



Simultaneous use of alcohol and cannabis and attenuated age-related declines in alcohol and cannabis use disorder symptoms across young adulthood

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HIGHLIGHTS

- Findings support maturing out of high-risk alcohol and cannabis across young adulthood.
- Simultaneous use of alcohol and cannabis (SAM) attenuated age-related declines in AUD and CUD.
- More frequent SAM use related to less declines in AUD and CUD symptoms.
- SAM use may be a risk-factor for prolonged high-risk substance use during young adulthood.

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ABSTRACT

Most young adults naturally mature out of high-risk substance use patterns, but it is important to identify factors that may impede normative declines. Use of alcohol and cannabis simultaneously (i.e., simultaneous alcohol and marijuana/cannabis [SAM]) is cross-sectionally associated with alcohol and cannabis concerns, and SAM use increases acute risks at the daily level. However, less is known about long-term risks of SAM use and, specifically, how SAM use relates to maturing out of alcohol and cannabis use. Using four consecutive years of survey data from young adults who reported SAM use ($N=409$; 1636 responses; aged 18–25 at baseline), we first estimated age-related changes in symptoms of alcohol and cannabis use disorder (AUD/CUD) using multilevel growth modeling. Findings supported a maturing out process, as both AUD and CUD symptom severity significantly declined across young adulthood, on average (4 % and 5 % per year respectively, with significant acceleration). Cross-level interactions tested whether participants' mean SAM use frequency across all four timepoints moderated age-related trajectories in AUD/CUD symptom severity. Significant interactions indicated that, relative to less-frequent SAM use, participants with more frequent SAM use showed less steep declines in AUD (1 % decrease per year vs. 6 % per year) and CUD symptoms (0 % decrease per year vs. 7 % per year); thus, SAM frequency was associated with slower/delayed maturing out of hazardous alcohol and cannabis use. Findings highlight that SAM use may be a correlate or risk-factor for prolonged high-risk substance use during young adulthood that relates to deviations from maturing out processes.

Young adulthood, the developmental stage from late teens to late twenties, is a high-risk period for substance use and misuse (Andrews and Westling, 2016; Sussman and Arnett, 2014). Prevalence estimates of past-month alcohol (66.3 %) and cannabis use (28.5 %) among US young adults are concerningly high given mounting evidence of salient societal costs and public health concerns attributed to these substances

(Hall and Lynskey, 2020; Patrick, Schulenberg, et al., 2022; Rehm and Shield, 2019). This high prevalence coupled with evidence that young adulthood is a critical period for the development of substance use disorder (Sussman and Arnett, 2014) is inauspicious; however, most young adults go through a normative maturing out of high-risk substance use (Jochman and Fromme, 2010; Waddell et al., 2022). Indeed,

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for both alcohol and cannabis, rates of use and related concern typically peak in the early twenties and then decrease across young adulthood (Arria et al., 2016; Brook et al., 2011; Lee and Sher, 2018; Windle, 2020). Nevertheless, there is variability in these processes: Some people are delayed or may never mature out of high-risk substance use patterns, yet little is known about factors that may be associated with this variability (Jochman and Fromme, 2010).

Alongside the risks associated with alcohol and cannabis use, separately, use of both substances simultaneously such that the effects overlap (i.e., simultaneous alcohol and marijuana/cannabis¹ use; SAM use) presents unique risks above-and-beyond the amount of each substance being used (Fairlie et al., 2023). SAM use is prevalent among young adults, with estimates generally indicating between 15 % and 25 % of all young adults use both substances simultaneously (Lee et al., 2022). Individuals who engage in SAM use experience more negative consequences relative to those who only use alcohol (Jackson et al., 2021; Patrick, Terry-McElrath, Lee, et al., 2019; Thompson et al., 2021), but these cross-sectional data may only reflect contemporaneous, not longitudinal, risk. Moreover, daily-level research shows that SAM use days, relative to alcohol- or cannabis-only use days, are associated with increased quantity of use and more negative consequences even when controlling for quantity (Egan et al., 2019; Lee et al., 2020; Linden-Carmichael et al., 2020). A more complete understanding of the risks of SAM use requires longitudinal examination. Beyond use levels and consequences, less is known about how SAM use may contribute to symptoms of alcohol and cannabis use disorder, which entail persistent problematic patterns of use. As such, there is a need to examine the extent to which SAM use relates to alcohol and cannabis use disorder at within-person levels across young adulthood, and whether SAM use is associated with delayed transitions out of high-risk substance use behaviors.

1. Current study

Much of the etiological literature on maturing out processes focuses only on the average effect, that many young adults will mature out of substance use, but the knowledge gap regarding the at-risk subgroup of young adults who experience slower/delayed age-related declines has only begun to be addressed. To further fill this gap, the current study tested whether SAM use contributes to the maintenance of symptoms of alcohol use disorder (AUD) and cannabis use disorder (CUD) across young adulthood. Using four annual surveys with age coverage from 18 to 29 years old (i.e., similar to an accelerated longitudinal design), our first aim examined changes in AUD and CUD symptoms across age to provide an initial estimate of maturing-out processes in this sample (i.e., original inclusion entailed past-month SAM use at baseline) and tested within-person and between-person associations between AUD and CUD symptoms, as evidence suggests AUD and CUD are often comorbid (Baggio et al., 2018). We hypothesized that, on average, both AUD and CUD symptoms will decrease with age during the mid- and late-twenties (e.g., Waddell et al., 2022). We also hypothesized that AUD and CUD symptoms will be positively associated at both the between-person level (i.e., averaged across all timepoints) and the within-person level (i.e., AUD symptoms will be relatively higher at timepoints that CUD symptoms are relatively higher).

In the second aim, we examined the extent to which SAM frequency was associated with AUD and CUD symptoms at both the within-person and between-person levels (main effects) and the third aim tested whether SAM frequency moderates associations between age and AUD/CUD symptoms. We hypothesized that SAM use frequency will be positively associated with both AUD and CUD symptoms at the within-

person and between-person levels, and that young adults with more frequent SAM use will show less reduction in AUD/CUD symptoms over time, relative to those who less frequently engage in SAM.

2. Method

2.1. Participants and procedures

Data came from a longitudinal study on SAM use among 409 young adults in the greater Seattle, Washington metropolitan area (Lee et al., 2020; Patrick et al., 2020). At enrollment, eligible participants were 18–25 years old, reported alcohol use 3+ times in the past month, reported past-month SAM use (at least once), and lived within 60 miles of the study office. Approximately half (50.9 %) the participants identified their assigned birth sex as female and 48.2 % identified as White Non-Hispanic (NH), 20.0 % Other NH (e.g., Black/African American, multiracial), 15.9 % Hispanic, and 15.9 % Asian NH. At baseline, the average age was 21.61 years ($SD = 2.17$), 48.9 % were enrolled in a four-year college, 40.8 % were employed part-time, and 25.2 % were employed full-time.

The present analyses use data from the baseline survey (December 2017 through September 2018) and three yearly follow-up surveys (Year 1 follow-up: November 2018 through October 2019; Year 2 follow-up: November 2019 through September 2020; Year 3 follow-up: May 2021 for all participants). Retention across years was high with 98.0 %, 94.9 %, and 91.9 % of participants completing the Year 1, Year 2, and Year 3 follow-up surveys, respectively. Additional details of study procedures are described elsewhere (Fairlie et al., 2021; Patrick, Ramirez, et al., 2022). The study was approved by the University of Washington Institutional Review Board.

2.2. Measures

2.2.1. Symptoms of Alcohol Use Disorder (AUD)

At each assessment, participants completed the Alcohol Use Disorder Identification Test (AUDIT; Babor et al., 2001), a 10-item measure of hazardous/harmful drinking referencing the past year. In this sample, the reliability of the AUDIT was good, as evidenced by Cronbach alphas ranging from 0.77 to 0.83.

2.2.2. Symptoms of Cannabis Use Disorder (CUD)

At each assessment, participants completed the 8-item Cannabis Use Disorder Identification Test–Revised (CUDIT-R; Adamson et al., 2010), a measure designed to screen for cannabis misuse during the previous six months and indicate risk for possible CUD. The reliability was good, as evidenced by Cronbach alphas ranging from 0.82 to 0.86.

2.2.3. SAM use frequency

At each assessment, participants were asked, “On how many occasions (if any) during the last 30 days have you used alcohol and marijuana at the same time—that is, so that their effects overlapped?” Response options included “0 occasions” (0), “1–2 occasions” (1), “3–5 occasions” (2), “6–9 occasions” (3), “10–19 occasions” (4), “20–39 occasions” (5), and “40 or more occasions” (6).

2.2.4. Age

Participants’ age at baseline was calculated as an integer from their date of birth. Survey completion dates, at each follow-up, were used to calculate participants’ age in years (with two decimals) at each follow-up.

2.2.5. COVID-19 pandemic indicator

Given prior work suggesting that the COVID-19 pandemic was associated with changes in young adult substance use (Graupensperger et al., 2023; Graupensperger, Fleming, et al., 2021; Graupensperger, Jaffe, et al., 2021; Patrick, Terry-McElrath, et al., 2022), a binary

¹ We recognize that the term ‘marijuana’ may entail stigmatization. We retain the acronym “SAM” to be consistent with the extant literature, although we use the term ‘cannabis’ elsewhere in line with preferred terminology.

indicator variable was created to control for surveys completed prior to (0) versus on or after (1) March 1, 2020 to account for changes in alcohol and cannabis use and related outcomes that may have been influenced by the COVID-19 pandemic.

2.3. Analyses

All aims were tested using Poisson multilevel growth models fit using maximum likelihood estimation based on the Laplace Approximation in the *glmmTMB* package (Brooks et al., 2017) in R. Models used an individually-varying time metric of age, and an age-squared parameter allowed for non-linear changes in outcomes to be modeled (Grimm et al., 2017). Random slopes were specified for Level 1 variables when doing so improved fit based on likelihood ratio tests. Age and age-squared were both centered at age 21. To isolate pure within- and between-person associations at Levels 1 and 2, respectively, all Level 1 variables except for age and age-squared were person-mean centered (Hamaker and Muthén, 2020). Level 2 variables were grand-mean centered. Multilevel models can accommodate missing data on outcome variables and are expected to produce unbiased parameter estimates under the assumption that data are missing at random (Hox et al., 2017).

3. Results

3.1. Descriptive statistics

Descriptive statistics are presented in Table 1. Participants ranged in age from 18.00 to 29.33 across assessments, with a mean age of 23.05 ($SD=2.46$). Averaged across all assessments without accounting for the hierarchical structure of the data, the average AUDIT score was 8.70 ($SD=5.59$, range: 0–31), and the average CUDIT-R score was 9.57 ($SD=6.63$, range: 0–31). More than two-thirds (72.6 %) of participants reported hazardous/harmful alcohol use (i.e., AUDIT scores ≥ 8) on at

Table 1
Descriptive statistics.

Level 1: Assessment Level (N = 1636)						
Variable	n	M	SD	Median	Min.	Max.
AUDIT	1558	8.70	5.59	7	0	31
CUDIT	1540	9.57	6.63	9	0	31
SAM use frequency	1537	1.13	1.29	1	0	6
Age	1563	23.05	2.46	22.96	18.00	29.33
COVID	1574	0.42	0.49	0	0	1
Level 2: Person Level (N = 409)						
Variable	n	%	Min.	Max.		
Male sex	409	49.1	0	1		
Race/ethnicity	409					
Asian NH		15.9	0	1		
Hispanic		15.9	0	1		
Other NH		20.0	0	1		
White NH		48.2	0	1		

Note. AUDIT = Alcohol Use Disorder Identification Test (Babor et al., 2001); CUDIT = Cannabis Use Disorder Identification Test (Adamson et al., 2010); SAM = Simultaneous alcohol and marijuana use; NH = Non-Hispanic. COVID: 0 = Survey date prior to March 1, 2020, 1 = Survey date on or after March 1, 2020.

least one assessment, and more than half (53.3 %) reported cannabis misuse (i.e., CUDIT-R scores ≥ 13)² on at least one assessment. The intraclass correlation coefficients (ICCs) for AUDIT and CUDIT-R scores were 0.59 and 0.65, respectively, indicating that AUD and CUD symptoms varied both within- and between-persons.

3.2. Age-related changes in and associations between AUD and CUD symptoms

Table 2 presents the results of the extent to which AUD and CUD symptoms changed with age during young adulthood. The first model shows that AUD decreased linearly across age at an average rate of 4 % per year and that there was an acceleration in this decrease at an average rate of 1 % per year-squared. The rate of linear decrease in AUD symptoms across age varied between persons ($SD=0.05$), and the 95 % predictive interval (slope $\pm 1.96 \times SD$) indicated that 95 % of participants had linear rates of change between a 14 % decrease ($RR=0.86$) and a 7 % increase ($RR=1.07$) per year (Fig. 1).

The second model in Table 2 shows that CUD symptoms decreased linearly across age at an average rate of 5 % per year and that there was an acceleration in this decrease at an average rate of 1 % per year-

Table 2
Poisson multilevel growth models testing age-related changes in AUDIT and CUDIT scores during young adulthood.

Fixed Effects	Outcome: AUDIT		Outcome: CUDIT	
	$N_{Obs} = 1547$ $N_{Persons} = 409$		$N_{Obs} = 1531$ $N_{Persons} = 409$	
	Rate Ratio	95 % CI	Rate Ratio	95 % CI
Level 2: Person Level				
Intercept	8.65***	8.12, 9.22	9.12***	8.43, 9.88
Male sex	1.15**	1.04, 1.28	1.34***	1.18, 1.52
Race/ethnicity (Ref=White NH)				
Asian NH	0.85*	0.73, 0.98	0.76**	0.63, 0.92
Hispanic	1.06	0.91, 1.23	1.09	0.91, 1.31
Other NH	0.90	0.79, 1.03	1.00	0.85, 1.19
Level 1: Year Level				
Age	0.96***	0.94, 0.98	0.95***	0.92, 0.98
Age squared	0.99**	0.99, 1.00	0.99**	0.99, 1.00
COVID	0.83***	0.78, 0.89	0.87***	0.81, 0.94
Random Effects				
Intercept	SD	0.48	SD	0.63
Age	SD	0.05	SD	0.12
COVID	SD	0.28	SD	0.37

Note. AUDIT = Alcohol Use Disorder Identification Test (Babor et al., 2001); CUDIT = Cannabis Use Disorder Identification Test (Adamson et al., 2010); NH = Non-Hispanic. Age and age squared were centered at 21 years old. COVID: 0 = Survey date prior to March 1, 2020, 1 = Survey date on or after March 1, 2020.

*** $p < .001$.
** $p < .01$.
* $p < .05$.

² We provide descriptive information on thresholds for disordered use, but models treat symptoms scores as continuous given variable recommendations for cutoffs (e.g., Schultz et al., 2019 found evidence that lower CUDIT-R cutoffs have better sensitivity/specificity for college students).

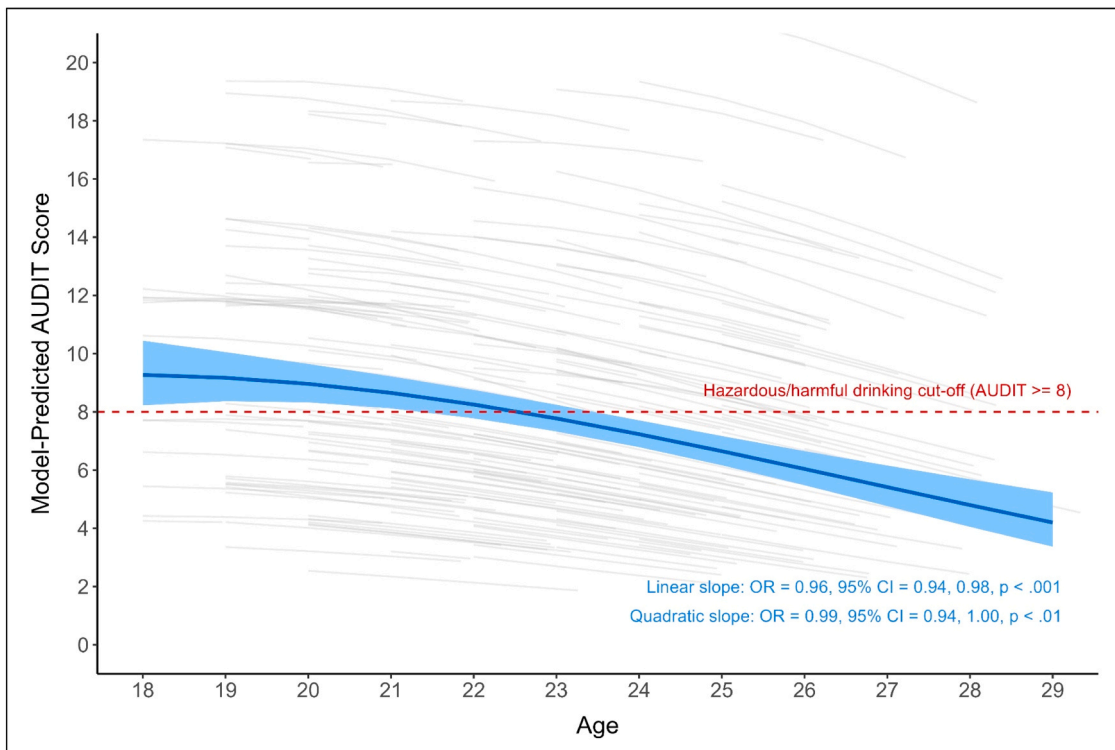


Fig. 1. Growth model of AUDIT scores by age with an individually varying time metric. The dark blue line represents the predicted change in AUDIT scores for the average participant, and the blue shaded area represents the 95 % confidence interval around those predictions. The light gray lines represent individual model predictions for a random selection of 50 % of participants.

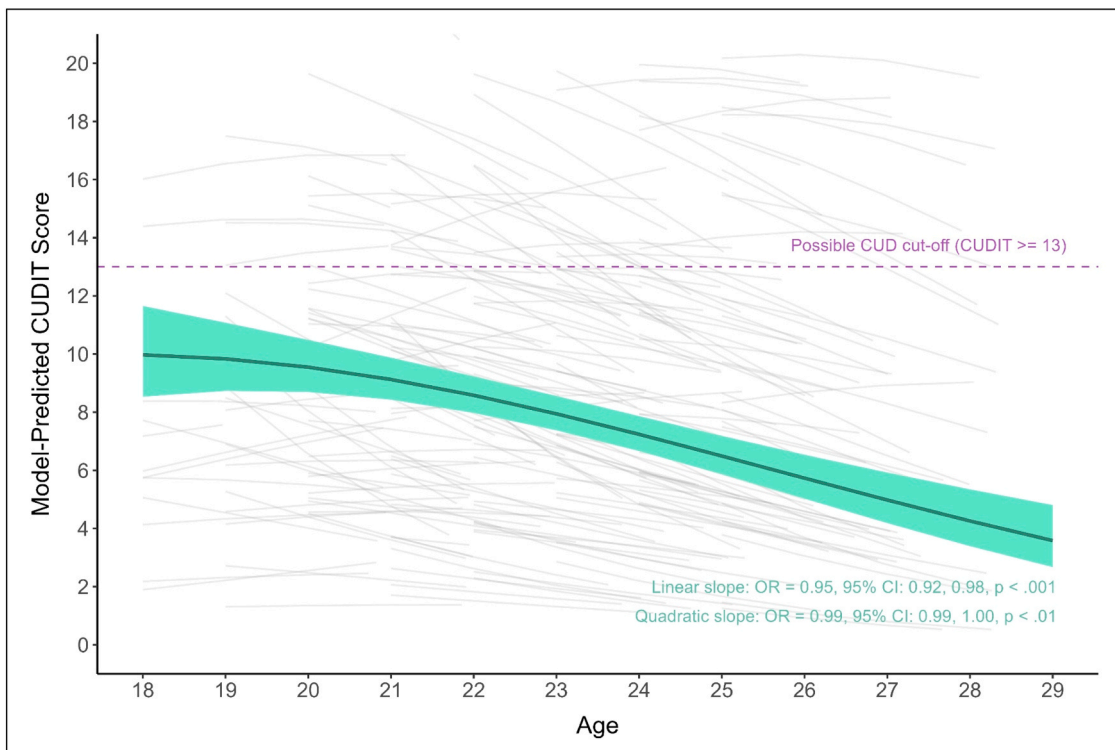


Fig. 2. Growth model of CUDIT-R scores by age with an individually varying time metric. The dark blue line represents the predicted change in CUDIT-R scores for the average participant, and the green shaded area represents the 95 % confidence interval around those predictions. The light gray lines represent individual model predictions for a random selection of 50 % of participants.

squared. The rate of linear decrease in CUD across age varied between persons ($SD=0.12$), and the 95 % predictive interval indicated that 95 % of participants had linear rates of change in CUD symptoms between a 25 % decrease ($RR=0.75$) and a 21 % increase ($RR=1.21$) per year (Fig. 2).

Table 3 presents estimated associations between AUDIT and CUDIT-R scores. At the within-person level, AUD and CUD symptoms were positively associated; each one-unit increase on the AUDIT was associated with a 4 % concurrent increase on the CUDIT-R, on average. The magnitude of this association varied across participants ($SD=0.05$), and the 95 % predictive interval suggested 95 % of participants had rate ratios for this association that were between 0.95 and 1.14. Although there was a positive association between AUD and CUD symptoms on average, 8.8 % of participants demonstrated model-estimated inverse associations across time (i.e., negative individual slopes ranged from $OR=.94$ to 0.99 ; the mean of the negative slopes was $OR=0.98$). The within-person associations between AUD and CUD symptoms is presented visually in Fig. 3. At the between person level, AUD symptoms were also positively associated with CUD symptoms; each one-unit increase in participants' mean AUDIT score was associated with a 2 % increase in mean CUDIT-R score.

3.3. SAM use frequency as a predictor of AUD and CUD symptoms

3.3.1. SAM use and AUD symptoms

The first model in Table 4 presents the results of whether SAM use frequency predicted AUD symptoms at within- and between-person levels and whether participants' average SAM use frequency across assessments moderated age-related changes in AUD symptoms. At the within-person level, SAM frequency was positively associated with AUD symptoms, such that each one-unit increase in SAM frequency was associated with an 8 % higher AUDIT score, on average. At the between person level, participants' mean SAM use frequency was positively associated with mean AUDIT score such that each one-unit increase in average SAM use frequency was associated with a 16 % increase in their average AUDIT score. Further, mean SAM use across all assessments

Table 3

Poisson multilevel growth model testing within- and between-person associations with between AUDIT and CUDIT scores.

Fixed Effects	Outcome: CUDIT Score	
	Rate Ratio	95 % CI
Level 2: Person Level		
Intercept	8.71***	8.04, 9.44
Mean AUDIT score	1.02**	1.01, 1.04
Male sex	1.30***	1.15, 1.47
Race/ethnicity (Ref=White NH)		
Asian NH	0.78**	0.65, 0.93
Hispanic	1.05	0.88, 1.25
Other NH	1.02	0.87, 1.20
Level 1: Assessment Level		
AUDIT score	1.04***	1.03, 1.05
Age	0.97*	0.94, 1.00
Age squared	0.99**	0.99, 1.00
COVID	0.90**	0.84, 0.97
Random Effects	SD	
Intercept	0.63	
AUDIT score	0.05	
Age	0.09	
COVID	0.24	

Note. $N = 1531$ assessments nested within 409 individuals. AUDIT = Alcohol Use Disorder Identification Test (Babor et al., 2001); CUDIT = Cannabis Use Disorder Identification Test (Adamson et al., 2010); NH = Non-Hispanic. Age and age squared were centered at 21 years old. COVID: 0 = survey date before 3.1.2020, 1 = survey date on or after 3.1.2020.

*** $p < .001$.

** $p < .01$.

* $p < .05$.

moderated the linear component (but not the quadratic component) of age-related changes in AUDIT scores such that young adults with lower mean SAM use frequency experienced steeper linear decreases in AUDIT scores across age than those with higher average SAM use frequency (Fig. 4).

For participants 1 SD below the sample mean SAM use frequency, there was a significant linear decrease in AUDIT scores across young adulthood ($OR=0.94$, 95 % CI: 0.91, 0.98, $p < .01$). The model-predicted AUDIT score for the average 18-year-old participant was 8.38 (95 % CI: 7.15, 9.83), and the model-predicted AUDIT score for the average 29-year-old participant was 3.22 (95 % CI: 2.43, 4.27). For participants 1 SD above the sample mean SAM use frequency, there was no statistically significant linear change in AUDIT scores across young adulthood ($OR=0.99$, 95 % CI: 0.97, 1.01, $p=0.60$).

3.3.2. SAM use and CUD symptoms

The second model in Table 4 presents the results of whether SAM use frequency predicted CUD symptoms at within- and between-person levels and whether participants' mean SAM use frequency moderated age-related changes in CUD symptoms. At the within-person level, SAM frequency was positively associated with CUD symptoms, such that each one-unit increase in SAM use frequency was associated with a 9 % higher CUDIT-R score, on average. At the between person level, average SAM use frequency was positively associated with CUD symptoms; each one-unit increase in participants' mean SAM use frequency was associated with a 41 % higher mean CUDIT-R score. Further, mean SAM use frequency across all assessments moderated the linear component (but not the quadratic component) of age-related changes in CUD symptoms, such that young adults with higher average SAM use frequency experienced less pronounced decreases in CUDIT-R scores during young adulthood than those with lower average SAM use frequency (Fig. 5).

For participants 1 SD below the sample mean SAM use frequency, there was a significant linear decrease in CUD symptoms across young adulthood ($OR=0.93$, 95 % CI: 0.90, 0.97, $p < .01$); the model-predicted CUDIT-R score for the average 18-year-old participant was 7.63 (95 % CI: 6.17, 9.44), and the model-predicted CUDIT-R score for the average 29-year-old participant was 2.43 (95 % CI: 1.66, 3.54). For participants 1 SD above the sample mean SAM use frequency, there was no significant linear change in model-predicted CUDIT-R scores across young adulthood ($OR=1.00$, 95 % CI: 0.96, 1.04, $p = 0.83$); the model-predicted CUDIT-R score for the average 18-year-old participant was 10.90 (95 % CI: 9.15, 13.00), and the model-predicted CUDIT-R score for the average 29-year-old participant was 8.12 (95 % CI: 5.90, 11.20).

4. Discussion

Consistent with prior work, these findings suggest that young adults showed signs of maturing out of alcohol and cannabis misuse, on average, as most young adults in this high-risk sample experienced age-related reductions in AUD and CUD symptoms that also accelerated with age (i.e., steeper declines at older age). Importantly, there was substantial variability in whether and how quickly young adults matured out of alcohol and cannabis misuse, and there was notable AUD/CUD comorbidity. Furthermore, frequent SAM use was associated with maintained AUD and CUD symptoms over time, such that young adults with higher SAM use frequency evinced slower declines in AUD and CUD symptoms with age, relative to young adults with less frequent SAM use.

Extending upon previous literature focused primarily on quantity and/or frequency of use (Brook et al., 2011; Lee and Sher, 2018; White et al., 2017; Windle, 2020), the present study showed that AUD and CUD symptoms decrease as young adults age. Alongside identifying these average age-related trajectories, findings also showed that some young adults experienced consistent or increased levels of AUD/CUD symptoms with age. There were important differences between AUD and CUD symptom trajectories, such that the direction and magnitude of associations with age appeared to vary more for CUD symptoms than AUD

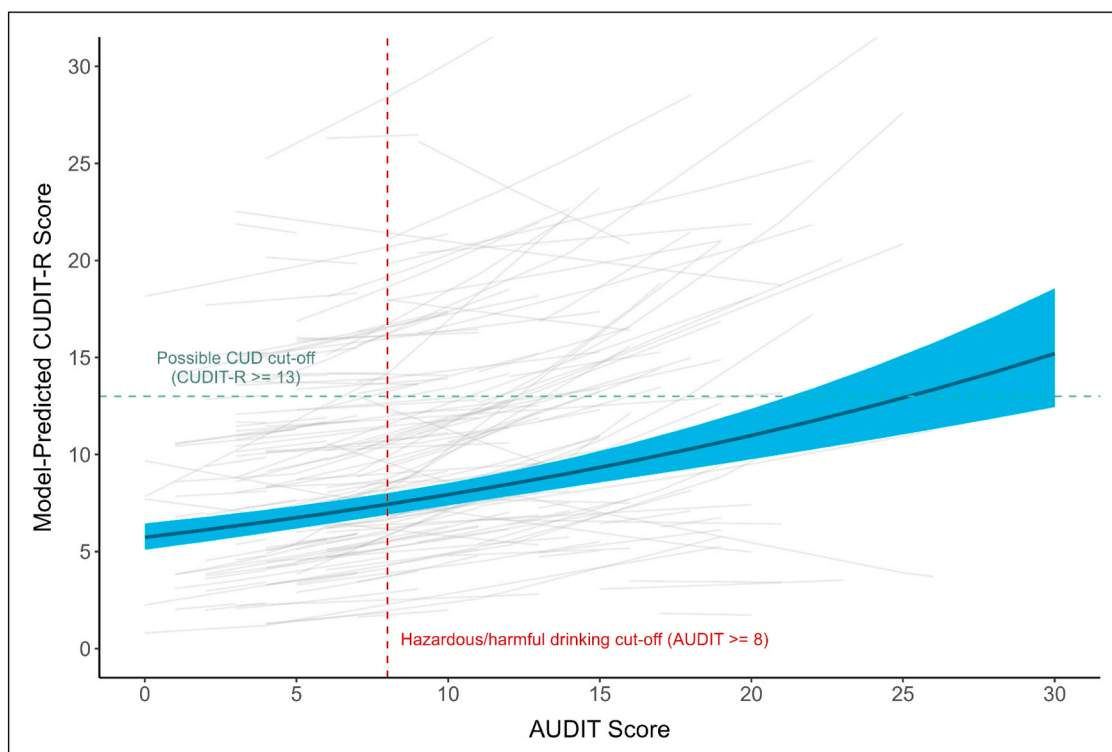


Fig. 3. Visualization of the within-person association between AUDIT and CUDIT-R scores. The dark turquoise line represents the predicted within-person association between AUDIT and CUDIT-R scores for the average participant, and the lighter turquoise band represents the 95 % confidence interval around those predictions. The light gray lines represent individual model predictions for a random selection of 50 % of participants.

symptoms. This may reflect historical trends, as cannabis use among young adults has generally been on the rise while prevalence of alcohol use been more stagnant (Patrick, Schulenberg, et al., 2022). The variability in CUD trajectories may also be partially due to no direct cannabis use screening criterion, other than SAM use within the past month. The greater variability in CUD symptom trajectories, relative to AUD, may also reflect age-related changes in substance use motives, such as social motives declining (i.e., particularly for alcohol use) but relaxation motives increasing (i.e., particularly for cannabis use) (Patrick et al., 2011).

Given the high prevalence of co-use among young adults (McCabe et al., 2020), the present study also examined associations between AUD and CUD symptoms across young adulthood at between- and within-person levels. Holding age (and age-squared) constant, multi-level growth models showed that AUD and CUD symptoms were indeed significantly associated, which is consistent with and extends prior work finding concurrent associations between CUD and AUD in young adulthood (Duncan et al., 2015). Notably, CUD symptoms were elevated at assessments in which AUD symptoms were relatively higher, supporting the study hypothesis and extending our understanding of AUD/CUD comorbidity at the within-person level. Indeed, AUD and CUD symptoms may track together across young adulthood, though the moderate magnitude of the association nevertheless suggests AUD and CUD are related but distinct, even amongst a sample that engages in SAM use. This interpretation aligns with a study of young adult men who engage in SAM use, which examined AUD/CUD comorbidity using a symptom network approach, concluding that AUD and CUD constructs are generally related, but that the individual symptoms of each respective disorder clustered only with one another and not with symptoms of the other disorder (Baggio et al., 2018).

The present findings extend our understanding of factors that may contribute to, or at least signify, deviations from normative maturing out processes. Young adults reporting more-frequent SAM use had less steep declines in AUD and CUD symptoms across young adulthood relative to

those who engaged in less-frequent SAM use. At age 18, young adults with both higher and lower SAM use frequency evinced relatively similar model-predicted estimates of AUD and CUD symptom scores. However, differences in symptom severity were much more pronounced in the older subset of our young adult sample. At age 29 for example, model-predicted estimates of AUD symptoms among individuals who engaged in more frequent SAM use were more than double that of young adults who engaged in less frequent SAM use, and model-predicted estimates of CUD symptoms among those with more frequent use were more than triple the scores of young adults with less frequent SAM use. That is, in support of hypotheses, more frequent SAM use was associated with attenuated maturing out processes in terms of AUD/CUD symptoms and may contribute to maintenance of these symptoms over time. However, when examining model-predicted AUD/CUD symptoms at various ages, it is important to consider previous evidence that maturing out processes typically do not begin until the early-mid 20's, and that there may be a normative *increase* in substance use behaviors between ages 18 and 22 (Arria et al., 2016; Patrick, Schulenberg, et al., 2022; Patrick, Terry-McElrath, Lanza, et al., 2019).

Whereas most SAM use research has examined risk and/or consequences cross-sectionally or at the daily-level (see review Lee et al., 2022), present findings provide novel evidence of potential long-term risks, or correlates, of SAM use. High-frequency SAM use may be a symptom or correlate of disordered use patterns, rather than a direct antecedent or cause. Unexplored third-variables may partially explain links between SAM use and maturing out of high-risk alcohol/cannabis use, such as social roles and lifestyles. Indeed, fully understanding potential risks posed by SAM use requires mechanistic research, but we can turn to existing studies showing that using simultaneously is often motivated by increasing the effects of each substance (i.e., cross-fading motives; Patrick et al., 2020). That is, needing increased levels of substance use to achieve the same effects (i.e., tolerance) is a hallmark characteristic of both AUD and CUD; thus, engaging in SAM use to increase effects of alcohol and/or cannabis could be indicative of

Table 4

Poisson multilevel growth models testing within- and between-person associations with between SAM use frequency and AUDIT/CUDIT scores.

Fixed Effects	Outcome: AUDIT		Outcome: CUDIT	
	$N_{\text{Obs}} = 1526$ $N_{\text{Persons}} = 409$		$N_{\text{Obs}} = 1522$ $N_{\text{Persons}} = 409$	
	Rate Ratio	95 % CI	Rate Ratio	95 % CI
Level 2: Person Level				
Intercept	8.45***	7.96, 8.97	8.67***	8.10, 9.27
Mean SAM use frequency	1.16***	1.10, 1.22	1.41***	1.33, 1.49
Male sex	1.10	1.00, 1.22	1.23***	1.11, 1.37
Race/ethnicity (Ref=White NH)				
Asian NH	0.90	0.78, 1.04	0.90	0.77, 1.06
Hispanic	1.03	0.89, 1.18	1.03	0.88, 1.20
Other NH	0.93	0.81, 1.06	1.04	0.91, 1.20
Level 1: Year Level				
SAM use frequency	1.08***	1.05, 1.10	1.09***	1.07, 1.11
Age	0.97*	0.95, 0.99	0.97	0.95, 1.00
Age squared	0.99**	0.99, 1.00	0.99**	0.99, 1.00
COVID	0.84***	0.79, 0.89	0.87***	0.81, 0.93
Cross-Level Interactions (Separate Model)				
Mean SAM use frequency × Age	1.03*	1.01, 1.05	1.04**	1.01, 1.07
Mean SAM use frequency × Age squared	1.00	1.00, 1.00	1.00	1.00, 1.01
Random Effects				
Intercept	SD		SD	
Age	0.44		0.50	
Age	0.03		0.10	
COVID	0.21		0.34	

Note. AUDIT = Alcohol Use Disorder Identification Test (Babor et al., 2001); CUDIT = Cannabis Use Disorder Identification Test (Adamson et al., 2010); SAM = Simultaneous alcohol and marijuana use; NH = Non-Hispanic. Age and age squared were centered at 21 years old. COVID: 0 = survey date before 3.1.2020, 1 = survey date on or after 3.1.2020.

*** $p < .001$.

* $p < .05$.

** $p < .01$.

developing problematic use and may facilitate a cycle of increased use over time.

4.1. Applied implications

Findings from the present study have important clinical implications, given the health risks of sustained or increasing substance use patterns across young adulthood (Caldeira et al., 2012). Although AUD and CUD symptoms decreased as young adults aged, on average, frequent SAM use was associated with maintaining higher CUD/AUD symptom severity into later young adulthood. Thus, understanding the impacts of SAM use should be a priority for substance-focused screening, prevention, and intervention efforts. It is important for providers and clinicians to screen for and monitor SAM use frequency among young adults as a potential correlate of disordered use. Combined intervention efforts that focus on alcohol, cannabis, and SAM use may be needed, as prevention and intervention efforts that primarily focus on either alcohol or cannabis use do not appear to have salient secondary effects on the use of other substances (Lee et al., 2013; Yurasek, Merrill, et al., 2017).

4.2. Limitations

The present study entailed a sample of relatively high-risk young adults, given baseline inclusion criteria for alcohol use and past-month SAM use. The total age range is 18–29, although each person only participated for up to approximately 3 years so there may be differences in the types of people who screened into the study at age 18 versus at age 25. Although national estimates suggest binge drinking prevalence peaks around age 21 or 22 and is followed by normative maturing out (Patrick, Terry-McElrath, Lanza, et al., 2019), having a sample with a wider age range may provide more insight into aging out processes at later ages.

The current study sheds light on maturing out among a higher-risk sample rather than, more generally, among young adults who may use alcohol/cannabis less frequently and those who do not engage in SAM use. Generalizability is also limited by the sample coming from one US state, though we see no apparently discernable reason why results may not hold in other geographic regions, but could differ in states where cannabis use is not legal. Indeed, it is worthwhile to investigate how moving from legal to non-legal states (or vice versa) impacts maturing out of cannabis use. In the current sample, only 77 participants were living in a different state at the end of our study period and 49 had moved to another state with legal cannabis use (e.g., California, Oregon, Arizona, Colorado), whereas only 28 had moved to state without legal use, thus precluding further investigation within these data.

Nearly 50 % of our sample were enrolled in college/university at baseline, which is slightly higher than the national average (NCES, 2023); thus, our sample may not generalize to all young adults. Analytic models statistically accounted for the COVID-19 pandemic, given evidence that some young adults' substance use patterns changed relative to pre-pandemic (Graupensperger, Fleming, et al., 2021), but other facets of the pandemic may not be cleanly disentangled, such as the pandemic-related stressors, mental health, and adherence to COVID-19 guidelines (Einberger et al., 2021; Graupensperger et al., 2022; Graupensperger, Cadigan, et al., 2021).

5. Conclusion

Cross-sectional and daily-level research has identified SAM use as a risk factor for increased consequences among young adults. The current study extends this literature by showing longitudinally that SAM use may be a risk factor for prolonged AUD and CUD symptoms, such that young adults who engaged in more frequent SAM use evidenced slower age-related reductions in AUD and CUD symptoms. Future work should further investigate the extent to which SAM use is an indicator of longer-term consequences and the potential stability of alcohol and cannabis use disorders as well as how longitudinal changes in etiological factors (like using substances for social or coping motives) may relate to age-related substance use trajectories.

Ethical approval

All aspects of the present study were approved by the Institutional Review Board at the University of Washington. No adverse events were reported. The study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments.

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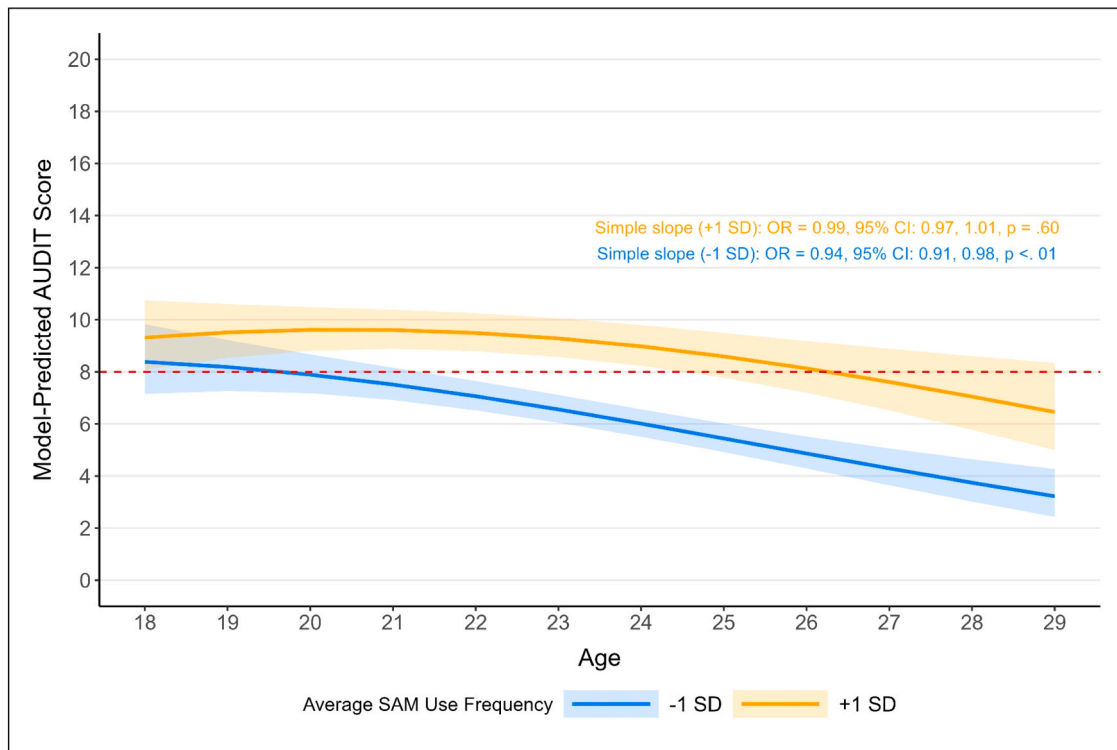


Fig. 4. Growth model testing whether average SAM use frequency moderated age-related changes in AUDIT scores. The shaded areas represent 95 % confidence intervals around model predictions. The dotted red line represents hazardous/harmful drinking as indicated by the AUDIT.

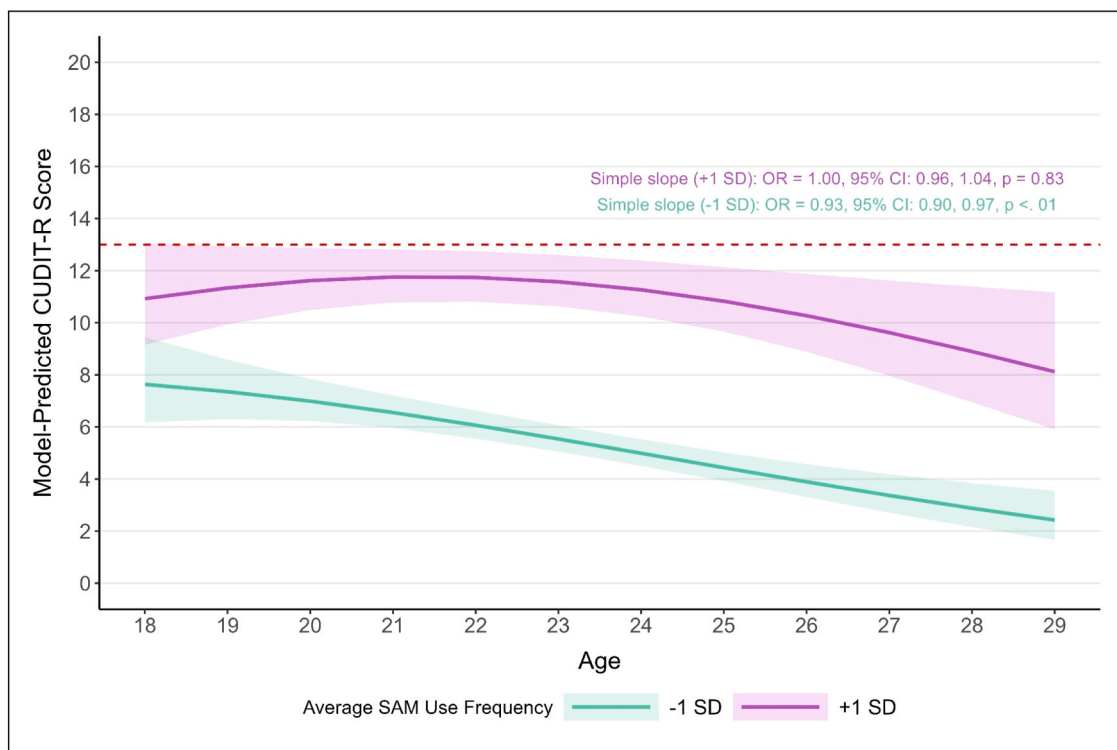


Fig. 5. Growth model testing whether average SAM use frequency moderated age-related changes in CUDIT-R scores. The shaded areas represent 95 % confidence intervals around model predictions. The dotted red line represents possible Cannabis Use Disorder as indicated by the CUDIT-R.

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Informed consent

All participants completed informed consent.

CRedit authorship contribution statement

Scott Graupensperger: Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Christine M. Lee:** Writing – review & editing, Writing – original draft, Supervision, Resources, Investigation, Funding acquisition, Conceptualization. **Katherine Walukevich-Dienst:** Writing – review & editing, Writing – original draft, Conceptualization. **Megan E. Patrick:** Writing – review & editing, Writing – original draft, Supervision, Resources, Investigation, Funding acquisition. **Brian H. Calhoun:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization. **Anne M. Fairlie:** Writing – review & editing, Writing – original draft, Conceptualization.

Declaration of Competing Interest

The authors have no conflicts of interest to disclose.

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