8 = “Five days a week”, 9 = “Six days a week”, and 10 = “Daily”. Participants who indicated less than monthly SCA use were coded as a 0, while participants who indicated at least monthly SCA use were coded as a 1. Note that to receive this question, participants were not required to report SCA use, meaning some individuals in the SCA- group may have never engaged in SCA use, but all participants reported lifetime alcohol and cannabis use.

The Depression, Anxiety, and Stress Scale (DASS; Lovibond and Lovibond 1995b) was used to measure levels of depression, anxiety, and stress in all participants. The scale had high internal consistency (Cronbach’s alpha: Depression = 0.91, Anxiety = 0.84, Stress = 0.90) in previous research, suggesting that the DASS is a reliable measure for assessing negative emotional states in college populations. Sample DASS items include “I felt downhearted and blue”; “I felt I was close to panic”; “I found it difficult to relax.” DASS responses were assessed on a scale from 0 (“did not apply to me at all”) to 3 (“applied to me very much, or most of the time”), and items comprising each subscale were summed. Greater prevalence of DASS symptoms equated to higher domain scores.

Analysis plan

All data management and initial statistical testing for random differences between groups on model variables was conducted using R statistical software (version 2023.03.0 + 386), specifically the tidyverse (Wickham et al. 2019), MplusAutomation (Hallquist and Wiley 2018), and car (Fox et al. 2024) packages. Participants were first coded into their respective groups: SCA+ including only individuals who reported typically using alcohol and cannabis simultaneously at least once per month, and SCA- including individuals who reported typically using alcohol and cannabis simultaneously less than once per month. The groups were compared using t-tests on age, typical alcohol use, and most recent cannabis use occasion, as well as using chi squared tests on sex, gender, race, and ethnicity. Note that for all analyses, ‘sex’ refers to the participant’s sex assigned at birth.

Next, a multigroup path analysis was conducted using *Mplus 8* (Muthén and Muthén 1998). While the current study is cross-sectional and cannot establish temporal precedence, given previous longitudinal research indicating a positive relationship between mental health outcomes and preceding co-use behaviors (Fleming et al. 2021; Thompson et al. 2021), we elected to assess SCA as a predictor of mental health outcomes. Individual DASS symptom domains (depression, anxiety, and stress subscales) were simultaneously regressed onto the dichotomously coded SCA group variable, age, most recent cannabis use occasion and typical alcohol use frequency, with sex as the grouping variable. All predictor variables were allowed to freely covary, and all outcome variables were allowed to freely covary. Parameters of the multigroup path analysis were estimated using maximum likelihood estimation and significant results were interpreted at $p < 0.05$. To assess overall model fit, criteria suggested by Hu and Bentler (Hu and Bentler 1999) were used, including the chi-squared goodness-of-fit test, Comparative Fit Index (CFI) > 0.95 , and Root Mean Square Error of Approximation (RMSEA) < 0.08 . To examine whether individual paths in the model significantly differed between males and females, z-tests were conducted using model constraints (Brown 2015) to assess whether differences existed in the relations between predictors and outcomes across sex. The z-tests were conducted such that a difference score was created between males and females for the coefficients linking predictors to outcomes, and these difference scores were tested to examine whether they were significantly different from 0. Z scores that were significantly different from 0 indicated that the relation between those variables was significantly different between males and females. To examine whether the current sample provided enough power to adequately assess the research questions, post-hoc Monte Carlo simulations based on estimates from the current model were run and sample size recommendations are provided for future research.

Results

The groups did not display significant differences on age, sex, gender, race or ethnicity. (p 's > 0.05). The groups did significantly differ on typical alcohol use frequency, $t(365) = -5.81$, $p < 0.001$, and most recent cannabis use occasion, $t(363.58) = -15.79$, $p < 0.001$. These variables were controlled in the analyses by including them as covariates. Because covariances among predictor variables, and among outcome variables, were constrained to be equal across sexes, a correlation table for the overall sample is provided in Table 3. The model reflected excellent fit to the data based on the chosen fit indices: chi squared test of model fit = 14.746 ($p = 0.098$), CFI = 0.992, RMSEA = 0.059. Results in the analysis for

Table 3 Correlation table for the overall sample

Variable	1	2	3	4	5	6
1. Age						
2. Cannabis Frequency	-0.06 [-0.16, 0.04]					
3. Alcohol Frequency	-0.02 [-0.12, 0.09]	0.14** [0.04, 0.24]				
4. SCA Group Membership	-0.01 [-0.11, 0.09]	0.58** [0.51, 0.64]	0.29** [0.19, 0.38]			
5. Depression	0.10 [-0.01, 0.20]	-0.03 [-0.13, 0.07]	-0.01 [-0.11, 0.09]	-0.04 [-0.15, 0.06]		
6. Anxiety	0.05 [-0.05, 0.15]	-0.07 [-0.17, 0.03]	0.01 [-0.09, 0.11]	-0.06 [-0.16, 0.04]	0.78** [0.74, 0.82]	
7. Stress	0.04 [-0.07, 0.14]	-0.05 [-0.15, 0.05]	-0.02 [-0.12, 0.08]	-0.02 [-0.12, 0.08]	0.75** [0.70, 0.79]	0.71** [0.65, 0.76]

Note. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation. * indicates $p < 0.05$. ** indicates $p < 0.01$. SCA Simultaneous Cannabis and Alcohol Use.

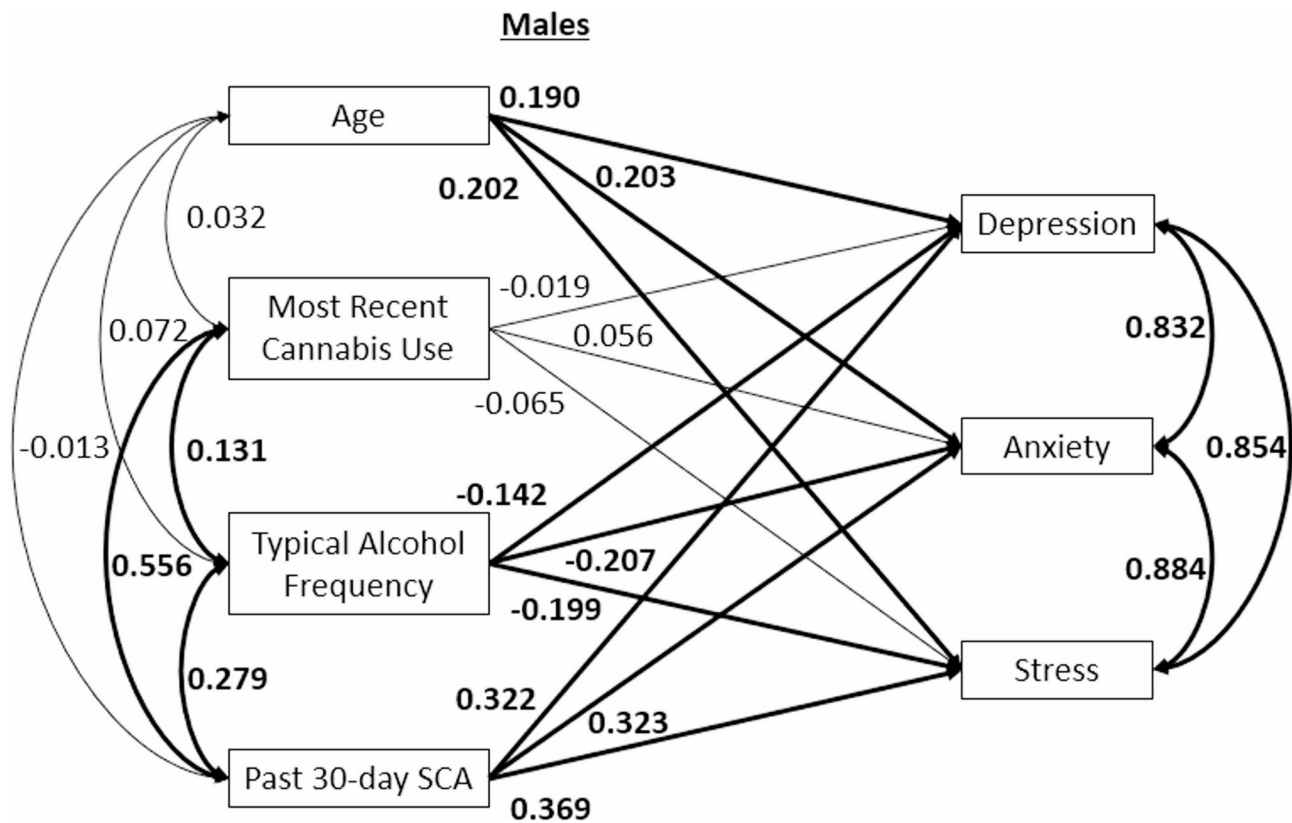


Fig. 1 Standardized path model for individuals assigned male at birth. Note. Associations between age, substance use, and psychological distress are shown. Statistically significant paths ($p < 0.05$) are bolded. All variables are observed. SCA = Simultaneous Cannabis and Alcohol Use

male students (see Fig. 1) indicated that the SCA + group (relative to SCA-) showed significantly higher scores on depression ($\beta = 0.322, p < 0.001$), anxiety ($\beta = 0.323, p < 0.001$) and stress ($\beta = 0.369, p < 0.001$). Age showed a significant positive association to scores on depression ($\beta = 0.190, p = 0.024$), anxiety ($\beta = 0.203, p = 0.007$), and stress ($\beta = 0.202, p = 0.008$). Typical alcohol use frequency showed a significant negative association to scores on

depression ($\beta = -0.142, p = 0.042$), anxiety ($\beta = -0.207, p = 0.001$) and stress ($\beta = -0.199, p = 0.001$). Most recent cannabis use occasion showed no significant associations to scores on depression ($\beta = -0.019, p = 0.793$), anxiety ($\beta = 0.056, p = 0.381$), or stress ($\beta = -0.065, p = 0.364$). For females (see Fig. 2), SCA + group membership was associated with significantly higher scores on depression ($\beta = 0.296, p = 0.001$), but not anxiety ($\beta = 0.162, p = 0.114$)

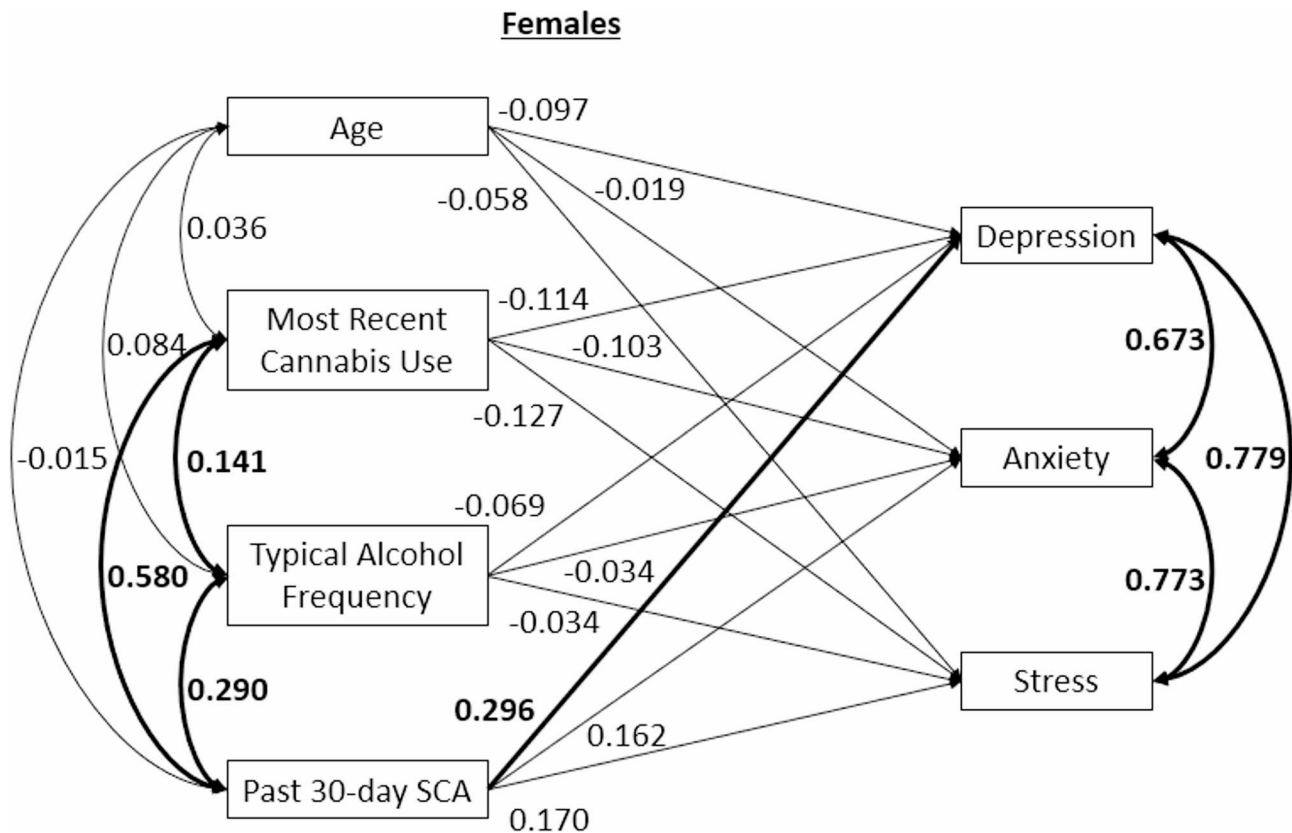


Fig. 2 Standardized path model for individuals assigned female at birth. Note. Associations between age, substance use, and psychological distress are shown. Statistically significant paths ($p < .05$) are bolded. All variables are observed. SCA = Simultaneous Cannabis and Alcohol Use

or stress ($\beta = 0.170, p = 0.063$). Age was not significantly associated with depression ($\beta = -0.097, p = 0.069$), anxiety ($\beta = -0.019, p = 0.775$), or stress ($\beta = -0.058, p = 0.339$) in female students. Typical alcohol use frequency was not significantly related to scores on depression ($\beta = -0.069, p = 0.346$), anxiety ($\beta = -0.034, p = 0.697$), or stress ($\beta = 0.034, p = 0.666$). Most recent cannabis use occasion did not show a significant association with depression ($\beta = -0.114, p = 0.145$), anxiety ($\beta = -0.103, p = 0.254$), or stress ($\beta = -0.127, p = 0.140$).

The z-tests conducted to compare coefficients across males and females yielded results showing that the relations between age and depression ($B = -1.832, p = 0.004$), anxiety ($B = -0.989, p = 0.040$), and stress ($B = -1.505, p = 0.010$) were found to be significantly larger for males compared to females. All other relations between predictor variables and outcomes displayed non-significant results ($p > 0.05$) when compared across sex. Estimated effects of outcomes on predictors grouped by sex, along with results from the z-tests, are shown in Table 4.

Finally, we conducted post-hoc power analyses via Monte Carlo simulations across 10,000 replications to ensure stable estimates. The Monte Carlo simulation estimates power for detecting significant differences based on the coefficients representing the strength of relations

among variables obtained from the present analysis. Simulations indicated that in our sample of $N = 367$ (245 females and 122 males), we were powered to detect a difference between males and females on the relation between SCA → depression 5.4% of the time, SCA → anxiety 21.6% of the time, and SCA → stress 36.6% of the time. Additional simulations based on coefficient estimates from the current sample indicated that to detect a difference between SCA → anxiety and SCA → stress at 80% power would require a total sample size of $N = 2050$ (1025 males and females), and $N = 1000$ (500 males and females), respectively.

Discussion

The increasing prevalence of SCA use (Cerdá et al. 2020; McCabe et al. 2021) and related consequences (Brière et al. 2011; Cummings et al. 2019; Fleming et al. 2021; Jackson et al. 2020; Linden-Carmichael et al. 2019, 2020; Patrick et al. 2022; Subbaraman and Kerr 2015; White et al. 2019) underscores the importance of studying SCA behaviors in college students. Greater knowledge of consequences related to SCA and how different variables (i.e., sex and frequency of use) impact these consequences may provide insight into potential intervention and prevention approaches for college students who

Table 4 Multigroup path analysis results

Males	β	SE	p value
<i>Outcome variable: Depression</i>			
Age	0.190	0.084	0.024*
Cannabis Use Frequency	-0.019	0.072	0.793
Alcohol Use Frequency	-0.142	0.070	0.042*
Monthly SCA Use	0.322	0.090	<0.001***
<i>Outcome variable: Anxiety</i>			
Age	0.203	0.075	0.007**
Cannabis Use Frequency	0.056	0.064	0.381
Alcohol Use Frequency	-0.207	0.062	0.001**
Monthly SCA Use	0.323	0.076	<0.001***
<i>Outcome variable: Stress</i>			
Age	0.202	0.076	0.008**
Cannabis Use Frequency	-0.065	0.072	0.364
Alcohol Use Frequency	-0.199	0.061	0.001**
Monthly SCA Use	0.369	0.089	<0.001***
Females			
<i>Outcome variable: Depression</i>			
Age	-0.097	0.053	0.069
Cannabis Use Frequency	-0.114	0.078	0.145
Alcohol Use Frequency	-0.069	0.073	0.346
Monthly SCA Use	0.296	0.085	0.001**
<i>Outcome variable: Anxiety</i>			
Age	-0.019	0.065	0.775
Cannabis Use Frequency	-0.103	0.091	0.254
Alcohol Use Frequency	-0.034	0.088	0.697
Monthly SCA Use	0.162	0.103	0.114
<i>Outcome variable: Stress</i>			
Age	-0.058	0.061	0.339
Cannabis Use Frequency	-0.127	0.086	0.140
Alcohol Use Frequency	-0.034	0.079	0.666
Monthly SCA Use	0.170	0.091	0.063
Z-Test Comparisons (Females vs. Males)			
SCA → Depression	-0.206	2.693	0.939
SCA → Anxiety	-2.177	1.996	0.276
SCA → Stress	-3.881	2.448	0.113
Cannabis Frequency → Depression	-0.335	0.355	0.346
Cannabis Frequency → Anxiety	-0.391	0.275	0.156
Cannabis Frequency → Stress	-0.174	0.334	0.602
Alcohol Frequency → Depression	0.742	1.245	0.551
Alcohol Frequency → Anxiety	1.399	0.991	0.158
Alcohol Frequency → Stress	1.775	1.098	0.106
Age → Depression	-1.832	0.628	0.004**
Age → Anxiety	-0.989	0.482	0.040*
Age → Stress	-1.505	0.580	0.010*

Note. Significant effects are indicated by boldface font and the following: $p < 0.05^*$, $p < 0.01^{**}$, $p < 0.001^{***}$. Standardized effect size values are provided for all paths except in the model comparisons across sex section, where reported values are unstandardized. SCA Simultaneous Cannabis and Alcohol Use.

co-use alcohol and cannabis and present with mental health challenges.

We found that monthly or greater SCA use is significantly associated with greater depression symptoms for both male and female college students, consistent with prior research finding that more frequent SCA use correlates with more severe mental health symptoms (Fleming et al. 2021; Patrick et al. 2022; Subbaraman and Kerr 2015; Thompson et al. 2021). We also report that SCA use is associated with higher anxiety and stress in males but not in females, however the strength of these relationships did not significantly differ between sexes. Post-hoc power analyses indicated that the present study was underpowered to detect sex differences in this sample. While larger samples are needed to clarify these associations, the observed pattern of results broadly aligns with evidence that in non-clinical samples, males may engage in heavier or more coping-driven substance use than females (Park and Levenson 2002), which may help explain why SCA could be more strongly associated with anxiety and stress in males. Adequately powered longitudinal studies should investigate these relations further. Our Monte Carlo simulations suggest sample sizes of at least 1000 are needed to detect sex differences in the association between SCA and stress at 80% power, and larger samples ($N = 2050$) are needed to detect sex differences in the relationship between SCA and anxiety. For the relationship between SCA and depression, increasing sample size did not improve power in the present study (for both a sample size of 367 and 2200, power hovered at approximately 5%), indicating a true sex difference may not exist between these variables.

Interestingly, we found that typical alcohol use frequency *negatively* predicted depression, anxiety, and stress among males but not among females. Although these sex differences also did not reach significance in the present sample, the pattern of results observed in males—negative associations between alcohol and mental health but positive associations between SCA and mental health—are notable and worth exploring in larger studies. It may be that while SCA use is associated with overall worse mental health among male college students, alcohol use on its own reflects social drinking and/or serves as a short-term stress buffer. Indeed, compared to young adult women, who are more than twice as likely to experience depression and anxiety than men (Cyranowski et al. 2000; Salk et al. 2017), and who tend to rely on emotion-focused coping strategies such as rumination and seeking social support (Tamres et al. 2002), young adult men report lower baseline internalizing symptoms and more frequent use of avoidant or externalizing coping strategies such as substance use (Park and Levenson 2002). Thus, for male college students, alcohol use may serve as an avoidant coping strategy with acute

stress-reducing effects (Claus et al. 2022; Linden-Carmichael et al. 2021), whereas for female college students, who already report higher baseline internalizing symptoms and may rely more on emotion-focused coping, alcohol use may not play the same role. Future longitudinal studies with adequate power to detect sex differences may be valuable to explore patterns of alcohol and cannabis use in males and females and how these behaviors interact with sex-specific coping strategies. Gaining a more detailed picture of students' daily substance use patterns over time would also help to disentangle the specific effects of alcohol and cannabis individually on mental health outcomes among students who co-use.

The present findings may have several possible implications for prevention and/or intervention efforts for college students. First, results add to prior evidence suggesting that SCA use may be an effective intervention target for mental health problems—particularly depression—among college students (Brière et al. 2011; Fleming et al. 2021; Patrick et al. 2022). Programs aimed at preventing depression in college students may benefit from assessing detailed patterns of substance use, including co-use behaviors (Helle et al. 2022; Montemayor et al. 2023). Such prevention and intervention efforts might be particularly relevant for male students, given the significant relations between SCA use and mental health outcomes examined in this study, though future studies with larger sample sizes are needed to better understand sex differences in the relationship between SCA and mental health.

Limitations and future directions

This study is subject to limitations related to the survey questions we asked, sample composition, and sample size. The questions regarding SCA and alcohol use assessed typical patterns of use, while for cannabis, most recent use was assessed. The SCA question assessed typical SCA patterns, resulting in potential heterogeneity within the SCA+ and SCA- groups (e.g., the SCA- group may include some individuals who have never engaged in SCA). Further, this question does not identify people who engage in concurrent alcohol and cannabis use or capture the fact that some individuals may engage in both simultaneous and concurrent co-use throughout their daily life. Future studies should include more detailed questions on simultaneous and concurrent co-use to explore these potentially important nuances.

All participants in the study were college students aged 18–25, and most identified as White non-Hispanic, thus limiting generalizability to other populations. Variations in substance use and frequency have been observed based on race and ethnicity (Chen and Jacobson 2012)—thus the underrepresentation of diverse ethnic backgrounds in this sample may bias the present results

towards those of a singular ethnic demographic. Future studies on this topic should include non-college populations, and more diverse (i.e., ethnically, racially, and other marginalized identities) populations. In addition, these students reside in Colorado, which was the first state to legalize recreational cannabis. Thus individuals in Colorado may have different overall attitudes toward cannabis compared to college students living in other states, particularly those with more stringent legal policies and presumably more negative attitudes toward cannabis (Carliner et al. 2017). Findings should be replicated across different universities/geographic locations including states with different cannabis policies. Finally, as revealed by the post-hoc power analysis, the small sample sizes ($N_{SCA+} = 133$, $N_{SCA-} = 234$; 245 females and 122 males) indicate the current study was underpowered to find statistically significant sex differences, and analyses should be replicated in a larger sample. Examining mental health outcomes across various levels of SCA use (i.e., daily, weekly, monthly) and intensity (i.e., quantity consumed) is another important future direction. Additional longitudinal research is needed to better understand the directionality, temporality, and etiology of these relations (i.e., does SCA result in mental health symptoms or vice versa).

Conclusions

This study adds to the growing evidence linking SCA to mental health concerns in college students. Mental health providers working with college students may wish to consider incorporating detailed assessments of alcohol and cannabis co-use, as SCA use may be a useful intervention target. SCA use could also be an important factor to assess in a prevention or mental health promotion context. Future studies employing larger, more representative samples, more nuanced assessments of co-use, and longitudinal designs are needed to clarify the patterns, directionality and mechanisms connecting SCA use with mental health outcomes.

Abbreviations

SCA	Simultaneous Alcohol and Cannabis use
SCA+ group	individuals that reported SCA at least once per month
SCA- group	individuals that reported SCA less than once per month
AUDIT	Alcohol Use Disorder Identification Test
DASS	Depression, Anxiety, and Stress Scale
CFI	Comparative Fit Index
RMSEA	Root Mean Square Error of Approximation

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Authors' contributions

HCK was responsible for the collection of data. TM and EMH conceived of the presented idea. EMH, MAP, AJT, and NNE performed the initial analysis. MAP, NNE and BTC verified the analytic methods, provided suggestions for improvement, and reviewed the new results. EMH and MAP further refined the analysis. TM and AJT wrote the first draft. TM, AJT, EMH, HCK, MAP, and BTC edited the writing and provided suggestions, which TM, AJT, and EMH

implemented. All authors have approved the submitted version, and have agreed to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Colorado State University Institutional Review Board, and all participants provided informed consent prior to enrollment.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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References

- Beiter R, Nash R, McCrady M, Rhoades D, Linscomb M, Clarahan M, et al. The prevalence and correlates of depression, anxiety, and stress in a sample of college students. *J Affect Disord*. 2015;173:90–6. <https://doi.org/10.1016/j.jad.2014.10.054>.
- Bravo AJ, Prince MA, Pilatti A, Mezquita L, Keough MT, Hogarth L. Young adult concurrent use and simultaneous use of alcohol and marijuana: a cross-national examination among college students in seven countries. *Addict Behav Rep*. 2021;14:100373. <https://doi.org/10.1016/j.abrep.2021.100373>.
- Brière FN, Fallu J-S, Descheneaux A, Janosz M. Predictors and consequences of simultaneous alcohol and cannabis use in adolescents. *Addict Behav*. 2011;36(7):785–8. <https://doi.org/10.1016/j.addbeh.2011.02.012>.
- Brown TA. *Confirmatory Factor Analysis for Applied Research: Second Edition*. Guilford Press. 2015. <https://www.guilford.com/books/Confirmatory-Factor-Analysis-for-Applied-Research/Timothy-Brown/9781462515363?srsltid=AfmBO062OAIMqtK4m3LRXPQ2Oix1wt-DpUOCdOigfbEkyFLYGFj1>
- Carliner H, Brown QL, Sarvet AL, Hasin DS. Cannabis use, attitudes, and legal status in the U.S.: a review. *Prev Med*. 2017;104:13–23. <https://doi.org/10.1016/j.ypmed.2017.07.008>.
- Cerdá M, Mauro C, Hamilton A, Levy NS, Santaella-Tenorio J, Hasin D, et al. Association between recreational marijuana legalization in the United States and changes in marijuana use and cannabis use disorder from 2008 to 2016. *JAMA Psychiatr*. 2020;77(2):165–71. <https://doi.org/10.1001/jamapsychiatry.2019.3254>.
- Chen P, Jacobson KC. Developmental trajectories of substance use from early adolescence to young adulthood: gender and racial/ethnic differences. *J Adolesc Health*. 2012;50(2):154–63. <https://doi.org/10.1016/j.jadohealth.2011.05.013>.
- Claus ED, Blaine SK, Witkiewitz K, Ansell EB. Sex moderates effects of alcohol and cannabis co-use on alcohol and stress reactivity. *Alcohol Clin Exp Res*. 2022;46(4):530–41. <https://doi.org/10.1111/acer.14797>.
- Cummings C, Beard C, Habarth JM, Weaver C, Haas A. Is the sum greater than its parts? Variations in substance-related consequences by conjoint alcohol-marijuana use patterns. *J Psychoact Drugs*. 2019;51(4):351–9. <https://doi.org/10.1080/02791072.2019.1599473>.
- Cuttler C, Spradlin A. Measuring cannabis consumption: psychometric properties of the daily sessions, frequency, age of onset, and quantity of cannabis use inventory (DFAQ-CU). *PLoS ONE*. 2017;12(5):e0178194. <https://doi.org/10.1371/journal.pone.0178194>.
- Cyrnowski JM, Frank E, Young E, Shear MK. Adolescent onset of the gender difference in lifetime rates of major depression: a theoretical model. *Arch Gen Psychiatry*. 2000;57(1):21–7. <https://doi.org/10.1001/archpsyc.57.1.21>.
- Erol A, Karpyak VM. Sex and gender-related differences in alcohol use and its consequences: contemporary knowledge and future research considerations. *Drug Alcohol Depend*. 2015;156:1–13. <https://doi.org/10.1016/j.drugalcdep.2015.08.023>.
- Fleming CB, Duckworth JC, Rhew IC, Abdallah DA, Guttmannova K, Patrick ME, et al. Young adult simultaneous alcohol and marijuana use: between- and within-person associations with negative alcohol-related consequences, mental health, and general health across two-years. *Addict Behav*. 2021;123:107079. <https://doi.org/10.1016/j.addbeh.2021.107079>.
- Fox J, Weisberg S, Price B, Adler D, Bates D, Baud-Bovy G, Bolker B, Ellison S, Firth D, Friendly M, Gorjanc G, Graves S, Heiberger R, Krivitsky P, Laboisiere R, Maechler M, Monette G, Murdoch D, Nilsson H, R-Core. ... (2024). *car: Companion to Applied Regression* (Version 3.1-3) [Computer software]. <https://cran.r-project.org/web/packages/car/index.html>
- Goodwin SR, Moskal D, Marks RM, Clark AE, Squeglia LM, Roche DJO. A scoping review of gender, sex and sexuality differences in polysubstance use in adolescents and adults. *Alcohol Alcohol*. 2022;57(3):292–321. <https://doi.org/10.1093/alcalc/agac006>.
- Haas AL, Wickham R, Macia K, Shields M, Macher R, Schulte T. Identifying classes of conjoint alcohol and marijuana use in entering freshmen. *Psychol Addict Behaviors: J Soc Psychologists Addict Behav*. 2015;29(3):620–6. <https://doi.org/10.1037/adb0000089>.
- Haberstick BC, Young SE, Zeiger JS, Lessem JM, Hewitt JK, Hopfer CJ. Prevalence and correlates of alcohol and cannabis use disorders in the united states: results from the National longitudinal study of adolescent health. *Drug Alcohol Depend*. 2014;136:158–61. <https://doi.org/10.1016/j.drugalcdep.2013.11.022>.
- Hallquist MN, Wiley JF. Mplusautomation: an R package for facilitating large-scale latent variable analyses in Mplus. *Struct Equ Modeling*. 2018;25(4):621–38. <https://doi.org/10.1080/10705511.2017.1402334>.
- Hankin BL, Abramson LY, Moffitt TE, Silva PA, McGee R, Angell KE. Development of depression from preadolescence to young adulthood: emerging gender differences in a 10-year longitudinal study. *J Abnorm Psychol*. 1998;107(1):128–40. <https://doi.org/10.1037/0021-843X.107.1.128>.
- Helle AC, Boness CL, Sher KJ. College students' receptiveness to intervention approaches for alcohol and cannabis use. *Psychol Addict Behav*. 2022;36(2):157–76. <https://doi.org/10.1037/adb0000699>.
- Hu L, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Struct Equation Modeling Multidisciplinary J*. 1999;6(1):1–55. <https://doi.org/10.1080/10705519909540118>.
- Jackson KM, Sokolovsky AW, Gunn RL, White HR. Consequences of alcohol and marijuana use among college students: prevalence rates and attributions to substance-specific versus simultaneous use. *Psychol Addict Behav*. 2020;34(2):370–81. <https://doi.org/10.1037/adb0000545>.
- Karriker-Jaffe KJ, Subbaraman MS, Greenfield TK, Kerr WC. S. adults who have never been to treatment. *Nordisk Alkohol- Narkotikatidskrift: NAT*. 2018;35(6):428–42. <https://doi.org/10.1177/1455072518806122>. Contribution of alcohol and drug co-use to substance use problems: Data from a nationally-representative sample of U.
- Kokotailo PK, Egan J, Gangnon R, Brown D, Mundt M, Fleming M. Validity of the alcohol use disorders identification test in college students. *Alcohol Clin Exp Res*. 2004;28(6):914–20. <https://doi.org/10.1097/01.alc.0000128239.87611.f5>.
- Kolp H, Horvath S, Fite PJ, Metrik J, Stuart GL, Lisdahl KM, et al. Development of the alcohol and cannabis simultaneous use scale (ACSUS) in college students. *J Subst Use*. 2024;29(4):509–16. <https://doi.org/10.1080/14659891.2023.2183149>.
- Linden-Carmichael AN, Stamates AL, Lau-Barraco C. Simultaneous use of alcohol and marijuana: patterns and individual differences. *Subst Use Misuse*. 2019;54(13):2156–66. <https://doi.org/10.1080/10826084.2019.1638407>.
- Linden-Carmichael AN, Van Doren N, Masters LD, Lanza ST. Simultaneous alcohol and marijuana use in daily life: implications for level of use, subjective intoxication, and positive and negative consequences. *Psychol Addict Behaviors: J Soc Psychologists Addict Behav*. 2020;34(3):447–53. <https://doi.org/10.1037/adb0000556>.
- Linden-Carmichael AN, Hochgraf AK, Cloutier RM, Stull SW, Lanza ST. Associations between simultaneous alcohol and cannabis use and next-day negative affect among young adults: the role of sex and trait anxiety. *Addict Behav*. 2021;123:107082. <https://doi.org/10.1016/j.addbeh.2021.107082>.

- Lovibond SH, Lovibond PF. Manual for the depression anxiety stress scales. 2nd ed. Sydney, N.S.W.: Psychology Foundation of Australia; 1995.
- McCabe SE, Arterberry BJ, Dickinson K, Evans-Polce RJ, Ford JA, Ryan JE, et al. Assessment of changes in alcohol and marijuana abstinence, co-use, and use disorders among US young adults from 2002 to 2018. *JAMA Pediatr.* 2021;175(1):64–72. <https://doi.org/10.1001/jamapediatrics.2020.3352>.
- Melchior M, Caspi A, Milne BJ, Danese A, Poulton R, Moffitt TE. Work stress precipitates depression and anxiety in young, working women and men. *Psychol Med.* 2007;37(8):1119–29. <https://doi.org/10.1017/S0033291707000414>.
- Montemayor B, Noland M, Ickes M, Barry A. Effectiveness of mandated interventions for Cannabis-using U.S. college students: a systematic review. *J Student Affairs Res Pract.* 2023;60(3):401–16. <https://doi.org/10.1080/19496591.2022.2027244>.
- Muthén LK, Muthén BO. (1998, 2017). Mplus User's Guide. <https://www.statmodel.com/html Ug.shtml>
- Park CL, Levenson MR. Drinking to cope among college students: prevalence, problems and coping processes. *J Stud Alcohol.* 2002;63(4):486–97. <https://doi.org/10.15288/jsa.2002.63.486>.
- Patrick ME, Veliz PT, Terry-McElrath YM. High-intensity and simultaneous alcohol and marijuana use among high school seniors in the United States. *Subst Abuse.* 2017;38(4):498–503. <https://doi.org/10.1080/08897077.2017.1356421>.
- Patrick ME, Fairlie AM, Lee CM. Motives for simultaneous alcohol and marijuana use among young adults. *Addict Behav.* 2018;76:363–9. <https://doi.org/10.1016/j.addbeh.2017.08.027>.
- Patrick ME, Fleming CB, Fairlie AM, Lee CM. Cross-fading motives for simultaneous alcohol and marijuana use: associations with young adults' use and consequences across days. *Drug Alcohol Depend.* 2020;213:108077. <https://doi.org/10.1016/j.drugalcdep.2020.108077>.
- Patrick ME, Ramirez JJ, Cadigan JM, Graupensperger S, Walukevich-Dienst K, Rhew IC, et al. Examining daily associations between mental health symptoms and simultaneous alcohol and marijuana use and consequences among young adults. *Psychol Addict Behav.* 2022;36(4):410–8. <https://doi.org/10.1037/adb0000791>.
- Ramón-Arбуés E, Gea-Caballero V, Granada-López JM, Juárez-Vela R, Pellicer-García B, Antón-Solanas I. The prevalence of depression, anxiety and stress and their associated factors in college students. *Int J Environ Res Public Health.* 2020;17(19):7001. <https://doi.org/10.3390/ijerph17197001>.
- Robinson T, Ali MU, Easterbrook B, Coronado-Montoya S, Daldegan-Bueno D, Hall W, et al. Identifying risk-thresholds for the association between frequency of cannabis use and development of cannabis use disorder: a systematic review and meta-analysis. *Drug Alcohol Depend.* 2022;238:109582. <https://doi.org/10.1016/j.drugalcdep.2022.109582>.
- Salk RH, Hyde JS, Abramson LY. Gender differences in depression in representative National samples: meta-analyses of diagnoses and symptoms. *Psychol Bull.* 2017;143(8):783–822. <https://doi.org/10.1037/bul0000102>.
- Saunders JB, Aasland OG, Babor TF, de la Fuente JR, Grant M. Development of the alcohol use disorders identification test (AUDIT): WHO collaborative project on early detection of persons with harmful alcohol consumption—II. *Addiction (Abingdon England).* 1993;88(6):791–804. <https://doi.org/10.1111/j.1360-0443.1993.tb02093.x>.
- Sokolovsky AW, Gunn RL, Micalizzi L, White HR, Jackson KM. Alcohol and marijuana co-use: consequences, subjective intoxication, and the operationalization of simultaneous use. *Drug Alcohol Depend.* 2020;212:107986. <https://doi.org/10.1016/j.drugalcdep.2020.107986>.
- Subbaraman MS, Kerr WC. Simultaneous versus concurrent use of alcohol and cannabis in the National alcohol survey. *Alcohol Clin Exp Res.* 2015;39(5):872–9. <https://doi.org/10.1111/acer.12698>.
- Subbaraman MS, Barnett SB, Karriker-Jaffe KJ. Risks associated with mid level cannabis use among people treated for alcohol use disorder. *Alcohol Clin Exp Res.* 2019;43(4):690–4. <https://doi.org/10.1111/acer.13973>.
- Tamres LK, Janicki D, Helgeson VS. Sex differences in coping behavior: a meta-analytic review and an examination of relative coping. *Pers Soc Psychol Rev.* 2002;6(1):2–30. https://doi.org/10.1207/S15327957PSPR0601_1.
- Terry-McElrath YM, Patrick ME. Simultaneous alcohol and marijuana use among young adult drinkers: age-specific changes in prevalence from 1977 to 2016. *Alcohol Clin Exp Res.* 2018;42(11):2224–33. <https://doi.org/10.1111/acer.13879>.
- Thompson K, Holley M, Sturgess C, Leadbeater B. Co-use of alcohol and cannabis: longitudinal associations with mental health outcomes in young adulthood. *Int J Environ Res Public Health.* 2021;18(7):3652. <https://doi.org/10.3390/ijerph18073652>.
- Tucker JS, Seelam R, Green HD, Rodriguez A, Pollard MS. Alcohol and cannabis co-use in a national sample of U.S. adults ages 30–80. *Addict Behav.* 2023;142:107663. <https://doi.org/10.1016/j.addbeh.2023.107663>.
- White HR, Kilmer JR, Fossos-Wong N, Hayes K, Sokolovsky AW, Jackson KM. Simultaneous alcohol and marijuana use among college students: patterns, correlates, norms, and consequences. *Alcohol Clin Exp Res.* 2019;43(7):1545–55. <https://doi.org/10.1111/acer.14072>.
- Wickham H, Averick M, Bryan J, Chang W, McGowan LD, François R, et al. Welcome to the tidyverse. *J Open Source Softw.* 2019;4(4):1686. <https://doi.org/10.21105/joss.01686>.
- World Health Organization. (n.d.). AUDIT: The Alcohol Use Disorders Identification Test: guidelines for use in primary health care. Retrieved March 4, 2025, from <https://www.who.int/publications/i/item/WHO-MSD-MSB-01.6a>
- Wright M, Wickens CM, Di Ciano P, Sproule B, Fares A, Matheson J, et al. Sex differences in the acute pharmacological and subjective effects of smoked cannabis combined with alcohol in young adults. *Psychol Addict Behaviors: J Soc Psychologists Addict Behav.* 2021;35(5):536–52. <https://doi.org/10.1037/adb0000749>.
- Yurasek AM, Aston ER, Metrik J. Co-use of alcohol and cannabis: a review. *Curr Addict Rep.* 2017;4(2):184–93. <https://doi.org/10.1007/s40429-017-0149-8>.
- Zahn-Waxler C, Shirtcliff EA, Marceau K. Disorders of childhood and adolescence: gender and psychopathology. *Ann Rev Clin Psychol.* 2008;44, 2008:275–303. <https://doi.org/10.1146/annurev.clinpsy.3.022806.091358>.

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