

Trajectories of Substance Use: Onset and Adverse Outcomes Among North American Indigenous Adolescents

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North American Indigenous communities experience disproportionately high rates of substance use, abuse, and dependence and their accompanying consequences. This study uses group-based trajectory modeling of past-year substance use (alcohol, marijuana, and cigarettes) with a longitudinal sample of Indigenous adolescents from the northern Midwest and Canada (spanning ages 10–18 years). The early-onset trajectory (36.3%) had more adverse psychosocial difficulties at baseline than the mid-onset group (38.3%); both trajectories were associated with several negative outcomes at the end of the study. The late-onset trajectory (25.3%) did not initiate substance use until later adolescence and had far better outcomes at the last wave of the study. Timing of onset matters. Prevention efforts should begin in late childhood and continue through mid-adolescence.

Serious health and social disparities persist in many North American Indigenous communities today, the result of a history of oppression and the ongoing marginalization of Indigenous people (Adelson, 2005; Walters, Simoni, & Evans-Campbell, 2002). A number of these disparities are linked to substance use (May, 1996; U.S. Department of Health and Human Services, 2014). For example, compared to White adults, American Indians/Alaska Natives (AI/AN) are two times more likely to be diagnosed with diabetes (Schiller, Lucas, & Peregoy, 2012). AI/ANs have the highest rate of alcohol-involved motor vehicle-related deaths of any racial/ethnic group (West & Naumann, 2011). Suicide, the second leading cause of death for Indigenous young adults (Centers for Disease Control and Prevention [CDC], 2012), has also been linked to alcohol and drug abuse (Yoder, Whitbeck, Hoyt, & LaFromboise, 2006). Moreover, substance use, particularly alcohol, is a key risk factor for involvement in the criminal justice system for Indigenous people (Perry, 2004), which perpetuates social disparities by limiting employment opportunities (Pager, 2003). Notably, Indigenous people in the United States and Canada experience higher than average rates of poverty and unemployment (Aboriginal Affairs and Northern Development Canada [AANDC], 2011; Bureau of Indian Affairs, 2005; Pendakur & Pendakur, 2013).

Substance use (i.e., alcohol, cigarette smoking, and marijuana) may begin at younger ages for Indigenous youth (Miller, Beauvais, Burnside, & Jumper-Thurman, 2008) and carries with it more immediate consequences as well. This includes the development of substance use disorders (SUDs; DeWit, Adlaf, Offord, & Ogborne, 2000), which are more prevalent in Indigenous populations than among other racial/ethnic groups (Substance Abuse and Mental Health Services Administration [SAMHSA], 2007). By approximately age 18, the rate of lifetime alcohol dependence among the adolescents in the current study was nearly 18%, nicotine was 19.3%, and marijuana abuse was 23.7% (Whitbeck, Sittner, Hartshorn, Crawford, Walls, Gentzler & Hoyt, 2014). Additionally, one-half of the sample met lifetime criteria for any SUD. Substance use disorders represent a significant health concern for these adolescents and their communities. Preventing or delaying substance use among Indigenous youth offers a critical avenue for reducing substance-related disparities later in life.

Research on Indigenous adolescent substance use has yielded important findings on the risk factors and consequences of substance-specific use. For example, studies have documented heightened risk among females for early alcohol, marijuana, and cigarette use (Cheadle & Whitbeck, 2011; Walls, 2008; Whitesell et al., 2014). The task of identifying other risk factors and outcomes across substances is made difficult by the fact that most research has focused on a single substance, with the exception of a few recent studies (e.g., Walls,

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Sittner Hartshorn, & Whitbeck, 2013; Whitesell et al., 2014). Studies of multiple substances have typically examined sequences of substance use (i.e., whether certain substances increase the likelihood of progressing to other substances; Novins & Barón, 2004). The focus on individual substances has potentially obscured the larger picture of Indigenous adolescent substance use, particularly given the overlap in substances used. It remains unclear whether it is the use of specific substances or the age of onset for use in general that is more problematic for Indigenous youth development. It may be beneficial to examine adolescent substance use more inclusively to understand patterns of onset, risk factor profiles, and adverse outcomes.

To address this issue, this study focuses on use of three substances (i.e., alcohol, marijuana, and cigarettes) over the course of adolescence (i.e., ages 10–18 years) among a sample of Indigenous youths from the Northern Midwest and Canada. I employed group-based trajectory modeling (GBTM; Nagin, 1999) to identify clusters of individuals following similar substance use patterns over time. I then created profiles to explore the distribution of risk factors across the trajectory groups. Finally, I assessed the association between trajectory group membership and negative outcomes in late adolescence, including mental and SUDs, early parenthood, school failure, risky sexual behavior, and criminal justice system involvement. I begin by reviewing the research that has been carried out on Indigenous adolescent substance use, with a focus on longitudinal studies that have identified emergence and patterns of use during adolescence, followed by a brief review of the literature on risk factors for and late-adolescence outcomes of substance use.

PATTERNS OF INDIVIDUAL SUBSTANCE USE

Substance use is not a problem for all Indigenous people. Alcohol abstinence rates are higher in this group than in other U.S. racial groups (SAMHSA, 2010), contrary to enduring stereotypes and assumptions (Beals et al., 2009). Significant variation exists in substance use between Indigenous tribes (May, 1996; Mitchell, Beals, Novins, & Spicer, 2003), between Indigenous people living on versus off reservations/reserves (Beauvais, 1992b), and by gender (Mitchell et al., 2003; Walls, 2008; Walls et al., 2013). For example, Mitchell et al. (2003), in a study of two tribes, found that lifetime rates of drug and alcohol use were highest for Northern Plains men and lowest for Southwest women.

Nevertheless, some Indigenous communities suffer from high rates of substance use, abuse, and dependence, and their associated consequences. For instance, in a sample of adults from one First Nations reserve, approximately 80% typically consumed four or more drinks per day and about 40% drank to intoxication at least once per week (Spillane, Greenfield, Venner, & Kahler, 2015).

Alcohol

Alcohol use, the most commonly studied substance, has been operationalized in a broad array of ways, ranging from lifetime drinking to meeting criteria for alcohol use disorder. Alcohol also tends to be the most commonly used substance and begins at a young age. In a study of Indigenous youth on or near reservations in two U.S. states, Beauvais, Oetting, Wolf, and Edwards (1989) found that a large percentage of seventh graders had tried alcohol. According to the National Study on Drug Use and Health (SAMHSA, 2007), from 2002 to 2005, approximately 35% of American Indian youth ages 12–17 years had used alcohol in the past year and 8.5% met criteria for a past-year alcohol use disorder.

Recent longitudinal studies also provide evidence of early alcohol use among Indigenous adolescents. Walls et al. (2013) found rapidly increasing probabilities of problem drinking starting at age 10 in a sample of Indigenous youth from a single culture in the northern Midwest and Canada. Two separate studies that examined alcohol use trajectories identified an early-onset group of approximately the same size, 20% in one Indigenous culture group (Cheadle & Whitbeck, 2011) and 25% in another study with adolescents from two culture groups (Whitesell et al., 2014). In both studies, this group consumed alcohol more frequently than other ethno-cultural groups starting at about age 11.

Marijuana

Marijuana use is less prevalent than alcohol use among Indigenous adolescents, but is more common than the use of other illicit drugs (Beauvais, 1992a). A statewide surveillance of marijuana use in California found that Indigenous youth were twice as likely as White adolescents to use marijuana in the past year (UCLA Center for Health Policy Research, 2012). Marijuana use disorders are the most common drug use disorders among American Indian/Alaska Native adults and

adolescents (Duran et al., 2004), and research indicates that American Indian adults and adolescents are more likely to have a marijuana use disorder than people of other racial/ethnic groups in the United States (SAMHSA, 2007).

Most of the research on Indigenous adolescent marijuana use has focused on the frequency of use. Despite different Indigenous cultures, ages, measures of marijuana use, and analytic methods, consistent developmental patterns have been identified across studies. First, research has shown a general pattern of increasing use in mid-adolescence (Mitchell, Novins, & Holmes, 1999; Walls et al., 2013). Furthermore, the probability of using marijuana increased more rapidly from ages 10 to 15 years than from 15 to 18 years in Walls et al.'s (2013) study. Second, in studies that examined multiple trajectories of use, there appears to be a sizable proportion of Indigenous youth using marijuana early in adolescence. In Whitesell et al.'s (2014) study, 26% of the sample used marijuana frequently over the course of adolescence, and another 17% increased their frequency of use starting at ages 11–12 years. Findings by Cheadle and Sittner Hartshorn (2012) differed somewhat, in that 14% increased marijuana use starting at age 11, and another 19% increased use at age 13. Overall, however, it appears that marijuana use begins in early adolescence and increases quickly among the Indigenous samples studied.

Tobacco/Smoking Cigarettes

National estimates show that Indigenous adults and adolescents are more likely than members of other ethno-cultural groups to be current smokers (National Center for Health Statistics, 2013; SAMHSA, 2010). As with alcohol and marijuana, use starts at quite young ages. Whitesell et al. (2012) found that initiation risk was greatest between ages 10 and 13, which matches the average age of smoking onset of 12.3 years for reservation-based youth in a Southwest culture (Yu, Stiffman, & Freedenthal, 2005).

Unlike alcohol and marijuana, there are few longitudinal studies of Indigenous youth cigarette smoking. In general, the risk for smoking increases as young people progress through adolescence. In studies by Whitbeck, Sittner Hartshorn, McQuillan, and Crawford (2012), and by Whitbeck, Walls, and Welch (2012), the odds of daily smoking increased, on average, by 67% for each year past age 10. Whitesell et al. (2014) found three distinct smoking trajectories among a sample of Indigenous youth

from the Northern Plains: an increasing but intermittent smoking group, a low stable smoking group, and a group that had an early increase in smoking frequency that declined in mid-adolescence.

RISK FACTORS AND NEGATIVE OUTCOMES OF SUBSTANCE USE

Research has identified a range of substance use risk factors, which, for the purposes of this review, are organized into individual, family, and peer/school domains. A concise review of substance use risk factors and consequences included in the current study is provided here, drawing from research on the broader substance use literature as well as on Indigenous substance use. As mentioned previously, most research addresses specific substances, but more general substance use research is noted where available.

Gender has inconsistently been linked to early and/or increasing use of various substances in samples of Indigenous youth. Some research has identified heightened risk of alcohol, tobacco, and marijuana use for females (Cheadle & Sittner Hartshorn, 2012; Cheadle & Whitbeck, 2011; Whitbeck, Sittner Hartshorn et al., 2012; Whitbeck, Walls et al., 2012; Whitesell et al., 2014), whereas studies with other samples of Indigenous youth found males to be at higher risk for more frequent marijuana use (Novins & Mitchell, 1998). Pubertal timing, in particular early pubertal development, also has been related to early and/or more frequent alcohol, tobacco, and marijuana use among Indigenous (Walls & Whitbeck, 2011; Whitesell et al., 2014) and non-Indigenous youth (Costello, Sung, Worthman, & Angold, 2007). Furthermore, mental health problems have been associated with substance use. In particular, depression and/or depressive symptoms have been identified as correlates of early alcohol and tobacco use in a sample of Minnesota middle school students (Kubik, Lytle, Birnbaum, Murray, & Perry, 2003), and of early cigarette smoking among Indigenous adolescents (Whitbeck, Sittner Hartshorn et al., 2012; Whitbeck, Walls et al., 2012; Yu et al., 2005). Early conduct disorder has also been linked to early cigarette use among Indigenous youth (Whitbeck, Sittner Hartshorn et al., 2012; Whitbeck, Walls et al., 2012; Yu et al., 2005) and to SUD in non-Indigenous samples (Armstrong & Costello, 2002).

Several parent and family risk factors have been correlated with adolescent substance use. Parent

substance use problems, either as problematic use or SUD, have been associated with early or increasing alcohol and marijuana use for Indigenous youth (Cheadle & Sittner Hartshorn, 2012; Mitchell, Beals, & Whitesell, 2008; Walls, Whitbeck, Hoyt, & Johnson, 2007). Parent substance abuse was also associated with initiating substance use by age 12 (Kaplow, Curran, & Dodge, 2002) and with the development of alcohol dependence (Lieb et al., 2002) in non-Indigenous samples. In Chassin, Presson, Pitts, and Sherman's (2000) study of cigarette smoking, the early stable group had more parents who smoked than groups who smoked later and less often. A less common finding concerns parental depression. It has been inconsistently linked to adolescent substance use in general samples (e.g., Weissman, Warner, Wickramaratne, Moreau, & Olfson, 1997) but was a risk factor for early alcohol and marijuana use in an Indigenous sample (Cheadle & Sittner Hartshorn, 2012; Cheadle & Whitbeck, 2011).

Risk factors for substance use are also found within the peer and school environments. A large body of research has noted the relationship between peer substance use and adolescent substance use among both non-Indigenous (Chassin, Pitts, & Prost, 2002) and Indigenous samples (Cheadle & Sittner Hartshorn, 2012; Cheadle & Whitbeck, 2011; Whitbeck, Sittner Hartshorn et al., 2012; Whitbeck, Walls et al., 2012; Whitesell et al., 2014). Across studies, having peers who consume alcohol or marijuana or who smoke cigarettes is associated with more substance use. Additionally, difficulties at school, including school failure and school adjustment, are significant predictors of substance use in non-Indigenous samples (Hawkins, Catalano, & Miller, 1992).

In addition to the longer-term health problems highlighted earlier, substance use may bring with it more immediate consequences for adolescents. The majority of research in this area has focused on alcohol. For instance, both alcohol intoxication and more frequent drinking were significantly correlated with school and legal problems for Indigenous youth in a U.S. boarding school (Dick, Manson, & Beals, 1993). Additionally, early alcohol use has been linked to later delinquency and criminal convictions for AI (Barnes, Welte, & Hoffman, 2002; Whitesell et al., 2014). Alcohol may be a more important predictor of criminal justice system involvement for Indigenous youth than youth from other cultures, as arrest rates for alcohol-related offenses among American Indian youth are more than twice the national average (Greenfeld & Smith, 1999).

Furthermore, earlier onset of substance use is associated with increased risk of developing an SUD at later ages (Chassin et al., 2002; Grant & Dawson, 1997), perhaps because there is a faster progression from onset of use to dependence among adolescents than adults (Clark, Kirisci, & Tarter, 1998). Research with Indigenous samples has also noted that early use of alcohol and marijuana increases the risk of later SUD (Cheadle & Sittner Hartshorn, 2012; Cheadle & Whitbeck, 2011).

Although not with an Indigenous sample, Hanna, Yi, Dufour, and Whitmore (2001) found that early regular smoking was associated with a host of negative outcomes for adolescents, including other substance use, problems in school, and early pregnancy. Conversely, in another study of adolescent substance use (Guo et al., 2002), the associations between substance type (i.e., alcohol, cigarettes, marijuana, other illicit drugs) and risky sexual behavior in early adulthood were inconsistent. In that study, there were few differences among the different cigarette smoking trajectories and risky sexual behavior, specifically number of sex partners.

To summarize, the onset of substance use is especially problematic at younger ages. It is increasingly clear that substance use, whether it is alcohol, cigarettes, or marijuana, contributes to many of the health and social disparities that exist for Indigenous communities. The current study adds to the existing literature on Indigenous adolescent substance use in three ways. First, different developmental patterns of substance use from ages 10 to 18 are described, characterized by different ages of onset and changes in the number of substances used. Second, the distributions of selected risk factors are explored to determine their prevalence in each trajectory group as well as to identify between-group differences. Third, I examine whether and to what extent different patterns of substance use are associated with various adverse outcomes at the final wave of the study.

DATA AND METHODS

Study Procedure

These data were collected as part of the "Healing Pathways Project," an eight-wave longitudinal study designed in partnership with five U.S. reservations, four Canadian reserves and a university-based research team. The reservations/reserves share a common cultural tradition and language

with minor regional variations in dialects and are located in a single geographic region in the northern Midwest and Canada. It is among the most populous Native cultures in the United States and Canada. Prior to the application funding, the research team was invited to work on these reservations/reserves, and tribal resolutions were obtained. As part of the agreement to work together, the researchers promised that participating reservations/reserves would be kept anonymous in published reports. Tribal councils for each reservation/reserve appointed advisory boards, which were responsible for handling difficult personnel problems, advising on questionnaire development, and reviewing reports for respectful wording. All participating staff (i.e., supervisors, interviewers) on the reservations/reserves were approved by the advisory board and were either tribal members or, in a few cases, nonmembers who were spouses of tribal members. To ensure quality of data collection, all the interviewers underwent special training for conducting pencil-and-paper and computer-assisted personal interviewing for the diagnostic measures. The training included practice and feedback sessions.

Families were recruited through a personal visit by an interviewer in which the project was explained to them. They were presented with a traditional gift and were invited to participate. If a family agreed to be interviewed, each participating family member received \$40 for his or her time when the interviews were completed. The recruitment procedure resulted in an overall response rate of 79.4%. Annual retention rates ranged from 94.6% at Wave 2 to 78.8% at Wave 8. More information on the study design and sampling procedures can be found in Whitbeck, Sittner Hartshorn, and Walls (2014).

Sample

The sample used in the current analysis consists of adolescents from seven of the original eight reservations/reserves (one location did not have an active advisory board and we chose to exclude their data in order to honor community rights to review papers prior to publication), ages 10–13 at the first wave of data collection (mean age = 11 years). Only those adolescents for whom there were at least three observations were included, which resulted in a final sample size of 619 (82.6% of the original sample). For the trajectory analyses, data come from Waves 1, 2, 3, 5, and 7 (only diagnostic data were collected in Waves 4

and 6). The distal outcomes used in the final analysis were drawn from the eighth (final) wave of data collection.

Descriptive statistics from the first wave of the study are given in the first column of Table 2. The sample is evenly split by gender (50.4% female, 49.6% male). The per capita family income was \$5,673. Although the entire sample lives in rural settings, about 10% of the respondents lived in more remote settings (defined as being 50 or more miles from other cities or towns, and accessible by dirt roads or over water). Nearly, 14% of the respondents lived off (but proximal to) a reservation/reserve.

Measures

Dependent variable. Past-year substance use. At each wave of nondiagnostic data collection (Waves 1, 2, 3, 5, and 7), adolescents were asked whether they had ever (1) had a drink of alcohol (beer, wine, or liquor), (2) used marijuana, or (3) smoked cigarettes. If they responded yes, they were asked whether they had consumed each substance in the past year. Affirmative responses were summed into a count of past-year substance use at each wave, with a possible range of 0–3. Distributions of each substance used across ages 10–18 are shown in Table 1. It should be noted that no single measure of substance use predominates in substance use research, including in samples of Indigenous youth. Measures of individual substances range from lifetime use to past-year use, to problematic use (e.g., binge drinking or maximum number of drinks consumed), to frequency of use, to meeting criteria for a substance abuse and/or dependence disorder. In the present study, the intention is to explore onset and trajectories use of substance use starting at age 10, hence the choice of past-year alcohol, cigarette, and marijuana use. Another option was to dichotomize the outcome into any substance use versus no substance use, but constructing the dependent variable as a count also allows changes in the overlap in use among the three substances to be modeled (also shown in Table 1).

Profile variables. Profile variables come from the first wave of the study. Adolescent *gender*, per capita family *income*, *remote* location, and *off-reservation* location were included as adolescent demographic variables. I included two adolescent mental health characteristics. Lifetime *conduct disorder* and *major depressive disorder* were assessed using the

TABLE 1
Percent of Youth Using Individual Substances and Any Substances, by Age

	Age in Years								
	10	11	12	13	14	15	16	17	18
Individual substances									
Alcohol	2.0	5.5	12.6	26.7	38.6	47.8	58.4	59.2	55.9
Marijuana	2.0	3.4	9.5	19.9	28.1	34.5	37.9	34.5	37.2
Cigarettes	6.5	9.7	16.9	30.4	40.1	45.5	50.0	52.4	50.8
Any substance									
None	93.7	87.2	77.5	57.3	44.2	34.6	26.8	22.3	13.5
One	4.6	8.7	11.3	16.1	19.7	17.9	24.0	26.3	26.4
Two	1.1	3.2	7.2	11.6	15.6	16.0	20.0	21.4	27.7
All Three	0.6	0.9	4.0	15.0	20.5	31.5	29.2	30.0	32.4

Diagnostic Interview Schedule for Children-Revised (DISC-R), each coded so that 1 = *met criteria for the disorder* and 0 = *did not meet criteria*. Adolescents were considered to have completed (by Wave 1, mean age = 11 years) *early pubertal development* (1 = *yes*, 0 = *no*) if they had experienced (for boys) growth in body hair or facial hair, or voice changes, and (for girls) growth in body hair, breast development, or menstruation. *Best friends who drink or smoke* was measured as the number of respondents' three best friends who drank alcohol or smoked cigarettes. *Expelled from school* was assessed with a single question to which respondents reported ever being expelled from school. Two lifetime parent/caretaker mental health variables were measured at Wave 1 using the University of Michigan Composite International Diagnostic Interview (UM-CIDI) *major depression* and *substance use* (alcohol abuse/dependence, marijuana abuse/dependence) disorder modules. Both were coded as 1 = *met criteria* and 0 = *did not meet criteria*.

Outcome variables. All outcome variables were assessed at the final wave of the study and dichotomized (1 = *yes or met criteria* and 0 = *no or did not meet criteria*). Past-year *substance use disorder, at least one disorder*, and *two or more disorders* were assessed with the Diagnostic Interview Schedule for Children-Revised (DISC-R). *Did not complete high school* was measured by asking the young adults whether they had not graduated from high school and were not still attending. *Risky sexual behavior* assessed whether respondents engaged in sexual behavior while under the influence of alcohol or marijuana at least some of the time. Respondents who reported that they had at least one child by Wave 8 were regarded as experiencing *early parenthood*.

Arrest measured as self-reported arrest in the past year, and those who reported being arrested also reported whether they had spent some time in *jail or juvenile detention*.

Analytic Strategy

I used group-based trajectory modeling (GBTM), a type of semi-parametric mixture modeling (Jones & Nagin, 2007; Nagin, 1999) using the Stata *traj* plugin (Jones & Nagin, 2013), on the first seven waves of the study. This method identifies clusters of individuals who follow similar progressions of an outcome over time. GBTM fits censored normal, zero-inflated Poisson (ZIP), and Bernoulli distributions of the outcome variable of interest. Because substance use was a count of how many of three substances were used in the past year and it had an excess of zeroes at the youngest ages, ZIP distribution was specified (although the censored normal model specification was tested, the ZIP model fit the data better). Models with up to five groups were estimated, and Bayesian information criterion (BIC) values were used to determine the best-fitting number, as described in Jones, Nagin, and Roeder (2001) and recommended by Raftery (1995). Preference was given to models that had lower BIC values. Fit values are provided in Table 2. The BIC values for the three group (BIC = -3088.38) and four-group models (BIC = -3082.52) were very similar. The BIC is sensitive to the number of parameters and favors more parsimonious models. Following Nagin's (Nagin, 2005; Nagin & Odgers, 2010) recommendation that decisions regarding the number of groups should be guided by fit statistics in addition to model parsimony, adequacy, and comprehensibility, the three-group model was selected.

TABLE 2
Bayesian Information Criterion Values for Model Selection

Number of Groups	BIC
1	-3379.24
2	-3204.34
3	-3088.38
4	-3082.52
5	-3092.63

The three-group model was refined by re-estimating with different polynomials to determine the trajectory shape for each group and comparing BIC values (not shown). The best-fitting model had a linear term for the first group and cubic terms for the remaining two groups (BIC = -3070.20). Posterior probabilities of group membership were examined next to determine how well the model fit the data (Appendix S1). These values are calculated for every individual for all of the trajectory groups and provide a basis for assigning individuals to trajectory groups: the largest probability for each individual indicates the trajectory that best conforms to that individual's behavior over time. The average posterior probabilities of group membership ranged from .76 to .86, exceeding the .70 cutoff recommended by Nagin (2005).

After the number and shapes of the trajectory groups were identified, the posterior probability-based classifications were used to create profiles of each group. The profiles provide the prevalence and distribution of key correlates of substance use at baseline across the trajectory groups. Mean differences were assessed across groups for continuous variables using ANOVA with Bonferroni post hoc tests, and chi-square tests of proportions for dichotomous variables.

The last stage in the analysis was to use the trajectory groups as predictors of distal outcomes (i.e., at Wave 8, the final wave of data collection). Because all of the Wave 8 variables were dichotomous, the outcome model is a logistic regression with outcomes regressed on the probability of group membership. The parameters provided are the log-odds of the outcome within trajectory group, converted to the probability that the outcome = 1. The estimates can be interpreted as the expected prevalence of the outcome within each trajectory group. Post-estimation Wald tests were used to compare coefficients across trajectory groups.

RESULTS

Trajectories of Past-Year Substance Use

The three developmental trajectories are shown in Figure 1. The first group, the early-adolescence onset group, is composed of more than one-third of the sample (36.3%). There was a steep increase in past-year substance use between ages 10 and 15, when use peaked at about two substances in the past year and remained stable through age 18. The second trajectory group, with onset in mid-adolescence, is composed of 38.3% of the sample. This group had virtually no substance use from ages 10 to 11 but a steep increase in use occurred between ages 12 and 17. By late adolescence, this group had used approximately 1.5–2 substances in the past year. The last group, the late-onset group, was the smallest of the three groups at 25.3%. There was practically no substance use until age 15, which was followed by a gradual increase though age 18. By that time, the group used one substance in the past year.

Profiles of Trajectory Groups

Baseline measures were used to create profiles of trajectory group members and compare the means and proportions of the profile variables across the trajectory groups using ANOVA and chi-square tests (Table 3). Compared to the other two trajectory groups, a significantly larger proportion of the early-onset group was female (61.3%), met criteria for conduct disorder (22.1%), and had been expelled from school (24.9%). In addition, this group had a significantly greater mean number of friends who drank or smoked ($M = .80$) and a significantly lower average per capita family income ($M = \$4,712$) than the late-onset trajectory group.

Compared to the late-onset trajectory, the mid-onset group had a significantly larger percentage of adolescents meeting criteria for conduct disorder (9.7%) and being expelled from school (18%). The mid-onset and late-onset groups did not differ in the proportion of females, mean per capita family income, or mean number of best friends who drank or smoked.

The early-onset trajectory group was characterized by more risk factors for substance use than the other two groups (e.g., lower income, higher prevalence of conduct disorder). The profile of the late-onset group reflected the fewest risk factors of the three groups. There were no differences across trajectory groups by prevalence of major depressive disorder, proportion experiencing early pubertal development, or either of the parent mental health characteristics, although the

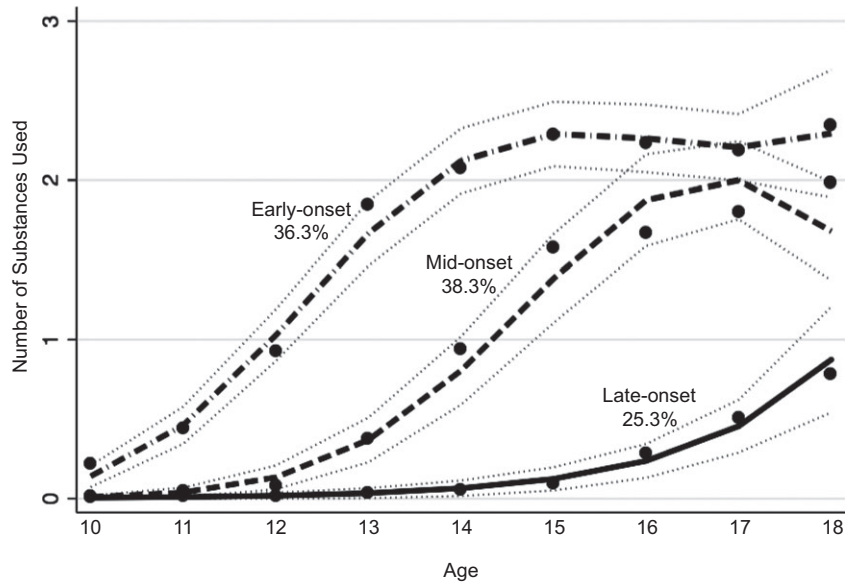


FIGURE 1 Substance use trajectories, ages 10–18 years ($n = 619$). Note: 95% confidence intervals around each trajectory group shown with dotted lines.

TABLE 3
Wave 1 Profiles of Substance Use Trajectory Groups (Means/
Percentages)

	Group			
	Full Sample ($n = 619$)	Early Onset ($n = 217$)	Mid-Onset ($n = 228$)	Late Onset ($n = 174$)
Demographics				
Female (%)	50.4	61.3 _a	46.1 _b	42.5 _b
Per capita family income	\$5,489	\$4,712 _a	\$5,592 _{ab}	\$6,315 _b
Remote location (%)	10.5	8.8 _a	12.7 _a	9.8 _a
Off-reservation (%)	14.9	9.8 _a	16.7 _a	19.0 _a
Adolescent psychosocial characteristics and behaviors				
Conduct disorder (%)	12.8	22.1 _a	9.7 _b	5.2 _c
Major depressive disorder (%)	3.1	5.5 _a	2.2 _a	1.1 _a
Early puberty (%)	42.3	47.0 _a	42.1 _a	36.8 _a
Expelled from school (%)	17.0	24.9 _a	18.0 _b	5.7 _c
Peers who drink/smoke	0.46	0.80 _a	0.33 _{ab}	0.20 _b
Parent characteristics				
Parent MDD (%)	20.3	25.4 _a	18.9 _a	15.7 _a
Parent SUD (%)	72.9	77.9 _a	72.7 _a	66.9 _a

Note. Means and percentages in the same row that do not share subscripts differ significantly at $p < .05$ using Bonferroni’s method for multiple comparisons for continuous variables and chi-square tests for categorical variables. MDD = major depressive disorder. SUD = substance use disorder.

patterns were in the expected direction. Additionally, there were no differences across groups by location (either remote or off-reservation).

Trajectory Group Outcomes

The trajectory groups were used to predict outcomes measured in the final wave of the study, shown in Table 4. In the descriptive analysis of group profiles (Table 1), the early-onset group had more negative characteristics (e.g., meeting criteria for mental disorders at Wave 1) than did the middle onset group. Yet there was only one difference in Wave 8 outcomes between the early- and mid-onset trajectory groups, which was in the expected prevalence of becoming young parents (33.1% for early-onset vs. 18.4% for mid-onset). In other words, onset of substance use at age 12 (the mid-onset trajectory) and at age 10 (the early-onset trajectory) was associated with nearly all of the same adverse outcomes.

The late-onset group had significantly lower prevalence estimates than either of the other two groups for six of the eight outcome variables examined. For example, being in the late-onset group had an expected prevalence of 9.4% for meeting past-year SUD criteria at Wave 8, compared to the significantly greater prevalence estimates of 37.3% for early-onset and 30.8% for mid-onset trajectories. More simply put, a significantly smaller proportion of the late-onset trajectory group is expected to meet criteria for mental disorders, to have sex

TABLE 4
Substance Use Trajectory Groups Associated With Wave 8 Outcomes

	Early Onset		Mid-Onset		Late Onset	
	Prevalence (%)	95% CI	Prevalence (%)	95% CI	Prevalence (%)	95% CI
Substance use disorder	37.3 _a	30.6, 44.6	30.8 _a	15.4, 52.0	9.4 _b	5.6, 15.2
Any disorder	37.7 _a	31.1, 44.8	37.4 _a	20.8, 57.6	3.6 _b	1.1, 11.8
Two or more disorders	18.7 _a	12.6, 26.7	13.9 _a	8.2, 22.7	1.0 _b	0.0, 4.0
Early parenthood	33.1 _a	25.4, 41.9	18.4 _b	12.2, 26.7	13.9 _b	8.5, 22.0
Sex under the influence	31.1 _a	23.8, 39.4	36.6 _a	26.6, 47.9	3.6 _b	1.4, 8.9
Not finishing HS	32.3 _a	26.0, 39.2	24.0 _{ab}	14.0, 37.9	9.5 _b	3.9, 21.2
Arrested	31.2 _a	23.7, 39.9	22.8 _a	15.8, 31.7	5.6 _b	2.6, 11.6
Jail/detention	24.4 _a	17.6, 32.9	16.9 _a	11.0, 25.2	3.2 _b	1.2, 8.4

Note. Prevalence estimates in the same row that do not share subscripts are significantly different across trajectory groups, $p < .05$.

while under the influence of substances, and to spend time in jail or detention at Wave 8 than are members of either of the other two trajectory groups. Compared to the early-onset group, smaller proportions of the late-onset group are expected to become early parents or to not finish high school; on those two variables, there were no statistically significant differences between the mid-onset and late-onset groups.

DISCUSSION

By age 13, about 35% of the adolescents in this sample had used marijuana, 47% had consumed alcohol, and 64% had smoked cigarettes in the past year, much larger percentages for that age group than are indicated in national studies. For example, data from the National Survey of Drug Use and Health (NSDUH, years 2002–2008 to correspond to the present study) show that 9.5%–12.2% of 12- to 13-year-olds had used alcohol, 4.1%–7.2% had smoked cigarettes, and 2.5%–3.1% had used marijuana (Center of Behavioral Health, Statistics, and Quality, 2010). In Monitoring the Future data from 2002–2014 on eighth-grade students, annual prevalence of substance use was 20.8%–38.7% for alcohol and 10.9%–14.6% for marijuana (annual prevalence of cigarette use not available; Miech, Johnston, O'Malley, Bachman, & Schulenberg, 2015). The estimates for each substance are notably smaller in the national studies for young adolescents. The present study points to the need to examine substance use onset and its trajectories among Indigenous adolescents to identify key periods of risk as well as opportunities for prevention and intervention.

Both early- and mid-onset groups, comprising 74.6% of the sample, were using more than one substance in the past year by age 15. This is a very different pattern than emerged in Whitesell et al.'s

(2014) trajectory analysis of individual substances in a Northern Plains sample of adolescents, in which nonusers were the largest class for each substance studied, ranging from 58% to 62% of the sample. But a closer look across substances produced findings more similar to those in the current study, namely that 60% of the adolescents used at least one substance. This underscores the importance of understanding general as well as specific patterns of substance use.

The conservative estimate of substance use (i.e., alcohol, marijuana, and/or cigarettes in the past year) used in the current study yields two important and compelling findings. First, the early-onset substance use trajectory had a profile characterized by multiple psychosocial difficulties at a very young age, which matches other non-Indigenous studies that link more risk factors with earlier and/or heavier use of various substances (Chassin et al., 2000; Kaplow et al., 2002). Second, in spite of an early profile that indicated fewer psychosocial difficulties, the mid-onset group trajectory was correlated with nearly the same adverse outcomes in the last wave of the study as the early-onset group, including an increased risk for the development of SUD and comorbid disorders. As reported in an earlier study from this sample examining overall diagnostic rates (Whitbeck, Sittner Hartshorn et al., 2014), 15.3% met criteria for alcohol abuse, 7.4% for marijuana dependence, 5% for nicotine dependence, and 25.8% for any alcohol or SUD. Lifetime estimates of SUD are quite high, with 51% meeting criteria for any alcohol or SUD. Given the overlap in substances and the deleterious effects of substance use, an important area for future research is to explore the different patterns of disorder, including changes in the probability of meeting criteria as well as comorbid SUDs.

There was a sizable late-onset group (25.3%) that did not begin using substances until around age 15

and averaged one substance used in the past year by age 18. This group had a healthier profile overall. For example, at Wave 1, this trajectory had lower prevalence of mental health problems and school expulsion, and fewer substance-using friends. Furthermore, this group had lower prevalence of all negative outcomes considered at Wave 8 than either of the other two trajectory groups. Understanding the factors associated with delayed substance use would likely provide important information for prevention and intervention efforts, and unquestionably merits further attention.

I posit that the two early use trajectories are linked to a cluster of early problem behaviors, whereas the later onset trajectory is likely linked to more normative social processes, similar to findings by Tucker, Ellickson, Orlando, Martino, and Klein (2005). Problem behaviors tend to cluster together, with shared risk factors (Donovan & Jessor, 1985; Jessor & Jessor, 1977). Importantly, those early trajectories have critical implications for life-course development. Not only are they associated with adverse outcomes at the final wave of the study (when adolescents were ages 17–19), but likely will continue to have consequences for the youth as they move into adulthood and beyond.

LIMITATIONS

As with all research, this study has its limitations. First, these data come from a single Indigenous culture residing on or near rural reservations/reserves. The results may not reflect patterns of substance use among youth in other Indigenous cultures or living in urban areas. Second, the measure of past-year substance use does not capture different frequencies of use and thus does not distinguish between heavy vs. experimental users. Third, there were concerns that the findings regarding the outcome analyses could be driven by alcohol and/or marijuana use, which have more immediate social and behavioral costs than smoking has. To address those concerns, post hoc analyses were conducted individually for each substance. The findings were nearly identical: The early-onset group profile for each substance indicated more early health and behavior concerns, and both early- and mid-onset trajectories were associated with worse outcomes at the final wave of the study. In general, these results suggest that age of onset is an important correlate of contemporaneous psychosocial problems and an important predictor of later adverse outcomes, regardless of

whether we examine one specific substance or any of three different substances.

A fourth limitation lies with the group-based trajectory method. A number of critiques of mixture models in general have been advanced, including the estimation of different groups where no mixtures exist or the extraction of too many groups (Bauer, 2007; Bauer & Curran, 2003) and the mutability of trajectory shapes and number through the addition of other time points or changes in the types of indicators used (Jackson & Sher, 2005). For more nuanced discussions of the limitations of mixture models, please see Bauer and Curran (2003), Bauer (2007), and Tofghi and Enders (2008). These critiques remind researchers to exercise care when interpreting trajectories and in making generalizations across studies. As Nagin (Nagin, 2005; Nagin & Odgers, 2010) cautions, GTBM is a statistical device that approximates groups of individuals following similar patterns in a distribution; it does not identify literally distinct entities. The focus should be on the mixture of trajectory groups within the population (Bauer, 2007) and what that distribution tells us about substance use among Indigenous adolescents. Post hoc analyses support the current study's contention that different patterns of substance use exist in the data and can be distinguished by age of onset and change in the number of substances used over time. Additional models were tested (i.e., using the censored normal distribution for substance use and using logit models for each substance individually; see above), and for each one the best-fitting models had three groups with similar trajectory shapes and of approximately the same size. Moreover, there were significant differences across trajectory groups regarding both profiles of risk factors and associations with later outcomes, which suggests that "the clustering has served a useful purpose, and their continued study may have merit by whatever statistical method one may choose" (Nagin & Odgers, 2010, p. 118).

CONCLUSION

Many of the risk factors included in this study have been associated with substance use across multiple cultures, yet there is a growing realization that culture is important for understanding health disparities and developing appropriate and targeted prevention programs (Kagawa-Singer, Dressler, George, & Elwood, n.d.). This is echoed in calls for responsible research situated within Indigenous contexts and communities (Beals et al.,

2009; Manson, 1995; Smith, 2012; Whitbeck, Sittner Hartshorn et al., 2014). For North American Indigenous youth, researchers must recognize that substance use risk factors and consequences are tied to the “colonized, Fourth World context of modern AI communities” (Walters, Simoni, & Evans-Campbell, 2002, p. S113). Indigenous youth, particularly those residing on reservations and reserves, often develop in highly disadvantaged environments. This has resulted in higher rates of substance use, abuse, and dependence, and more prevalent risk factors.

These findings have important prevention implications. First, it is not the specific substances that adolescents use but the timing of substance use onset that is important in terms of predicting early adulthood outcomes. As discussed above, substance use starts earlier in this sample, making even the mid-onset group early by most standards. Indeed, it may make more sense to describe the onset as “very early” and “early,” rather than “early” and “mid.” Second, early substance use is often accompanied by multiple problems, including conduct disorder and difficulties in school. Prevention programs aimed at high-risk middle schoolers that target multiple problem behaviors as well as multiple substances would substantially benefit this group. Even though not indicated in the descriptive analyses, it is very likely that these programs would also benefit the mid-adolescence onset group because of its greater risk for adverse outcomes. Third, the late-onset group’s substance-using behavior is likely tied to social processes associated with adolescent development, such as peer influence and the assertion of adult status (Coie, Dodge, & Kupersmidt, 1990), and prevention programs aimed at this group in early high school would yield positive results. Taken together, these results suggest that delaying the onset of alcohol, cigarette, and marijuana use would provide immense payoffs for Indigenous adolescents and their communities, in both short and long terms.

As stated previously, culturally relevant programs are needed for effective substance use prevention programs (Kagawa-Singer et al., n.d.). Numerous programs that incorporate cultural components have been developed and adapted for use with Indigenous young people (for reviews, see Hawkins, Cummins, & Marlatt, 2004; Whitbeck, Sittner Hartshorn et al., 2012; Whitbeck, Walls, et al., 2012). For instance, Bii Zin Da De Dah is a family-centered alcohol and drug prevention program that has been implemented with Indigenous pre-adolescents from multiple U.S. and Canadian tribes or

nations (Whitbeck, Sittner Hartshorn et al., 2012; Whitbeck, Walls et al., 2012). It is currently being evaluated in a randomized control study. Another example is Schinke, Tepavac, and Cole’s (2000) prevention program that targeted Native youth in third thru fifth grades to provide life skills training to prevent substance use as well as promote an awareness that substance abuse is contrary to many cultural traditions. Given the addictive nature of many substances, treatment programs should also incorporate Indigenous culture. As Daley et al. (2006) found through focus group interviews, smoking cessation programs for Indigenous adults would be more successful if they are culturally appropriate, including addressing the traditional role of tobacco in many Indigenous cultures. Successful prevention programs are those that incorporate concepts and strategies proven to work across cultures but adapted to specific cultures (Hawkins et al., 2004; LaFromboise & Rowe, 1983; Schinke et al., 2000; Whitbeck, Sittner Hartshorn et al., 2012; Whitbeck, Walls et al., 2012).

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Appendix S1. Mean assignment probability for three-group model.