ELSEVIER

ADDICTIVE BEHAVIORS
AN INTERNATIONAL JOURNAL

Check for updates

Conjoint adolescent developmental trajectories of alcohol and marijuana use and early adult outcomes among North American Indigenous people

Kelley J. Sittner [a,*], Dane S. Hautala [b], Melissa L. Walls [b]

[a] Department of Sociology, Oklahoma State University, 431 Murray Hall Stillwater, OK 74078, United States
[b] Johns Hopkins University Bloomberg School of Public Health, Department of International Health, Center for American Indian Health, 1915 South Street Duluth, MN 55812, United States

ABSTRACT

Objective: The current study examined the developmental interrelationships between alcohol and marijuana use trajectories from ages 10 to 18 years in a sample of North American Indigenous adolescents. Distinct co-use groups were formed to create profiles of young adult outcomes.
Method: Dual group-based trajectory models of marijuana and alcohol frequency were estimated using data from a longitudinal community-based participatory study of Indigenous adolescents from the upper Midwest and Canada. Joint probabilities were used to create co-use groups, and profiles were created using early adult (Mean Age – 26.28 years) outcomes.
Results: Four joint trajectory groups were identified: 1) no marijuana and no/low alcohol use (34.4%), 2) mid-onset alcohol only (14%), 3) mid-onset co-use starting at age 13 (24%), and 4) early-onset co-use starting at age 11 (22%). High probabilities existed that adolescents would use marijuana early if they began drinking alcohol at the youngest ages, and that adolescents would not use marijuana if they drank infrequently or delayed drinking until mid-adolescence. Adult outcomes were poorer for the early- and mid-onset co-use groups, but there were few differences between the no/low use and alcohol-only groups.
Conclusion: Co-use of marijuana and alcohol was associated with poorer outcomes in early adulthood, particularly for the group with an earlier age of onset. Abstaining from either substance in adolescence was associated with better outcomes.

1. Introduction

Social determinants of health including colonization and differential exposure to stressors have led to tremendous health inequities affecting many Indigenous communities. This includes the unequal burden of substance use-related problems, such as diabetes, suicide, motor vehicle fatalities, and heart disease (Heron, 2014; May, 1996; West & Naumann, 2011; Yoder, Whitbeck, Hoyt, & LaFromboise, 2006; Schiller et al., 2012). Notably, a majority of Native people abstain from substance use (Substance Abuse and Mental Health Services Administration (SAMHSA), 2010), yet the public health consequences of riskier substance use patterns (i.e., early onset and use of multiple substances) are of concern.

Through over 20 years of longitudinal research in partnership with North American Indigenous communities, we have documented high rates of alcohol or marijuana use by age 13 (Whitbeck & Armenta,

2015); and rapid escalation from first use to weekly binge drinking and marijuana use through age 15 (Cheadle & Sittner Hartshorn, 2012), both of which are associated with higher odds of developing substance use disorders (SUD) in later adolescence and early adulthood (Cheadle & Sittner Hartshorn, 2012; Cheadle & Whitbeck, 2011). These general patterns, similar to findings with other Indigenous cultural groups (O'Connell et al., 2011; Whitesell, Asdigian, & Kaufman, 2014), veil tremendous variation in onset, escalation/desistance, and stability of use over time.

Little research has examined co-use of alcohol and marijuana among Indigenous youth. Polysubstance use is normative among adolescent substance users: those who use one substance are likely to use another (Connor, Gullo, White, & Kelly, 2014). Whitesell and colleagues (Whitesell et al., 2006) found common concurrent alcohol and marijuana use among Indigenous youth, and early co-use of alcohol and marijuana (i.e., before age 14) has been associated with increased risk

for alcohol use disorder (AUD) and marijuana use disorder (MUD) later in life (O'Connell et al., 2011). Indigenous people in the U.S. exhibit the highest rates of comorbid AUD and other drug use disorders (Falk, Yi, & Hiller-Sturmhöfel, 2008). In our previously published research, roughly half of Indigenous youth met criteria for an alcohol use disorder, one-third met criteria for a marijuana use disorder, and one-quarter met lifetime criteria for both AUD and MUD (Hautala et al., 2019). Importantly in that same study, onset of abuse/dependence criteria for one substance prospectively increased the odds of meeting other abuse/dependence criteria across adolescence.

A major gap in the extant polysubstance use literature, which is not limited to Indigenous samples, is the lack of attention to longitudinal heterogeneity and the dynamic nature of co-use across key periods of risk (e.g., adolescence and early adulthood). Dual trajectory models can be used to examine the associations between the developmental trajectories of two substances (Jackson, Sher, & Schulenberg, 2005; Nagin, 2005). Linking probabilities across substances provides a nuanced summary of longitudinal substance use comorbidity compared to previous approaches because various stages of substance use (e.g., onset, escalation/desistance, frequency) can be jointly captured within one analytic framework. Prior studies employing this method show high concurrence between alcohol and marijuana trajectory groups (Whitesell et al., 2014; Brook, Zhang, Rubenstone, Primack, & Brook, 2016; Nelson, Ryzin, & Dishion, 2015), although small groups of alcohol users without any marijuana use have also been found (Brook et al., 2016).

Further, our understanding of the differential outcomes of polysubstance use is limited. Although sparse, dual trajectory research shows that adolescents who follow trajectories characterized by early-adolescent onset and persistence of both alcohol and marijuana use have the highest risk for developing multiple SUDs and other psychiatric disorders compared to adolescents who abstain (Brook et al., 2016; Chassin, Flora, & King, 2004). Overall, patterns of polysubstance use across adolescence, and particularly early-onset combined use, are predictive of a variety of negative outcomes (Brook et al., 2016; Chassin et al., 2004; Nelson et al., 2015; Moss, Chen, & Yi, 2014). These findings underscore the need for dual trajectory models in which various stages of substance use can be modeled within a single analytic framework, rather than any use within a specific time-frame.

For the current study, we examined the developmental interrelationships between alcohol and marijuana use trajectories from ages 10 to 18 years in a sample of North American Indigenous adolescents, and used the joint probabilities to form distinct co-use groups. We then examined young adult (Mean Age – 26.28 years) outcomes of these adolescent co-use trajectory groups.

2. Methods

2.1. Participants and procedures

Data are from the Healing Pathways project, a panel study of 735 Indigenous adolescents/young adults from eight reservations/reserves in the upper Midwest and Canada. The reservations/reserves share the same cultural language and traditions, and represent one of the largest Indigenous cultures in the U.S. and Canada (the communities are not named to respect confidentiality agreements). This community-based participatory research study began with invitations from the communities to a university-based research team to answer questions about health, mental health, and substance use. All tribally-enrolled children between the ages of 10 and 12 years, along with at least one caregiver, were invited to participate. Youth and caregivers received cash incentives for each interview. The recruitment rate was 79.4%. All procedures were approved by university institutional review boards and tribal community research councils. A more detailed description of the study has been published elsewhere (Whitbeck et al., 2014).

The first phase of the study took place between 2002 and 2010 and included eight annual interviews. The second phase of the study, which

began in 2017, includes three additional waves (in progress) of the adolescents, now young adults ages 24 to 29. In both phases, data were collected via in-person paper-and-pencil and computer-assisted diagnostic interviews. The baseline sample consisted of 735 adolescents. Over the course of the two studies, 27 participants passed away and 3 became ineligible because of disability or military service. Retention rates were high during the original study, ranging from 96.2% at wave 2 to 81.9% at wave 8. For wave 9, which began seven years after the original study ended, 453 young adults were interviewed (64.3% of the original sample).

2.2. Measures

Marijuana and Alcohol Use Frequency. Frequency of marijuana and alcohol were measured at 5 time points in adolescence by first asking the youth whether they had ever used the substances and, if they had, whether they had used them in the past year. Follow-up questions measured the frequency of use on a six-point scale ($1 = 1$ or 2 times, $2 =$ less than monthly, $3 =$ once a month, $4 =$ every week, $5 =$ nearly every day, $6 =$ every day). Adolescents who reported no past-year use were coded $0 =$ never.

Wave 9 Profile Variables. Four demographic characteristics were included, including *gender* ($0 =$ male; $1 =$ female), *highest level of education* (coded $1 =$ less than high school and $0 =$ at least high school), *employment* status ($1 =$ full-time and $0 =$ other than full-time), and *income* (personal income, divided by $1000 to set the metric in thousands of dollars). Two health outcomes were examined. *Depressive symptoms* were assessed using a shortened version of the Centers for Epidemiological Studies Depression scale (Radloff, 1977) which has also been used in national studies of adolescents and young adults (Meadows, Brown, & Elder, 2006). Young adults were asked how often in the past week they experienced nine symptoms related to depression. Response options ranged from zero days (0) to 5–7 days (3). Positively worded items were reverse coded, and responses to all nine items were summed to create an index of depressive symptoms ($\alpha = 0.87$). *Self-rated physical health* was assessed with a single question asking young adults about their overall physical health on a five-point Likert scale ranging from (0) poor to (4) excellent. We also examined a range of alcohol and marijuana use outcomes. SUD were assessed using the Diagnostic Interview Schedule for Children-Revised (DISC-R) in waves 1–8, and the World Mental Health Survey Initiative version of the World Health Organization Composite International Diagnostic Interview (CIDI) in wave 9. Both instruments are intended for use with lay interviewers (Kessler & Üstün, 2004; Shaffer, Schwab-Stone, & Fisher, 1993). Scoring algorithms were used to calculate whether the young adults met criteria for *past-year* and *lifetime alcohol* and *marijuana abuse/dependence* using DSM-IV TR criteria (abuse and dependence assessed separately, but combined for analysis). Cumulative rates of lifetime disorders at wave 9 were calculated as a sum of the cases at wave 9 plus any cases meeting criteria at any adolescent wave. Current substance use behaviors were assessed using the same *marijuana and alcohol frequency* as above but dichotomized into weekly or more often $= 1$ versus less than weekly use $= 0$, along with *drinking quantity* (average number of drinks consumed on drinking days). A measure of any concurrent past-year *marijuana and alcohol use* was dichotomized as $0 =$ no co-use use and $1 =$ used both alcohol and marijuana.

2.3. Analysis

We modeled the marijuana and alcohol frequency trajectories using group-based trajectory modeling with STATA *traj* (Nagin, 2005; Jones & Nagin, 2013) and a zero-inflated Poisson distribution for count outcomes (Cheadle & Sittner Hartshorn, 2012; Cheadle & Whitbeck, 2011). Participants with valid alcohol and marijuana data for at least three adolescent waves were included in the trajectory analysis. We began by iteratively fitting the frequency of marijuana use model to determine the

best number and shape of trajectories. The final model was selected based on the smallest Bayesian information criterion (BIC) value and parsimony, with a polynomial age function to describe the trajectory shapes (e.g., constant, linear, nonlinear) (Table 1). We repeated these steps for frequency of alcohol use, then fit a dual trajectory model to jointly estimate marijuana and alcohol groups. The dual trajectory model was used to identify groups with the largest joint posterior probabilities of marijuana and alcohol use for further analysis. Groups that comprised less than 3% of the sample were excluded. The joint posterior probabilities were used to create profiles of each group. We used χ (May, 1996) and ANOVA with Bonferroni post-hoc tests to compare proportions and means of the profile variables at Wave 9 across these joint alcohol and marijuana trajectory groups.

3. Results

3.1. Frequency of marijuana and alcohol use trajectories

Although five- and four-group marijuana frequency models had the smallest BIC values (Table 1), these models would not converge in the dual trajectory analysis because of small cell sizes. We proceeded with a three-group model of marijuana use: the first group was characterized by a linear trajectory and the remaining two groups both characterized by quadratic trajectories. As shown in Fig. 1a, approximately 51% of the sample followed a trajectory with little to no marijuana use, 27% followed a trajectory characterized by onset around age 12 and an increasing slope through age 17, and 22.2% followed a trajectory with onset at age 10 and a peak in frequency of use around ages 15–16. For the alcohol model, the 3-group model had the smallest BIC value, and looked very similar to the marijuana use trajectories in the number and shapes of trajectories, but different in group size and frequency of use. The low/no use and mid-onset groups each had slightly more than one-third of the sample (35% and 37.7%, respectively). The early-onset group represented one-quarter of the sample with lower frequency than the early-onset marijuana use trajectory.
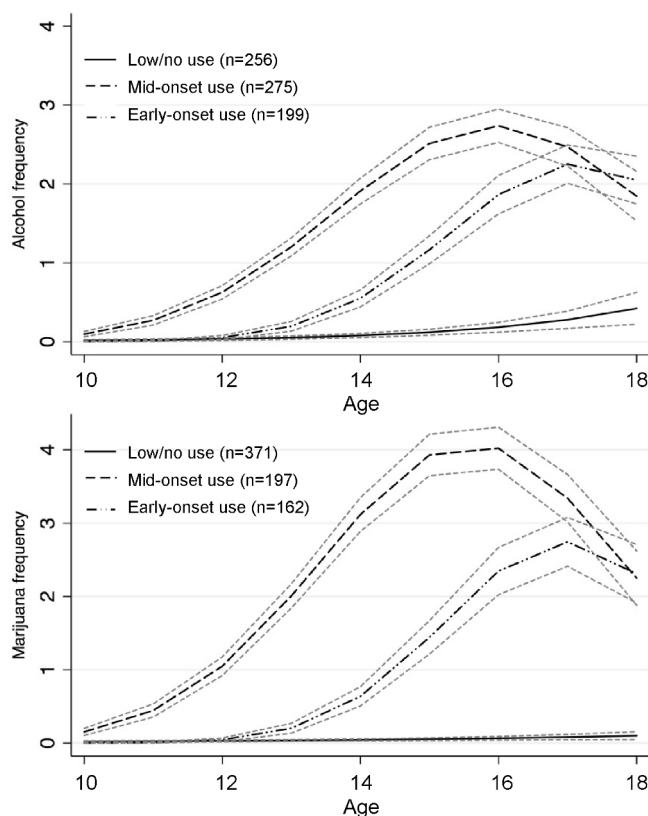
3.2. Dual trajectories of marijuana and alcohol use

Joint probabilities of membership in adolescent marijuana and alcohol groups (part A, Table 2) were used to form the joint trajectory groupings for the young adult profile analysis. Four groups accounted for 94% of the sample. The largest group (34%) followed the no marijuana and no/low alcohol use trajectories, 14% followed a mid-onset alcohol only trajectory, 24% followed the mid-onset marijuana and alcohol trajectories, and 22% followed the early-onset marijuana and alcohol trajectories.

Conditional probabilities of membership in trajectory groups are shown in Table 2 parts B and C. There was strong concordance between the two sets of developmental trajectories. For example, there was 100% probability that someone would follow the early-onset marijuana trajectory if also following the early-onset alcohol trajectory, and 87% probability of following the mid-onset marijuana trajectory if also following the mid-onset alcohol trajectory. The probability that an adolescent would follow a low/no alcohol use trajectory if also following a no marijuana use trajectory was 99%. There was zero probability of

Table 1
Model Fit Statistics.

Number of Groups	Marijuana BIC	Alcohol BIC
1	−4373.50	−3495.95
2	−3408.83	−3422.69
3	−3224.66	−3147.93
4	−3137.90	−3158.70
5	−3111.39	−3163.65

Note: BIC = Bayesian Information Criterion.

Fig. 1. Adolescent Alcohol (top) and Marijuana (bottom) Use Trajectory Groups.

Table 2
Joint and conditional probabilities of adolescent marijuana and alcohol use (n = 730).

Alcohol Frequency Trajectory	Marijuana Frequency Trajectory		
	No use (n = 371)	Mid-onset use (n = 197)	Early-onset use (n = 162)
	A) Probability of joint marijuana and alcohol use		
Low/no use (n = 256)	0.34	0.01	0.00
Mid-onset use (n = 275)	0.14	0.24	0.00
Early-onset use (n = 199)	0.02	0.03	0.22
	B) Probability of marijuana use conditional on alcohol use		
Low/no use (n = 256)	0.68	0.02	0.00
Mid-onset use (n = 275)	0.28	0.87	0.00
Early-onset use (n = 199)	0.04	0.11	1.00
	C) Probability of alcohol use conditional on marijuana		
Low/no use (n = 256)	0.99	0.38	0.08
Mid-onset use (n = 275)	0.01	0.62	0.11
Early-onset use (n = 199)	0.00	0.00	0.81

Note: A) The sum of the cells is 1 after rounding. B) Each row sums to 1. C) Each column sums to 1.

being in the early-onset alcohol group if also following the no marijuana trajectory, and zero probability of following early- or mid-onset marijuana trajectories if also following the low/no alcohol use trajectory. The conditional probabilities of mid-onset marijuana group membership

on alcohol use group were weaker (i.e., 67% or lower).

3.3. Profile analysis

We examined differences in demographic, health, and substance use means/proportions at Wave 9 (young adulthood) across the four joint trajectory groups (Table 3). Several significant differences emerged among the groups, but few significant post-hoc contrasts. Nearly all of the significant contrasts concerned the early-onset combined group. This group was more likely to be female (68.47%) than the mid-onset combined group (49.06%). However, the number and shapes of trajectories were very similar for both males and females (supplemental analyses available upon request). The early-onset combined group was less likely to report full-time employment (31.53%) than the non-use (49.08%) and alcohol only groups (52.12%), and to have lower average income ($15,680) than the non-use group ($20,170). The early-onset combined group also had more depressive symptoms than the other three groups, and poorer self-rated physical health than the non-use group (1.80 vs. 2.23).

Of particular interest was substance use behavior in early adulthood. The non-use group had a significantly lower rate of lifetime AUD (41.1%) than the other groups, but there were no significant contrasts between the groups for past-year AUD or MUD. The early-onset combined group had the highest rate of lifetime MUD (64.55%), followed by mid-onset combined (46.23%); the non-use and alcohol only groups did not differ from each other on lifetime MUD. Notably, joint group membership differentiated neither current drinking frequency nor quantity, but did differentiate concurrent use of alcohol and marijuana, and marijuana use frequency. The early-onset combined use group had a larger proportion (54.95%) using both alcohol and marijuana in early adulthood than the non-use group (32.52%), and was marginally significantly larger than the alcohol-only group (34.38%, p = 0.056). The mid-onset combined group had the largest proportion reporting weekly or more frequent marijuana use (43.24%), followed by the early-onset combined group (32.08%), both of which were significantly larger than the non-use (15.95%) and alcohol only (12.50%) groups.

4. Discussion

Identifying patterns of polysubstance use over the life-course is critical both in terms of understanding key periods of risk for targeted prevention and intervention and to reduce the consequences linked to polysubstance use (Flory, Lynam, Milich, Leukefeld, & Clayton, 2004; Jackson, Sher, & Schulenberg, 2008; Nelson et al., 2015). This is particularly relevant for Indigenous young people, a group differentially exposed to known risk factors (Whitbeck et al., 2014; Warne & Frizzell, 2014; Costello, Farmer, Angold, Burns, & Erkanli, 1997) for substance use and related consequences (Schiller et al., 2012; West & Naumann, 2011; Dick, Manson, & Beals, 1993) and for whom substance abuse inequities have been documented (Heron, 2014; May, 1996; West & Naumann, 2011; Yoder, Whitbeck, Hoyt, & LaFromboise, 2006; Schiller et al., 2012). We used dual group-based trajectory analysis among a sample of tribally-enrolled Indigenous young people from the upper-Midwest and Canada to examine the longitudinal interrelationships between alcohol and marijuana use, and their demographic, mental/physical health, and substance use profiles in early adulthood.

Alcohol and marijuana co-use for the majority of the adolescents (94%) followed four general patterns: 1) No/infrequent use between ages 10 and 18 described the largest group (34%); Two groups characterized by increasing frequency of alcohol and marijuana use, differentiated only by different ages of onset: 2) Onset between ages 10 and 11 (i.e., early-onset group, 22.2%), and 3) about two years later for the mid-onset group (23.6%); and 4) An alcohol-only group (14.2%) with onset around 12 to 13 years. Early-onset substance use is typically defined as use prior to the age of 14 years (O'Connell et al., 2011), and nearly two-thirds of the adolescents followed trajectories with onsets of use prior to this age. The primary differences between the early- and mid-onset use groups is that early-onset users drink and use marijuana more frequently through the age of 16, at which point frequency of use converges. As found in prior studies (Brook et al., 2016), the alcohol-only group had a later onset and less frequent/heavy use than the co-use groups.

Conditional probabilities of group membership in the marijuana and alcohol trajectories demonstrated strong interrelationships. In particular, there was a very high probability that adolescents followed the early marijuana trajectory if they began drinking alcohol at the youngest

Table 3
Profiles of Trajectory Groups at Wave 9 (n = 444).

	Sample Mean/%	Non-use (n = 163)	Mid-onset alcohol only (n = 64)	Mid-onset combined (n = 106)	Early-onset combined (n = 111)	F/χ^2 test
Gender (% female)	57.43	57.67$_{ab}$	51.56$_{ab}$	49.06$_b$	68.47$_a$	9.48, p = 0.024
Education (% did not graduate HS)	27.85	21.88$_a$	21.88$_a$	35.24$_a$	33.03$_a$	8.29, p = 0.040
Employment (% FT)	43.34	49.08$_a$	53.12$_a$	40.95$_{ab}$	31.53$_b$	11.23, p = 0.011
Income (thousands $)	18.05	20.17$_a$	20.12$_{ab}$	16.01$_{ab}$	15.68$_b$	3.90, p = 0.009
Depressive symptoms	6.62	6.02$_a$	5.03$_a$	6.37$_a$	8.66$_b$	7.23, p < 0.001
Self-rated physical health	2.05	2.23$_a$	1.97$_{ab}$	2.09$_{ab}$	1.80$_b$	4.06, p = 0.007
Alcohol use disorder (% past year)	12.05	10.43$_a$	20.97$_a$	10.38$_a$	11.01$_a$	5.45, p = 0.142
Alcohol use disorder (% LT)	60.00	41.10$_a$	67.74$_b$	66.98$_b$	80.91$_b$	48.23, p < 0.001
Marijuana use disorder (% past year)	4.46	3.68$_a$	1.61$_a$	2.83$_a$	9.17$_a$	7.61, p = 0.055
Marijuana use disorder (% LT)	34.62	12.88$_a$	19.05$_a$	46.23$_b$	64.55$_c$	90.61, p < 0.001
Alcohol/Marijuana co-use (% used both)	41.89	32.52$_a$	34.38$_{ab}$	47.17$_{ab}$	54.95$_b$	16.37, p = 0.001
Drinking frequency (% weekly or more)	25.90	29.45$_a$	23.44$_a$	22.52$_a$	25.47$_a$	1.94, p = 0.0.585
Drinking quantity	4.72	4.41$_a$	4.13$_a$	5.21$_a$	5.02$_a$	0.73, p = 0.536
Marijuana frequency (% weekly or more)	26.13	15.95$_a$	12.50$_a$	43.24$_b$	32.08$_b$	33.70, p < 0.001

Note: Subscripts indicate significant differences between groups; values that do not share a subscript in a row are significantly different at p < 0.05. Chi-square test was used for categorical profile variables; ANOVA test was used for continuous profile variables. Depressive symptoms past week: zero days (0) to 5–7 days (3). Self-rated health range: poor (0) to excellent (4). Drinking and marijuana frequency in past year range dichotomized weekly or more (1) and less than weekly (0). Drinking quantity average on drinking days in past month range: 0–48.

ages. Conversely, when adolescents drank infrequently or delayed drinking until mid-adolescence, they had a high probability of not using marijuana at all. Following the non-use marijuana trajectory had a high probability of also following the no/low alcohol use trajectory. Thus, there was substantial overlap in abstaining from or infrequently using the two substances.

There were clear variations in the outcomes across joint trajectory groups. As found in prior studies using these data (Walls, Sittner Hartshorn, & Whitbeck, 2013; Walls, 2008), females are likely to begin using alcohol and marijuana at earlier ages compared to males, whereas males' substance use matches or exceeds girls' by late-adolescence. In addition, compared to the non/low use group, early-onset co-users had lower odds of current full-time employment, lower mean levels of income, and poorer self-rated physical health. Although the two co-use groups had similar trajectory shapes and were differentiated primarily by their ages of onset, substantive differences emerged between the two groups in their early adult profiles. Compared to the mid-onset combined group, the early-onset combined group had higher rates of lifetime marijuana use disorder and more depressive symptoms. A prior study with this sample that looked at trajectories of general substance use (i.e., past-year use of alcohol, marijuana, and cigarettes) found that the baseline profiles of the early-onset and mid-onset trajectory groups also looked different from each other, although these differences diminished as the adolescents aged (Sittner, 2016). Taken together, these results suggest that age of onset is part of qualitatively different early life course patterns and fewer but still important differences in early adulthood. Early-onset, persistent use of both alcohol and marijuana appears to be risker than alcohol use only or later co-use (Brook et al., 2016; Chassin et al., 2004), underscoring the contribution of plotting joint developmental trajectories. Thus, early co-use of both alcohol and marijuana may carry important consequences for socioeconomic status and health into early-adulthood, which are closely linked (Goodman & Huang, 2002).

Our early-adult profiles for alcohol use based on adolescent substance use trajectories did not align with the extant polysubstance use literature (Chassin et al., 2004; Nelson et al., 2015). The proportion of early adults with past-year AUD was lowest in the non-use trajectory group, but differences across the three remaining groups were not statistically significant. Further, the four trajectory groups did not differentiate young adult alcohol use frequency or quantity. These unexpected findings may signal culturally unique patterns or norms of alcohol use, perhaps stemming from the complex roots of alcohol as a weapon of subjugation during colonization and the internalized stigma (Gonzales, Jacob, & Mercier, 2018) and stereotypes surrounding alcohol for many Indigenous communities. On average, 60% of participants reported lifetime AUD, with only 12% meeting criteria for past year AUD as young adults. Such "aging out" of heavy alcohol use aligns with prior research from other Indigenous communities: normative heavy episodic drinking in adolescence may not continue into early adulthood, owing in part to misalignment with traditional cultural values, health concerns, and life-course transitions to parenting and professional roles (Quintero, 2000). Indeed, in recent open-ended assessment of those in the current study, participants cited many of these same concerns as their reasons for quitting drinking. Despite a greater burden of AUD, Indigenous adults are more likely to abstain from alcohol use than white adults (Cunningham, Solomon, & Muramoto, 2016), and show steep declines in use throughout adulthood (Beals et al., 2003). These points, coupled with our results, suggest opportunity for early adolescent prevention and intervention to negate the longer-term socio-economic consequences of early SUD. They also suggest that Indigenous young people's early substance abuse may not translate to a lifetime of substance abuse, doing much to refute racist conceptions of "drunken Indians." More research on alcohol use patterns across the life course among Indigenous people is critical, with particular attention given to desistance or recovery stages of alcohol use, which are not well understood in the extant literature.

Contrary to alcohol use findings, the profiles of early-adult marijuana use largely conformed to expectations and prior research. The two combined marijuana and alcohol use groups had the highest proportions of lifetime marijuana use disorders and higher average marijuana frequency in early adulthood. Unlike alcohol use, Indigenous marijuana patterns tend to increase slightly or remain stable throughout early-adulthood (Copeland, Hill, Costello, & Shanahan, 2017). Our findings demonstrate that marijuana use in early adulthood is related to alcohol and marijuana co-use in adolescence, which may suggest that youth who use both substances in adolescence select into primary use of marijuana in early adulthood, rather than continue to co-use with high frequency.

4.1. Limitations

These findings should be considered within the context of three primary limitations. First, North American Indigenous groups across different geographical and cultural distinctions are not homogenous, and epidemiological research shows tremendous diversity in substance use prevalence (Beals et al., 2003; Mitchell, Beals, Novins, & Spicer, 2003). The original sample from the current study was comprised of youth from one cultural group residing on or proximate (within 50 miles) of reservation/reserve land. The findings from our within-culture study may not be generalizable to other Indigenous cultural groups or to Indigenous people residing in urban areas.

Second, the gap in time between the first and second phases of the study was 7 years, which excludes the years between late adolescence and emerging adulthood. It may be that the reasons for the similar drinking behaviors in early adulthood across trajectory groups lie in the transition between adolescence and early adulthood, a period that we could not assess.

Third, we must note some measurement limitations. Only concurrent use data were available at Wave 9, and we were unable to assess simultaneous use of marijuana and alcohol. Further, we had to combine the Wave 9 data into two groups (i.e., using both alcohol and marijuana versus not using both) due to small numbers of early adults using only marijuana or using neither substance. Drinking behaviors were assessed using recommended guidelines (Institute, 2020) but with one modification: drinking quantity was assessed with an open-ended question about the average number of drinks consumed on drinking days rather than specific response options. This may have introduced bias into the measure based on coding decisions. Future research should examine drinking quantities and frequencies to better understand early adult drinking patterns.

5. Conclusion

Our study demonstrated strong interrelationships between alcohol and marijuana co-use during adolescence, and their differential associations with early adult outcomes. Use of both substances in adolescence was associated with poorer outcomes in early adulthood, particularly for the group with an earlier age of onset. Further, abstaining from either substance in adolescence was associated with better early adult outcomes. These results can inform prevention and intervention efforts. For example, our results showed that adolescents who abstained from using alcohol were likely to not use marijuana, and vice versa. Programs that target preventing or delaying use of one substance may have reciprocal effects on use of others. Attention to early polysubstance use is important to reducing the burden of substance-related health problems affecting Indigenous Peoples.

6. Role of funding sources

the data, writing the manuscript, or the decision to submit the paper for publication.

7. Contributors

Kelley Sittner was a Co-Investigator on the study from which the data were drawn, contributed to study conceptualization, and was responsible for all data analyses. Dane Hautala contributed to the study conceptualization, wrote the literature review, and consulted on data analyses. Melissa Walls was Primary Investigator on the study and co-wrote the literature review. All authors contributed to paper writing and manuscript preparation, and read and approved the final manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

References

Beals, J., Spicer, P., Mitchell, C. M., Novins, D. K., Manson, S. M., & AI-SUPERPFP Team. (2003). Racial disparities in alcohol use: Comparison of 2 American Indian reservation populations with national data. *American Journal of Public Health, 93* (10), 1683–1685.

Brook, J. S., Zhang, C., Rubenstone, E., Primack, B. A., & Brook, D. W. (2016). Comorbid trajectories of substance use as predictors of antisocial personality disorder, major depressive episode, and generalized anxiety disorder. *Addictive Behaviors, 62*, 114–121. https://doi.org/10.1016/j.addbeh.2016.06.003.

Chassin, L., Flora, D. B., & King, K. M. (2004). Trajectories of alcohol and drug use and dependence from adolescence to adulthood: The effects of familial alcoholism and personality. *Journal of Abnormal Psychology, 113*(4), 483–498. https://doi.org/10.1037/0021-843X.113.4.483.

Cheadle, J. E., & Sittner Hartshorn, K. J. (2012). Marijuana use development over the course of adolescence among North American Indigenous youth. *Social Science Research, 41*(5), 1227–1240. https://doi.org/10.1016/j.ssresearch.2012.03.015.

Cheadle, J. E., & Whitbeck, L. B. (2011). Alcohol use trajectories and problem drinking over the course of adolescence a study of North American Indigenous youth and their caretakers. *Journal of Health and Social Behavior, 52*(2), 228–245. https://doi.org/10.1177/0022146510393973.

Connor, J. P., Gullo, M. J., White, A., & Kelly, A. B. (2014). Polysubstance use: Diagnostic challenges, patterns of use and health. *Current Opinion in Psychiatry, 27*(4), 269–275. https://doi.org/10.1097/YCO.0000000000000069.

Copeland, W. E., Hill, S., Costello, E. J., & Shanahan, L. (2017). Cannabis use and disorder from childhood to adulthood in a longitudinal community sample with American Indians. *Journal of the American Academy of Child & Adolescent Psychiatry, 56*(2), 124–132.

Costello, E. J., Farmer, E. M. Z., Angold, A., Burns, B. J., & Erkanli, A. (1997). Psychiatric disorders among American Indian and white youth in Appalachia: The great smoky mountains study. *American Journal of Public Health, 87*(5), 827.

Cunningham, J. K., Solomon, T. A., & Muramoto, M. L. (2016). Alcohol use among Native Americans compared to whites: Examining the veracity of the "Native American elevated alcohol consumption" belief. *Drug and Alcohol Dependence, 160*, 65–75. https://doi.org/10.1016/j.drugalcdep.2015.12.015.

Dick, R. W., Manson, S. M., & Beals, J. (1993). Alcohol use among male and female Native American adolescents: Patterns and correlates of student drinking in a boarding school. *Journal of Studies on Alcohol and Drugs, 54*(2), 172.

Falk, D., Yi, H., & Hiller-Sturmhöfel, S. (2008). An epidemiologic analysis of co-occurring alcohol and drug use and disorders: Findings from the National Epidemiologic Survey of Alcohol and Related Conditions (NESARC). *Alcohol Research & Health, 31* (2), 100.

Flory, K., Lynam, D., Milich, R., Leukefeld, C., & Clayton, R. (2004). Early adolescent through young adult alcohol and marijuana use trajectories: Early predictors, young adult outcomes, and predictive utility. *Development and Psychopathology, 16*(01), 193–213. https://doi.org/10.1017/S0954579404044475.

Gonzales, K. L., Jacob, M. M, Mercier, A., et al. (2018). An indigenous framework of the cycle of fetal alcohol spectrum disorder risk and prevention across the generations: historical trauma, harm and healing. Ethnicity & Health. 1–19. doi:10.1080/13557858.2018.1495320.

Goodman, E., & Huang, B. (2002). Socioeconomic status, depressive symptoms, and adolescent substance use. *Archives of Pediatrics & Adolescent Medicine, 156*(5), 448–453. https://doi.org/10.1001/archpedi.156.5.448.

Hautala, D., Sittner, K., & Walls, M. (2019). Onset, comorbidity, and predictors of nicotine, alcohol, and marijuana use disorders among North American Indigenous adolescents. *Journal of Abnormal Child Psychology, 47*(6), 1025–1038.

Heron, Melonie (2014). Deaths: Leading Causes for 2017. *National Vital Statistics Reports, 68*(6).

Jackson, K. M., Sher, K. J., & Schulenberg, J. E. (2005). Conjoint developmental trajectories of young adult alcohol and tobacco use. *Journal of Abnormal Psychology, 114*(4), 612–626. https://doi.org/10.1037/0021-843X.114.4.612.

Jackson, K. M., Sher, K. J., & Schulenberg, J. E. (2008). Conjoint developmental trajectories of young adult substance use. *Alcoholism, Clinical and Experimental Research, 32*(5), 723.

Jones, B. L., & Nagin, D. S. (2013). A note on a stata plugin for estimating group-based trajectory models. *Sociological Methods & Research, 42*(4), 608–613. https://doi.org/10.1177/0049124113503141.

Kessler, R. C., & Üstün, T. B. (2004). The World Mental Health (WMH) Survey Initiative version of the World Health Organization (WHO) Composite International Diagnostic Interview (CIDI). *International Journal of Methods in Psychiatric Research, 13*(2), 93–121. https://doi.org/10.1002/mpr.168.

May, P. A. (1996). Overview of Alcohol Abuse Epidemiology for American Indian Populations. In G. D. Sandefur, R. R. Rindfuss, & B. Cohen (Eds.), *Changing Numbers, Changing Needs: American Indian Demography and Public Health* (pp. 235–256). National Academy Press.

Meadows, S. O., Brown, J. S., & Elder, G. H. (2006). Depressive Symptoms, Stress, and Support: Gendered Trajectories From Adolescence to Young Adulthood. *Journal of Youth and Adolescence, 35*(1), 89–99. https://doi.org/10.1007/s10964-005-9021-6.

Mitchell, C. M., Beals, J., Novins, D. K., & Spicer, P. (2003). Drug use among two American Indian populations: Prevalence of lifetime use and DSM-IV substance use disorders. *Drug and Alcohol Dependence, 69*(1), 29–41.

Moss, H. B., Chen, C. M., & Yi, H. (2014). Early adolescent patterns of alcohol, cigarettes, and marijuana polysubstance use and young adult substance use outcomes in a nationally representative sample. *Drug and Alcohol Dependence, 136*, 51–62. https://doi.org/10.1016/j.drugalcdep.2013.12.011.

Nagin, D. S. (2005). *Group-Based Modeling of Development.* Harvard University Press.

National Institute on Alcohol Abuse and Alcoholism. (2020). Drinking Levels Defined. Alcohol's Effects on Health. Accessed August 3, 2020. https://www.niaaa.nih.gov/alcohol-health/overview-alcohol-consumption/moderate-binge-drinking.

Nelson, S. E., Ryzin, M. J. V., & Dishion, T. J. (2015). Alcohol, marijuana, and tobacco use trajectories from age 12 to 24 years: Demographic correlates and young adult substance use problems. *Development and Psychopathology, 27*(1), 253–277. https://doi.org/10.1017/S0954579414000650.

O'Connell, J. M., Novins, D. K., Beals, J., Whitesell, N. R., Spicer, P., & Team TA-S. (2011). The association between substance use disorders and early and combined use of alcohol and marijuana in two American Indian populations. *Journal of Substance Use, 16*(3), 213–229. https://doi.org/10.3109/14659891.2010.545857.

Quintero, G. (2000). "The lizard in the green bottle": "aging out" of problem drinking among Navajo men. *Social Science & Medicine, 51*(7), 1031–1045. https://doi.org/10.1016/S0277-9536(00)00017-4.

Radloff, L. S. (1977). The CES-D scale a self-report depression scale for research in the general population. *Applied Psychological Measurement, 1*(3), 385–401.

Schiller, J. S, Lucas, J. W, Peregoy, J. A. (2012). Summary Health Statistics for U.S. Adults: National Health Interview Survey, 2011. National Center for Health Statistics. Accessed May 3, 2014. http://www.cdc.gov/nchs/data/series/sr_10/sr10_256.pdf.

Shaffer, D., Schwab-Stone, M., Fisher, P., et al. (1993). The Diagnostic Interview Schedule for Children-Revised Version (DISC-R): I. Preparation, Field Testing, Interrater Reliability, and Acceptability. *Journal of the American Academy of Child & Adolescent Psychiatry, 32*(3), 643–650.

Sittner, K. J. (2016). Trajectories of substance use: Onset and adverse outcomes among North American indigenous adolescents. *Journal of Research on Adolescence, 26*(4), 830–844. https://doi.org/10.1111/jora.12233.

Substance Abuse and Mental Health Services Administration (SAMHSA). (2010). Results from the 2009 National Survey on Drug Use and Health: Volume I. Summary of National Findings. Accessed August 7, 2013. http://www.samhsa.gov/data/2k9/2k9Resultsweb/web/2k9results.htm.

Walls, M. L. (2008). Marijuana and alcohol use during early adolescence: Gender differences among American Indian/First Nations Youth. *Journal of Drug Issues, 38* (4), 1139–1160. https://doi.org/10.1177/002204260803800410.

Walls, M. L., Sittner Hartshorn, K. J., & Whitbeck, L. B. (2013). North American Indigenous adolescent substance use. *Addictive Behaviors, 38*(5), 2103–2109. https://doi.org/10.1016/j.addbeh.2013.01.004.

Warne, D., & Frizzell, L. B. (2014). American Indian health policy: Historical trends and contemporary issues. *American Journal of Public Health, 104*(S3), S263–S267. https://doi.org/10.2105/AJPH.2013.301682.

West, B. A., & Naumann, R. B. (2011). Motor vehicle-related deaths — United States, 2003–2007. *Morbidity and Mortality Weekly Report Supplement., 60*(2), 52–55.

Whitbeck, L. B., & Armenta, B. E. (2015). Patterns of substance use initiation among Indigenous adolescents. *Addictive Behaviors, 45*, 172–179. https://doi.org/10.1016/j.addbeh.2015.01.006.

Whitbeck, L. B, Walls, M. L, Sittner Hartshorn, K. J. (2014). Indigenous Adolescent Development: Psychological, Social and Historical Contexts. Routledge.

Whitesell, N. R., Asdigian, N. L., Kaufman, C. E., et al. (2014). Trajectories of substance use among young American Indian adolescents: Patterns and predictors. *Journal of Youth and Adolescence, 43*, 437–453. https://doi.org/10.1007/s10964-013-0026-2.

Whitesell, N. R., Beals, J., Mitchell, C. M., et al. (2006). Latent class analysis of substance use: Comparison of two American Indian reservation populations and a national sample. *Journal of Studies on Alcohol and Drugs, 67*(1), 32.

Yoder, K. A., Whitbeck, L. B., Hoyt, D. R., & LaFromboise, T. (2006). Suicidal ideation among American Indian Youths. *Archives of Suicide Research, 10*(2), 177–190. https://doi.org/10.1080/13811110600558240.