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ALCOHOLISM CLINICAL & EXPERIMENTAL RESEARCH

ORIGINAL ARTICLE

Dual trajectories of cannabis and alcohol use among young adults in a state with legal nonmedical cannabis

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Abstract

Background: Understanding the nature of the association between cannabis and alcohol use within individuals over time in the era of legalized cannabis is of crucial importance for assessing the public health consequences of increasing cannabis use. An important unanswered question is whether cannabis and alcohol use substitute for one another. Specifically, is greater use of one substance associated with less use of the other substance (i.e., a negative association) or are the substances complementary and their association positive?

Methods: We used 24 consecutive months of data on a young adult sample (n = 774; 56% female, age 18–25 during the study) who drank alcohol in the year prior to enrollment. The sample was recruited in Washington State in 2015/2016 (after legalization of nonmedical cannabis) using media advertisements and community flyers and outreach. Using parallel process latent growth curve models, we assessed three types of association between cannabis and alcohol use across the 24-month period: (1) an association between *average levels* of cannabis and alcohol use; (2) an association between *rates of change* in cannabis and alcohol use; and (3) correlations between shorter-term *deviations/fluctuations* off of longer-term trajectories of level and change in cannabis and alcohol use.

Results: We found a positive association between the average frequency of cannabis and alcohol use; individuals who used cannabis more frequently on average also drank alcohol more frequently on average. Change over time in cannabis use was positively associated with change in alcohol use. There was also a contemporaneous positive association between fluctuations in cannabis and alcohol use.

Conclusions: Overall, we found no evidence of substitution. Rather, the results suggest a complementary relationship between cannabis and alcohol use, such that the use of cannabis and alcohol rises and falls together.

KEYWORDS
alcohol use, cannabis use, substitution, young adults

This manuscript has not been published elsewhere and has not been submitted simultaneously for publication elsewhere.

INTRODUCTION

Liberalization of cannabis policy at the state and federal levels has raised concern that changes in availability, cost, and potency of cannabis may lead to increases in misuse of cannabis, with deleterious public health consequences (Cambron et al., 2017; Caulkins et al., 2016; Pacula & Sevigny, 2014a; Volkow et al., 2016). Some have argued, however, that consequences of increased cannabis use will be outweighed by benefits of legalization. These benefits include reductions in the number of individuals experiencing arrest and incarceration and the associated adverse human and societal costs, increases in tax revenue from cannabis sales, and reductions in the source of revenue for criminal organizations (for discussion see, e.g., Hawken et al., 2013; Kilmer, 2017; Pacula & Sevigny, 2014a, 2014b). An additional pro-legalization argument is that cannabis use may *substitute* for misuse of alcohol and other drugs leading to substantial benefits and savings if cannabis use has less deleterious public health consequences than alcohol or other substance use (e.g., Anderson & Rees, 2014; for critical review see Guttmannova et al., 2016; Pacula & Sevigny, 2014a, 2014b; Smart & Pacula, 2019). However, it is also possible that cannabis and alcohol *complement* one another, in which case increases in cannabis use in a context where cannabis has been legalized for nonmedical use among adults could be accompanied by increases in alcohol consumption (e.g., Wen et al., 2015) and related public health and safety costs (Guttmannova et al., 2016; Hall, 2015, 2017; Pacula & Sevigny, 2014a, 2014b).

The past decade and a half have been characterized by increases in cannabis use among young adults (Schulenberg et al., 2020; Substance Abuse & Mental Health Services Administration, 2020), but there is no strong and consistent evidence that those increases were greater in states that liberalized their cannabis laws. Cerdá et al. (2020) examined data from the National Survey of Drug Use and Health and found no statistically significant increases in the prevalence of any and frequent cannabis use or cannabis use disorder among young adults (18–25 years of age) before and after enactment of nonmedical or "recreational" cannabis laws. In terms of other substance use and its association with the loosening of state-level restrictions on cannabis, the evidence is also mixed (for review see, e.g., Darnell, 2020; Guttmannova et al., 2016; Risso et al., 2020; Smart & Pacula, 2019). Most recently, Veligati et al. (2020) demonstrated that neither alcohol nor cigarette consumption (as measured by state tax receipt data) has increased or decreased as a result of "recreational" and medical cannabis legalization. Evidence regarding substitution versus complementarity in the association between cannabis and other substances likely remains mixed because these population-level studies do not allow examination of whether intraindividual change over time in use of one substance is associated with intra-individual change in use of another (for a brief review of design and dataset recommendations, see, e.g., Guttmannova et al., 2016, 2019).

Thus, studies that track the associations between substances within individuals are needed to more clearly elucidate the possibility of substitution; that is, whether increases in cannabis use are associated with decreases in alcohol use over time. Cross-sectional data on general population samples of adolescents and adults consistently indicate positive correlations among use of cannabis and alcohol (e.g., Fleming et al., 2016). There is some evidence of substitution between alcohol and cannabis among medical cannabis patients (e.g., Hayat & Piper, 2020; Reiman, 2009; for review, see Subbaraman, 2014) but young adults who use cannabis are also more likely to drink alcohol (for review, see, e.g., Yurasek et al., 2017), and daily cannabis use predicts greater amount of daily alcohol intake (Gunn et al., 2018; Lee et al., 2020). Event-level data have also indicated that, among college students, there is a positive association between overall levels of cannabis use and alcohol consumption, as well as consumption on a given occasion (O'Hara et al., 2016). Additional evidence is needed on whether changes in the two types of substance use, either as trends across time or as shorter-term fluctuations in use, are positively or negatively correlated, particularly in the context where the use of both substances is legal for adults. Even if overall levels are positively correlated, it is possible that an increase in cannabis use will be associated with decreases in alcohol use, either across time or within a shorter time period, especially if the use of both substances has the same legal consequences and cannabis use is perceived as having fewer individual harms. Thus, longitudinally and in the context where both cannabis and alcohol have been legalized for nonmedical use among those 21 or older, there could be a negative association between the two substances, which would point to substitution with respect to these dimensions of within-individual change. Or, consistent with other studies in general populations, the positive association could also be evidenced over time indicating that as cannabis use increases, alcohol use also increases. This would be particularly problematic especially during the young adult years, a vulnerable period marked by continued brain development and acquisition of vital educational, labor-market, and personal roles that could be derailed by increases in alcohol and cannabis use (e.g., Arria et al., 2015; Batalla et al., 2013; Brook et al., 2013; Gorey et al., 2019; Meda et al., 2017; Yurasek et al., 2017).

The present study used 24 consecutive months of data on a young adult sample in Washington State, where cannabis is legal for those 21 or older, to examine longitudinal associations between cannabis and alcohol use. Using parallel process growth models of the two types of substance use, we examined the following three research questions: (1) Do young adults who use cannabis more on average drink more on average?; (2) Are rates of change in cannabis use across two years positively or negatively associated with rates of change in alcohol use across that same time period?; and (3) Are short-term increases or decreases in cannabis use relative to individual trajectories of change in cannabis use correlated with short-term deviations/fluctuations off of trajectories of change in alcohol use?

METHODS

Participants and procedures

Data come from 774 young adults who were part of a longitudinal study on substance use and young adult social role transitions

(Lee, Cadigan, & Patrick, 2017; Patrick, Fairlie, & Lee, 2018). At the time participants met eligibility for the project, participants were age 18 to 23 years, had reported consuming alcohol in the prior year, lived within 60 miles of the study office in Seattle, WA, and were willing to come to the study office for consent and completion of a baseline assessment. From January 2015 to January 2016, we used a multimethod recruitment strategy that included online, print, and social media advertisements, posted community flyers, outreach at community colleges, and friend referral to recruit participants. Those interested in being part of the project completed an online eligibility survey followed by an in-person session in the study offices, during which we verified identity and age, explained study procedures, and obtained informed consent. Immediately after enrolling in the project, participants completed an online baseline assessment while still in the study office, for which they received a $40 gift card.

Beginning the first day of the subsequent month, participants completed 24 consecutive months of online surveys. Participants did monthly surveys within seven to 10 days at the beginning of each calendar month. Most survey items asked about experiences from the previous calendar month. We emailed Amazon gift card codes as compensation for each completed survey (up to $680 total). The University of Washington's Institutional Review Board approved all procedures.

Of the 779 participants enrolled in the project, five were excluded from the current study because they did not complete at least one monthly survey in which alcohol and cannabis use were assessed. The analytic sample's (n = 774) mean age at baseline was 21.11 years (SD = 1.70), and 56.2% of the sample reported sex at birth as female. In this study, 8.9% participants identified as Hispanic/Latinx. Of those participants who identified as non-Hispanic/Latinx, 55.0% identified as White, 17.7% as Asian, 9.8% as multiracial, 4.5% as Black/African American, 0.7% as Indian/Alaskan Native, 0.5% as Native Hawaiian/Pacific Islander, and 2.8% as "other". At the beginning of the study, 74.7% of participants were in school and 59.4% were employed at least part-time. Ten participants were married, and nine had at least one child. Thirty-four percent of participants reported scores of eight or higher on the Alcohol Use Disorder Identification Test (AUDIT; Babor et al., 2001) and 26% reported scores of eight or higher on the Cannabis Use Disorder Identification Test-Revised (CUDIT-R; Adamson et al., 2010) denoting hazardous levels of drinking and cannabis use, respectively. Retention rates were high with more than 70% completing 80% or more of their monthly surveys.

Measures

Substance use

For measures of both cannabis and alcohol use in each month, we used ordinal measures with seven categories capturing frequency of use. The monthly alcohol use measure was based on the item, "How often did you usually have any kind of drink containing alcohol?" (NIAAA, 2003). Response options were as follows: 0 = Never, 1 = Once a month, 2 = 2 to 3 days a month, 3 = 1 day a week, 4 = 2 days a week, 5 = 3 to 4 days a week, 6 = 5 to 6 days a week, and 7 = Every day. Due to sparse endorsement, the top two categories were collapsed in a 5 or more-days-per-week category. The monthly cannabis use measure was based on the item, "In the past 30 days, how many days did you use marijuana?" In the monthly surveys, we used the term "marijuana" since this is the term the majority of young adults use. We defined "marijuana" as "any form of the drug cannabis, including marijuana (weed, pot), hashish or kief, and any method of use, including dried buds/flowers/leaves for smoking or in edibles, or hash oil." Responses were recoded to correspond to the alcohol use variable into the following categories: 0 = Never, 1 = Once a month, 2 = 2 to 3 days a month, 3 = 1 day a week, 4 = 2 days a week, 5 = 3 to 4 days a week, 6 = 5 to 6 days a week, and 7 = Every day.

Covariates

Biological sex (0 = male, 1 = female), age at baseline, and race/ethnicity (mutually exclusive dummy-codes for Hispanic/Latinx, non-Hispanic/Latinx Asian, and other—combining the aforementioned categories with relatively low prevalence; non-Hispanic/Latinx White served as the reference group) were included as covariates.

Data analysis

Analyses were conducted with Mplus 8.4 (L. K. Muthén & Muthén, 1998–2019). After examining descriptive data on substance use across months, we used latent growth models (Curran & Hussong, 2003; Duncan et al., 2006; McArdle, 1991) to capture the levels (intercepts), rates of change (slopes), and monthly fluctuations of cannabis and alcohol use frequency across the two-year period and to assess how these elements of substance use trajectories were associated across the two substances over time. For both substances, loadings of slope factors were specified so that the intercept represented the middle of the two-year study period and the slope represented linear change. Although other dimensions of change, such as acceleration or deceleration, that would be captured by additional growth factors are possible, the linear change addressed our second research question (i.e., Is rate of change in cannabis use across two years associated with rate of change in alcohol use across that same time period?) and this parallel process linear growth model specification showed excellent fit to the data. Growth factors were regressed on model covariates (age, sex, race/ethnicity) and covariances of growth factors were estimated, as were covariances among residuals for concurrent indicators of cannabis and alcohol use for each study month. Figure 1 depicts the model tested and the associations of interest. We applied the diagonally weighted least square estimation with mean

and variance (WLSMV) correction to accommodate the distributional properties of the outcomes (ordered categorical data) and model complexity as well as to reduce potential bias due to missing data (Hox et al., 2010; Muthén et al., 1997). Two sets of sensitivity analyses were specified. First, to assess whether associations differed for individuals over or under age 21, given that purchase of both alcohol and cannabis in Washington State is legal starting at age 21, we ran multiple-group models, comparing fit of models with parameters of interest constrained and unconstrained across the two age-groups (i.e., those who were below 21 vs. 21 or older at baseline). Second, we assessed whether the patterns of associations were similar when consistent nonusers of cannabis were excluded (n = 171 of participants indicated they did not use cannabis in any of the monthly assessments and had at least 66% of nonmissing data over time—i.e., were assessed at least 16 out of 24 monthly times).

RESULTS

Descriptive information on substance use

Descriptive statistics for alcohol and cannabis use, based on all the monthly data, are shown in Table 1. Approximately 22% did not drink in a given month; approximately 68% did not use cannabis.

Parallel process growth model

Figure 1 depicts the tested model and highlights the parameters of interest in terms of the associations among growth factors and concurrent associations among residuals. Model fit was excellent as indicated by CFI and TLI greater than 0.95 and RMSEA less than 0.05 (Hu & Bentler, 1999). Table 2 shows the fit statistics and the estimates representing the parameters of interest. Table 3 shows the associations between the demographic covariates and the latent factors. To answer our first question, there was a positive overall association between *average levels* of cannabis and alcohol use captured by the positive correlation between intercepts (Path A, see Figure 1 and Table 2). Addressing our second question, there was also a positive association between rates of change in substance use across the two-year time span indicating that an increase in cannabis use was associated with an increase in alcohol use; this is captured by the positive correlation between the linear growth factors (Path B, see Figure 1 and Table 2). This association was small and statistically significant only for the standardized (but not the unstandardized) estimate. Finally, there was also a positive association between month-to-month fluctuations in cannabis and alcohol use, captured by the positive within-time-point correlation between residuals for cannabis and alcohol use (Path C, see Figure 1 and Table 2). In other words, individuals used alcohol more often in a month (relative to their expected frequency of use given their average frequency and rate of change in frequency of alcohol use across 24 months) when

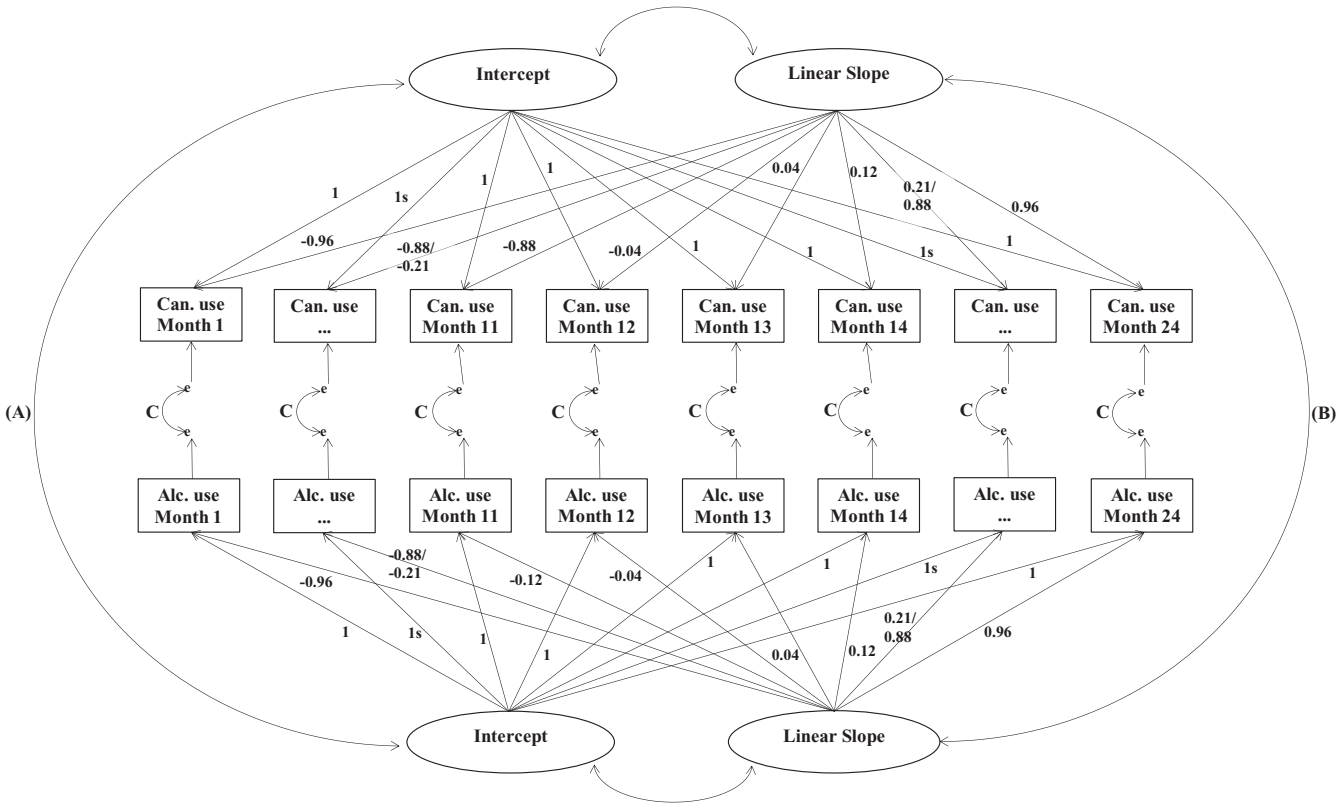

FIGURE 1 Model of longitudinal and concurrent associations between alcohol and cannabis use

TABLE 1 Descriptive statistics of outcome variables across time

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24
Outcome	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Cannabis use																								
Never	63.8	62.3	68.0	66.2	68.9	67.0	66.2	66.4	66.7	68.9	68.9	67.3	69.1	71.7	69.7	68.3	64.6	67.5	66.9	67.4	70.8	70.3	68.3	69.2
Once/ month	6.4	8.2	6.5	6.2	5.7	5.3	6.7	8.0	6.2	5.3	6.4	5.4	5.3	5.3	5.0	4.9	6.0	5.8	5.4	5.3	5.3	4.1	5.3	4.2
2–3 days/ month	7.1	6.4	4.2	5.2	4.1	6.3	5.9	5.5	6.0	5.2	5.5	6.5	5.8	4.2	5.3	5.4	8.5	7.3	6.4	7.5	4.2	5.7	6.5	5.7
1 day/ week	1.2	1.1	1.9	1.3	1.6	1.2	1.1	2.1	1.9	2.0	1.5	1.2	2.2	1.5	1.5	2.7	1.9	1.7	2.0	1.1	1.8	0.9	1.4	1.5
2 days/ week	6.1	5.4	4.7	4.1	3.9	3.6	2.9	3.1	4.2	3.7	2.8	4.3	3.0	2.2	3.6	3.2	3.6	3.6	2.5	2.6	2.7	3.0	3.5	3.4
3–4 days/ week	3.6	5.6	4.5	4.8	5.7	4.8	5.1	3.4	3.7	4.0	3.8	3.1	3.7	3.5	4.3	4.2	3.6	2.4	3.9	2.6	3.4	4.4	3.9	4.9
5–6 days/ week	4.8	5.0	4.2	4.4	4.1	4.4	5.9	6.0	4.9	5.3	4.7	5.7	4.2	5.3	4.5	4.7	5.1	4.2	7.0	5.6	4.6	4.4	3.2	3.7
Everyday	7.0	6.1	6.0	7.8	6.2	7.4	6.1	5.5	6.3	5.7	6.4	6.3	6.8	6.3	6.2	6.7	6.7	7.6	5.9	7.9	7.2	7.1	7.9	7.3
Alcohol use																								
Never	17.8	17.2	21.5	21.8	24.2	22.3	23.9	22.7	24.4	22.5	23.4	21.1	22.5	20.4	25.6	23.2	23.0	22.3	23.0	22.6	23.6	22.7	25.0	22.9
Once/ month	12.9	14.6	12.4	12.0	9.6	9.9	9.8	9.3	11.7	10.7	10.9	12.9	10.8	12.0	9.5	10.0	9.5	10.2	8.6	11.4	11.4	11.1	8.8	11.8
2–3 days/ month	21.9	21.5	21.9	20.5	21.5	21.0	18.4	20.7	19.6	18.9	17.4	19.7	22.5	20.3	18.4	20.8	21.2	18.7	17.5	17.3	21.4	18.0	16.4	17.4
1 day/ week	14.4	15.8	15.2	15.0	15.5	17.0	17.7	18.0	16.8	20.3	17.1	16.0	14.2	15.8	15.9	16.5	13.4	17.7	20.4	17.3	14.5	14.8	18.0	16.7
2 days/ week	18.0	17.9	15.1	16.3	15.0	17.3	15.7	15.5	13.9	13.3	17.9	15.7	15.2	15.2	15.7	14.9	18.4	17.1	15.1	17.5	15.7	18.4	17.2	17.4
3–4 days/ week	12.4	9.7	11.5	11.6	10.1	8.7	10.5	10.7	10.4	10.4	9.5	11.4	11.6	13.2	11.3	10.2	11.2	9.6	11.0	10.4	9.2	10.6	10.7	9.8
5+ days/ week	2.5	3.3	2.3	2.9	4.2	3.7	4.0	3.0	3.1	3.9	3.7	3.3	3.3	3.2	3.5	4.4	3.2	4.5	4.4	3.6	4.3	4.4	3.8	3.9

Abbreviation: M = Month of assessment.

TABLE 2 Fit statistics and estimates representing the parameters of interest in the parallel process growth model of cannabis and alcohol use

Tested associations	coeff	S.E.	stand coeff	*p*-Value
Association between average levels of cannabis and alcohol use (Path A in Figure 1)	**1.156**	0.231	**0.323**	<0.001
Association between change in cannabis and change in alcohol use (Path B in Figure 1)	0.114	0.064	**0.110**	0.046
Concurrent association between cannabis and alcohol use (Path C in Figure 1)	**0.160**	0.034	**0.160**	<0.001
Association between average level and change in alcohol use	**0.247**	0.116	**0.260**	0.004
Association between average level and change in cannabis use	**1.924**	0.956	**0.491**	<0.001
Association between average level of alcohol use and change in cannabis use	**0.257**	0.149	**0.141**	0.027
Association between average level of cannabis use and change in alcohol use	0.128	0.102	0.063	0.180
Fit Statistics				
CFI	0.990			
TLI	0.991			
RMSEA	0.032			
90% CI for RMSEA	(0.030; 0.034)			

Abbreviations: Coeff = unstandardized coefficient; *SE* = standard error; stand coeff = standardized coefficient; *p*-value = *p*-value associated with the standardized coefficient; coefficients in bold are statistically significant at *p*-value < 0.05; CFI = Comparative Fit Index; TLI = Tucker–Lewis Index; RMSEA = Root Mean Square Error of Approximation; CI = confidence interval.

they also used cannabis more often (relative to their trajectories of cannabis use).

The associations between covariates (age at baseline, sex, and race/ethnicity) and the growth factors indicate that, controlling for the other covariates in the model, older participants had higher average frequency and smaller change in alcohol use. Non-Hispanic/Latinx White participants had higher average frequency of alcohol use than participants who identified as non-Hispanic/Latinx Asian, non-Hispanic/Latinx Other, and Hispanic/Latinx participants, although their change in alcohol use was not statistically different from the other racial/ethnic groups. Non-Hispanic/Latinx White participants had also higher average frequency of cannabis use than non-Hispanic/Latinx Asian participants. Overall, females reported significantly lower average frequency of cannabis use than males. No other sex differences were statistically significant.

Sensitivity analyses

The first set of sensitivity analyses examined whether these associations were similar for those below 21 and those 21 or older, given that purchase of both alcohol and cannabis in Washington State is legal starting at age 21. We analyzed these associations in a multiple-group model with the parameters of interest constrained to be equal across age-groups. The test of equality of constraints supported the conclusion that the associations between latent factors were not statistically different for the two age-groups (chi-square(11) = 7.68; $p = 0.742$).

The second set of sensitivity analyses tested whether the patterns of associations were similar when consistent nonusers of cannabis were excluded and these results are shown in Table 4. The patterns of associations were similar to the full sample model, with estimates of all three associations of interest positive and statistically significant.

DISCUSSION

Understanding the nature of associations between cannabis and alcohol use in young adulthood is of critical public health and policy importance. Past population- as well as event-level studies have shown positive associations between cannabis and alcohol use among young adults (e.g., Gunn et al., 2018; Wen et al., 2015; Yurasek et al., 2017) but there is also some evidence of substitution relationship between cannabis and alcohol (for review, see, e.g., Guttmannova et al., 2016; Risso et al., 2020; Subbaraman, 2014, 2016) and longitudinal studies, particularly in legalized policy context, are needed to enhance this understanding (Guttmannova et al., 2019). Results from our unique longitudinal study of young adults residing in a state where both cannabis and alcohol are legal to use for those 21 or older show a positive association between the average frequencies of cannabis and alcohol use, with individuals who use cannabis more frequently on average also drinking more frequently on average. Our findings also indicate that the average rate of change in cannabis use over a two-year period was positively associated with average rate of change in alcohol use, although this association was small. Finally, controlling for the level and rate of change, we found a positive association between concurrent monthly deviations in cannabis and alcohol use off of two-year trajectories. In other words, months with unusually frequent cannabis use were associated with unusually frequent alcohol use in that same month. Taken together, these results do not support the substitution hypothesis that young adults who increase their cannabis use, either in terms of rate of change in cannabis use across two years or in terms of concurrent increases, would decrease their alcohol use with respect to either of those dimensions of within-person change. Instead, our findings point to a modest complementary relationship between cannabis and alcohol use and are in line with past research that demonstrated the positive

TABLE 3 Associations between the demographic covariates and the latent factors in the final parallel process growth model of cannabis and alcohol use

Predictors		Cannabis Intercept				Cannabis Slope				Alcohol Intercept				Alcohol Slope			
		Coeff	*SE*	Stand coeff	*p*-value	Coeff	*SE*	Stand coeff	*p*-value	Coeff	*SE*	Stand coeff	*p*-value	Coeff	*SE*	Stand coeff	*p*-value
Age	Age	−0.050	0.071	−0.017	0.481	−0.078	0.047	−0.055	0.086	**0.146**	0.031	**0.107**	<0.001	**−0.059**	0.020	**−0.079**	0.005
Sex	Female	−0.477	0.246	**−0.167**	0.045	0.021	0.163	0.015	0.897	−0.166	0.100	−0.122	0.092	0.057	0.066	0.077	0.391
Race/ethnicity	Non-Hispanic Asian	**−1.854**	0.409	**−0.647**	<0.001	−0.265	0.277	−0.186	0.301	**−0.876**	0.144	**−0.642**	<0.001	−0.054	0.091	−0.073	0.545
	Non-Hispanic Other	−0.611	0.322	−0.213	0.052	−0.213	0.213	−0.149	0.304	**−0.545**	0.131	**−0.399**	<0.001	−0.079	0.107	−0.107	0.452
	Hispanic	−0.551	0.431	−0.192	0.194	0.068	0.303	0.048	0.824	**−0.381**	0.190	**−0.279**	0.043	0.001	0.135	0.001	0.996

Abbreviations: Coeff = unstandardized coefficient; *SE* = standard error; stand coeff = standardized coefficient; *p*-value = *p*-value associated with the standardized coefficient; coefficients in bold are statistically significant at *p*-value < 0.05.

association between these two substances (e.g., Gunn et al., 2018; Lee et al., 2020; O'Hara et al., 2016).

Similar to prior research with national samples (e.g., Schulenburg et al., 2020), females reported lower average frequency of cannabis use than males and non-Hispanic/Latinx White young adults reported higher average frequency of cannabis and alcohol use than some other racial/ethnic groups. No differences by sex or racial/ethnic group were observed for changes in cannabis or alcohol use and the tested associations between cannabis and alcohol use did not differ significantly by whether individuals were below 21 and 21 or older. Future research should explore additional potential moderators of associations between cannabis and alcohol use.

It is noteworthy that months with higher frequency of cannabis use were also linked with higher frequency of alcohol use, suggesting that there may be time periods when young adults are more likely to engage in both high-risk cannabis and alcohol use. Cannabis and alcohol use may vary by calendar month (Fleming et al., 2021), and special events or holidays may increase risk for heavy use (Bravo et al., 2017; Lee et al., 2006; Lewis et al., 2009; Patrick & Lee, 2012). In tailoring preventive interventions that address time periods of heightened risk, our results suggest the need for addressing both cannabis and alcohol use since short-term increases in one substance are likely to be accompanied by short-term increases in the other. Future studies could examine whether young adults are more likely to engage in simultaneous use, that is, using cannabis and alcohol at the same time so that their effects overlap, during these times of heightened risk. Some studies have found that simultaneous use was associated with greater negative outcomes than using cannabis or alcohol alone (Duckworth & Lee, 2019; Egan et al., 2019; Lee et al., 2017; Lee et al., 2020; Lipperman-Kreda et al., 2017). Future studies should also focus on associated health risk behaviors such as driving under the influence of both substances and on malleable risk factors that predict such behaviors to inform prevention messaging and preventive intervention efforts. Finally, future research could examine whether particularly heavy cannabis or alcohol use at one time period is associated with increased simultaneous use during the same time period.

Limitations and additional directions for future research

This intensive, rich longitudinal study is not without limitations. Although we had 24 consecutive assessments of substance use, the cannabis and alcohol use data were based on self-report and retrospectively asked about the prior month, which may be subject to bias. However, the recall period for monthly assessments was relatively short, which should improve accuracy. Second, this study examined frequency of alcohol and cannabis use, rather than quantity consumed. It is possible that substitution still occurs at the event or day-level and future studies, particularly those that involve repeated reports in real time using ecological momentary assessment would be useful to address this issue. Third, ours is a community sample of young adults who reported drinking alcohol

TABLE 4 Sensitivity analyses: Fit statistics and estimates representing the parameters of interest in the final parallel process growth model of cannabis and alcohol use for the sample that excludes consistent nonusers of cannabis

Tested Associations	Coeff	*SE*	Stand coeff	*p*-Value
Association between average levels of cannabis and alcohol use (Path A in Figure 1)	**0.492**	0.145	**0.183**	<0.001
Association between change in cannabis and change in alcohol use (Path B in Figure 1)	**0.131**	0.063	**0.136**	0.016
Concurrent association between cannabis and alcohol use (Path C in Figure 1)	**0.172**	0.035	**0.172**	<0.001
Association between average level and change in alcohol use	0.192	0.113	**0.224**	0.031
Association between average level and change in cannabis use	**1.363**	0.669	**0.450**	<0.001
Association between average level of alcohol use and change in cannabis use	0.105	0.104	0.065	0.268
Association between average level of cannabis use and change in alcohol use	0.116	0.083	0.072	0.134
Fit Statistics				
CFI	0.985			
TLI	0.987			
RMSEA	0.035			
90% CI for RMSEA	(0.032; 0.037)			

Abbreviations: Coeff = unstandardized coefficient; *SE* = standard error; stand coeff = standardized coefficient; *p*-value = *p*-value associated with the standardized coefficient; coefficients in bold are statistically significant at *p*-value < 0.05; CFI = Comparative Fit Index; TLI = Tucker–Lewis Index; RMSEA = Root Mean Square Error of Approximation; CI = confidence interval.

in the past year and may not be representative of a general population of young adults in Washington State. Fourth, although age was included as a covariate in our analyses and associations between cannabis and alcohol use were similar for individuals under and over age 21, we modeled trajectories of substance use with reference to month of the study rather than age. This modeling approach matched our research questions concerning the nature of associations in young adults in general but did not assess trajectories of substance use by age. Future studies could explicitly incorporate age as time in their analyses and test more nuanced developmental hypotheses. An interesting extension of this research in future studies could involve examination of motivations to use substances. It may be that substitution of cannabis for alcohol is specific to young adults who use for coping reasons. For example, O'Hara et al. (2016) found positive association between cannabis and alcohol use among college students whose primary reason for drinking and cannabis use was social. In contrast, for those who reported using these substances to cope with stressful events, there was an evidence of negative association (or substitution) between alcohol and cannabis so that the more alcohol they consumed on an event, the less likely they were to use cannabis (O'Hara et al., 2016). Understanding the association between different types of motives and patterns of use as they relate to substitution vs. complementarity would be particularly informative for interventions aimed at reducing use and cessation of misuse of these substances.

Clinical implications

As both alcohol and cannabis use peak in young adulthood (e.g., Schulenberg et al., 2020; Terry-McElrath et al., 2017) and cannabis use is increasing nationally (SAMHSA, 2020), understanding how potential trajectories of young adult cannabis and alcohol use are associated and linked over time is critical for informing content and timing of prevention and intervention programs. As public health and individual harms are documented from high-risk alcohol use (e.g., Hingson et al., 2009), programs that support prevention and reductions in alcohol use are important. Due to the positive association between alcohol and cannabis use, current efficacious alcohol interventions (e.g., Dimeff, 1999) could incorporate components on cannabis use and focus on the hazardous simultaneous use of alcohol and cannabis since most of those who use both substances use report such use (Patrick et al., 2019; Subbaraman & Kerr, 2015). Findings from this study conducted in a state with legal nonmedical or "recreational" cannabis use suggest that efforts would be worthwhile to prevent initiation and escalations of cannabis use during young adulthood, which in turn may be associated with reduced negative harms of alcohol use, both individually and at the population-level.

CONCLUSIONS

Misuse of substances such as cannabis and alcohol can interfere with the transition to adulthood. Today's generation of young adults is coming of age and transitioning to young adulthood in the era of legalized cannabis. We found little evidence at the individual level of substitution between cannabis and alcohol such that increases in cannabis use would result in decreases in alcohol use in a sample of young adults.

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CONFLICTS OF INTEREST

The authors report no conflicts of interest.

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