

Trends in typologies of concurrent alcohol, marijuana and cigarette use among US adolescents:
An ecological examination by sex and race/ethnicity*

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Highlights

- Concurrent substance use made up 40% of past-month use among U.S. adolescents
- Prevalence rates of substance-use typologies vary by race/ethnicity and sex
- Female adolescent users were most likely to be alcohol only users
- Marijuana only users were disproportionately African American and Hispanic
- African American youth are at high risk for concurrent alcohol and marijuana use

Abstract

Substance use during adolescence is a public health concern due to associated physical and behavioral health consequences. Such consequences are amplified among concurrent substance users. Although sex and racial/ethnic differences in single-substance use have been observed, the current literature is inconclusive as to whether differences exist in the prevalence of concurrent use. The current study used data from the 2011-2014 National Survey on Drug Use and Health to examine typologies (single and concurrent patterns) of alcohol, marijuana, and cigarette use among current adolescent users age 12-18 by sex and race/ethnicity. Participants were 14,667 White, Hispanic, African American, Asian, and Native American adolescents. The most common typology was alcohol only, followed by concurrent use of alcohol and marijuana. Weighted prevalence estimates indicated that adolescent females were more likely to be current users of alcohol only, whereas male adolescents were more likely to belong to all other typologies. Compared to Whites, racial/ethnic minorities had larger proportions of marijuana only users and were generally less likely than or equally likely to be concurrent users. One exception was for

African American adolescents, who were more likely to be alcohol and marijuana users than their White counterparts. Results suggest that concurrent substance use is common among U.S. adolescents, making up over 40% of past-month use, but typologies of use vary by sex and race/ethnicity. Preventive interventions should consider all typologies of use rather than only single substance exposures and address patterns of use that are most pertinent to adolescents based on sex and race/ethnicity.

Keywords: adolescent, alcohol, marijuana, cigarettes, typologies, polysubstance use

1. Introduction

Alcohol, marijuana, and cigarettes are the most commonly used substances among school-aged adolescents in the United States, with current national data indicating annual prevalence rates of 24%, 13%, and 13% respectively among individuals age 12-17 (Miech et al., 2016). To date, most of the research on risk for substance use disorders (SUDs) among adolescents has examined each substance in isolation. However, substance use often occurs concurrently, with 11-15% of adolescents reporting past-year use of alcohol, marijuana and cigarettes (A+M+C; (Tomczyk et al., 2016). Moreover, the Substance Abuse and Mental Health Services Administration (SAMHSA; 2015c) documented that 51% of binge drinkers age 12-17 report past-month cigarette use, compared to 2% of same-aged non-drinkers. Similarly, 30% of binge drinkers and 56% of cigarette users in the past month report marijuana use in the same period (SAMHSA, 2015c).

Examining concurrent substance use—or the use of two or more substances within a specified time period—during adolescence is critical, as adolescents who engage in concurrent

use are at increased risk for negative health and social consequences compared to those who are single-substance users. For example, concurrent users of alcohol and cigarettes (A+C) are more likely to use illicit drugs, experience social consequences, engage in delinquency, have poorer health, and more treatment utilization than single-substance users (Hoffman et al., 2001; Johnson and Richter, 2002). The increased risk posed by concurrent A+C use also persists into adulthood, predicting more deviant and violent behavior, greater problems related to substance use, and a greater likelihood of arrest by age 29 compared to those adolescents who use alcohol only (AO) by late adolescence (Orlando et al., 2005).

Similar results have been found among concurrent alcohol and marijuana (A+M) and marijuana and cigarettes (M+C) users. Specifically, compared to adolescent AO users, A+M users report higher rates of substance use (Chun et al., 2010), psychological distress (Conway et al., 2013; Kelly et al., 2015a), and behavioral problems (Shillington and Clapp, 2002). Moreover, compared to AO use, A+M use during adolescence is associated with greater risk for SUD (Green et al., 2016; Moss et al., 2014), high-school non-completion, and having a criminal record in young adulthood (Green et al., 2016; Kelly et al., 2015b). Although studied less than A+M use, M+C use during adolescence has also been associated with more severe consequences than single substance use, including greater psychological distress and respiratory problems (Ramo et al., 2012). Among adolescents, M+C use has been found to be more strongly associated with depression, other psychiatric disorders (Boys et al., 2003), and neurocognitive deficits than marijuana only (MO) use or cigarette only (CO) use (Jacobsen et al., 2007). M+C users are also less likely to be involved in prosocial activities (e.g., sports) and report academic achievement (Suris et al., 2007). Yet, when comparing all typologies of use, the greatest risk for health and functional consequences has been found among youth who engage in concurrent use of all three

substances. A+M+C use is associated with higher levels of psychological distress (Kelly et al., 2015a), school non-completion (Kelly et al., 2015b) and SUD in adulthood relative to single- and dual-substance use (Moss et al., 2014).

Researchers have also documented differences in single and concurrent patterns of substance use based on sex and race/ethnicity. In general, male adolescents report higher rates of daily alcohol, marijuana, and cigarette use than female adolescents (Lanza et al., 2015; Miech et al., 2016). As for concurrent use, the most consistent sex effect has been found for occasional concurrent users (i.e., lifetime users of alcohol, marijuana and cigarettes, with little recent concurrent use), who are more likely to be female than male (Connell et al., 2010; Gilreath et al., 2014; Gilreath et al., 2015). However, findings have been mixed regarding sex differences in the frequent/recent use of alcohol, marijuana and cigarettes. Gilreath et al. (2014) and Gilreath et al. (2015) found that males were more likely to be frequent/current users of A+M+C than females, whereas Connell et al. (2010) found the opposite sex effect. Sex differences have also been equivocal regarding M+C use (Ramo et al., 2012); whereas some studies have found that male adolescents are more likely to be M+C users than females (Guxens et al., 2007; Victoir et al., 2007), others have found the opposite sex effect (Lanza et al., 2015; Suris et al., 2007), or no sex effect (Aung et al., 2004).

Racial/ethnic differences in adolescent substance use have also been observed. Asian, Hispanic, and African American youth, in general, report lower rates of 30-day use of alcohol, marijuana, and cigarette use than their White peers (Miech et al., 2016; Wallace et al., 2002; Wallace et al., 2003). Conversely, Native American adolescents tend to report higher rates of marijuana and cigarette use than White and other racial/ethnic minority adolescents, and report

rates of alcohol use comparable to those of White adolescents (Wallace et al., 2002; Wallace et al., 2003).

Prevalence of concurrent use has been found to hold a similar pattern for Asian adolescents, who show less A+M (Collins et al., 1998; Lanza et al., 2010) A+C (Hoffman et al., 2001), and M+C use than White and other racial/ethnic minority adolescents (Ramo et al., 2012). However, findings regarding racial/ethnic differences in concurrent use have been mixed for Hispanic, African American and Native American youth. Some researchers have noted no difference in substance use typology between White and Hispanic adolescents (Lanza et al., 2010), whereas several others have suggested that Hispanic youth are more likely to be concurrent substance users than Whites (Connell et al., 2009; Gilreath et al., 2014; Gilreath et al., 2015). Among African American adolescents, several studies have documented a lower prevalence of concurrent substance use compared to White adolescents (Connell et al., 2009; Gilreath et al., 2015; Lanza et al., 2010; Tomczyk et al., 2016). However, when examining typology of concurrent use, researchers have found variability in risk between African American and White adolescents. For example, African American adolescents have been found less likely to be concurrent users of A+M (Chung et al., 2013; Lanza et al., 2010; Terry-McElrath et al., 2013) and A+C than their White counterparts (Orlando et al., 2005), but more likely to be users of M+C (Aung et al., 2004; Ramo et al., 2012; Vaughn et al., 2008; Young and Harrison, 2001). Lastly, research examining differences in concurrent substance use between Native American adolescents and adolescents of other racial/ethnic groups are sparse, with equivocal findings. For example, a study comparing adolescents from two Native American tribes to nationally-representative data found that adolescents in one tribe had similar patterns of use to the national

population, whereas adolescents in the other tribe were more likely to be past-year concurrent substance users than the national population (Whitesell et al., 2006).

Thus, although sex and racial/ethnic differences in adolescent substance-use typologies have been documented, conclusions are indefinite (see Supplemental Table 1¹). The variability in results in the current literature may be due to differences in the sample (e.g., age, region, racial/ethnic composition), operationalization of substance use (which ranges from past two weeks to lifetime use), methodology (e.g., mixture modeling versus population estimates), and the typology of concurrent use examined (Conway et al., 2013; Tomczyk et al., 2016). Only one study to date has examined membership in all possible classes of single and concurrent use of alcohol, marijuana, and cigarettes based on sex and race/ethnicity. Among adolescents under age 16, Moss et al. (2014) found that male adolescents were most likely to be lifetime A+M users, whereas females were most likely to be CO users. The researchers also found that African American adolescents were more than twice as likely to belong to the lifetime MO typology than any other typology, whereas Whites were least likely to have engaged in lifetime MO use. White adolescents were most likely to have engaged in typologies characterized by single or concurrent alcohol and cigarette use (i.e., AO, CO, A+C, A+M+C), whereas African American and Hispanic adolescents were more likely to have engaged in typologies characterized by marijuana use (i.e., MO, M+C, A+M, A+M+C). However, this study was limited in that it excluded Native American and Asian American adolescents, and sex and race/ethnicity comparisons were conducted within-group rather than comparing differences between groups.

Thus, the current study seeks to expand this work by documenting the national prevalence of substance-use typologies (both single and concurrent) among current adolescent

¹ Supplementary material can be found by accessing the online version of this paper at <http://dx.doi.org> and by entering doi:...

users and comparing prevalence rates across sex and race/ethnicity. Specifically, data from the 2011-2014 National Survey on Drug use and Health (NSDUH) will be utilized to examine the following: 1) the 30-day prevalence of single and concurrent patterns of adolescent use of alcohol, cigarettes and marijuana by age, sex, and race/ethnicity; and 2) racial/ethnic and sex differences in the prevalence rates of various typologies of adolescent substance use.

2. Material and Methods

2.1 Data and Sample

Data were compiled from public-use data files from the 2011-2014 NSDUH (SAMHSA, 2012, 2013, 2014, 2015b), a series of population surveys providing annual nationwide data on substance use patterns in the United States. NSDUH interviews are administered by computer-assisted personal interviewing and audio computer-assisted self-interviewing for illegal drug use and other health-related behaviors (see SAMHSA, 2015a for more detailed survey methodology). Over the 4-year period, 224,096 responses were obtained from subjects who were 12 or older. These represented an average annual US population, ages 12 and older, of 261,292,647. For the current analysis, we only considered participants aged 12 to 18 years who reported past 30-day use of alcohol, tobacco or marijuana and identified as non-Hispanic White, Hispanic, non-Hispanic African American/Black, non-Hispanic Asian, or non-Hispanic Native American/Alaska Native. Participants who endorsed past-30-day use of illicit drugs other than marijuana were also excluded ($n = 883$). There were 14,667 participants who met these criteria, representing an average annual population of 5,841,802. The size of the population represented by the sample was computed by taking account of NSDUH survey designs over the study period.

2.2 Measures

Reported substance use in the past 30-days was used to code typology of use. For example, adolescents who endorsed past month use of alcohol, but not marijuana or tobacco, were categorized as AO users. Adolescents who endorsed both alcohol and marijuana use, but not tobacco use, in the past 30 days were categorized as dual alcohol and marijuana (i.e., A+M users). Typology of use was categorized in this way for all possible strata, resulting in seven total categories: AO; MO; CO; A+C; M+C; A+C; and A+M+C.

2.3 Statistical Analysis

The explanatory variables considered in this analysis include: race/ethnicity (White, Hispanic, African American, Asian, Native American); age (12-18) and sex (male, female). Age, and income (less than \$20,000, \$20,000-\$49,999, \$50,000-\$74,999, \$75,000 and greater) were included in analyses as control variables. In modeling, we compared Whites to each other racial/ethnic group separately. Overall subject characteristics were summarized based on population weighting. Categorical variables were summarized in terms of population-weighted percentages, and population-weighted averages were computed for continuous variables. Subject characteristics were also summarized based on substance-use stratification. In all summaries, unadjusted 95% confidence intervals were computed and used to examine within-group differences. Univariate associations between dependent and independent variables were tested at the 0.05 alpha-level using chi-squared tests.

Substance-use typology probabilities were computed using multinomial logistic regression with AO as the reference group, as it made up the largest class of users. The models were used to compare substance-use probabilities by sex and race/ethnicity, after adjusting for age and income. In addition, we computed conditional odds of each stratum relative to the AO stratum for males versus females, and Whites versus each racial/ethnic minority group. Multiple

hypothesis testing was adjusted for using Tukey's method. All statistical analyses accounted for the survey design and were performed in SAS version 9.4.

3. Results

3.1 Prevalence of Typologies by Demographics

Weighted prevalence estimates of past-30-day substance-use typology are presented in Table 1 by demographic characteristics. The largest category of substance-use typology was AO (37.84%), with nearly three times the prevalence of the next largest category: A+M. The smallest category was M+C users, making up only 5.08% of current substance users. Regarding age, MO users were the youngest class of users, whereas A+C and A+M+C users were the oldest. Males made up the majority of adolescents in every substance use category except for AO (females represented 52.59%). Among male adolescents, users were less likely to belong to the AO and A+C typology relative to their membership in the other typologies. There were minimal within-group differences for females.

Within race/ethnicity, White adolescents were most likely to belong to the CO, A+C, and A+M+C categories, and were significantly less likely to belong to MO than any other category. Contrarily, Hispanic adolescents were more likely to be MO users than any other typology, with few within-group differences among the other substance-use typologies. African Americans were also more likely to be MO users than any other typology, making up 24.15% of MO users, but only 12.75% of total substance users. African Americans were least likely to be A+C users. Among Asian adolescents, the most prevalent typology was AO, and the least prevalent was A+M+C; however, the only statistical difference in membership was observed between these two categories. Among Native American adolescents, there were also few differences in the

prevalence of substance-use typologies. Within each racial/ethnic group, the proportion of AO users was similar to the proportion of the substance-using population represented by the group.

3.2 Sex Differences in Substance-Use Typology

Results of multinomial logistic regression with AO as the reference group revealed that gender and income significantly predicted substance-use typology. Controlling for age and income, compared to AO users, male adolescents were more likely than females to belong to the other substance-use typologies (see Table 2 for regression results). The effect of male sex on substance-use category was particularly prevalent for the M+C typology as males were estimated to be 82% more likely to be M+C users than females.

3.3 Racial/Ethnic Differences in Substance-Use Typology

Results of multinomial regression revealed racial/ethnic differences in the typology of substance use among adolescents (see Figure 1 and Table 2 for regression results). Compared to White AO users, Hispanic adolescents were more likely to be MO users, but less likely to be CO users. As for concurrent use, Hispanic adolescents were less likely than White adolescents to be A+C or A+M+C users. There were no differences between Hispanic and White adolescents in probability of belonging to the A+M or M+C categories. African American adolescents were more than twice as likely to be MO users, but less likely to be CO users than White adolescents. As for concurrent use, African American adolescents were more likely than their White counterparts to be A+M users, but less likely to be A+C, and A+M+C users. African American and White adolescents were equally likely to be M+C users. Asian adolescents were less likely than White adolescents to be CO users, with no differences observed in likelihood of MO use. Asian adolescents were also less likely than Whites to be A+C or A+M+C users, but no other racial differences were found among concurrent substance-use typologies. Native American

adolescents were more likely than their White peers to be MO and CO users. No differences were observed between Native American and White adolescents on membership in concurrent substance-use typologies.

4. Discussion

Previous literature has documented elevated risk of health and functional outcomes among concurrent adolescent substance users compared to single users, which we also found within the current sample (see Supplemental Table 2²). However, previous literature has been equivocal as to whether typologies of substance use differ based on sex and race/ethnicity. The current study aimed to fill this gap by examining prevalence rates of single and concurrent substance use among current adolescent users, and comparing prevalence rates within and across demographic factors.

Similar to previous studies (Tomczyk et al., 2016), results revealed that AO was the most prevalent substance-use typology among adolescent populations. Yet, we documented that concurrent substance use was also common among U.S. adolescents, making up 42% of past-month substance use. In contrast to previous literature suggesting that sex risk for concurrent substance use may vary by typology (e.g., Lanza et al., 2010), our findings indicated that male adolescents were more likely belong to all concurrent substance-use typologies. These findings may help to explain higher risk for substance problems and SUDs among adolescent males (Green et al., 2016; Kelly et al., 2015b; Moss et al., 2014), which may be attributable to high prevalence of both single and concurrent substance use among this population.

Novel findings were also observed regarding racial/ethnic differences in concurrent substance use. We found that Hispanic and Asian youth were less likely to be concurrent users of

² Supplementary material can be found by accessing the online version of this paper at <http://dx.doi.org> and by entering doi:... <http://dx.doi.org> and by entering doi:...

some typologies than White adolescents (A+C and A+M+C) and null effects for the other typologies (A+M, M+C). These findings contradict previous research suggesting that Hispanic youth are at higher risk for concurrent use than their White peers (Connell et al., 2009; Gilreath et al., 2014; Gilreath et al., 2015), as well as research suggesting Asian youth are at lower risk for A+M and M+C than Whites and other racial/ethnic groups (Lanza et al., 2010; Ramo et al., 2012). Native American youth were found not to differ from Whites on use of any concurrent substance-use typology.

The finding that Whites were more likely to belong to A+C and A+M+C typologies than other racial/ethnic groups is consistent with previous research (Connell et al., 2009; Chung et al., 2013; Hoffman et al., 2001; Orlando et al., 2005). White adolescents not only report higher rates of alcohol use than their peers of other racial/ethnic groups (Miech et al., 2016; Wallace et al., 2002; Wallace et al., 2003), but also show more continuity of use (Malone et al., 2012) despite fewer risk factors (Chung et al., 2013). Researchers have attributed the increased risk for alcohol and cigarette use among White adolescents to cultural differences in peer and family norms, and differences in popularity of substances within racial/ethnic groups (Gilreath et al., 2015). Such norms may contribute to more permissive attitudes about alcohol and cigarettes among White adolescents, which in turn, contribute to greater use (Chung et al., 2013).

African Americans were the only racial/ethnic group in which higher risk for a concurrent-use typology was observed compared to White youth. Specifically, contrary to previous research (Chung et al., 2013; Lanza et al., 2010; Terry-McElrath et al., 2013), we found that African American adolescent users were more likely than Whites to be A+M users. Although African American adolescents were less or equally likely to belong to most concurrent substance use typologies than their White peers, their increased risk of A+M use warrants

attention. This finding supports recent evidence that the strength of the relationship between marijuana use and binge drinking has increased in the last six years among African American, but not White adolescents (Lanza et al., 2015). Taken with evidence that African American A+M users are more likely to become chronic users of these substances (Finlay et al., 2012) and experience a more rapid progression to SUD than their White counterparts (Sartor et al., 2013), these results suggest the potential for an increase in critical health disparities among African American substance users into adulthood.

Racial/ethnic differences in substance-use typologies were also found in single substance use. Most notably, Hispanic, African American and Native American adolescents were more likely to be MO users than their White counterparts, with African Americans and Native Americans twice as likely to belong to this typology. Recent nationally-representative data has shown that MO use among adolescents has increased over the last 10 years, exceeding the rate of A+M+C use in 2011 (Lanza et al., 2015). These results suggest that this increase may be driven primarily by minority adolescents. MO use warrants attention not only due to its recent increase, but also because research has shown that selective, frequent marijuana use during adolescence is associated with greater illicit substance use and poorer social outcomes in young adulthood than selective alcohol use or concurrent A+M use (Patton et al., 2007). Given that rates of marijuana use have increased disproportionately among racial/ethnic minority adolescents relative to their White peers over the last eight years (Johnson et al., 2015; Miech et al., 2016), and minority adolescents demonstrate increased rates of marijuana use (Keyes et al., 2015) and higher rates of progression to later substance use and dependence in adulthood than their White counterparts (Swendsen et al., 2012), more research on the impact of marijuana use among minority youth is warranted.

Another explanation for the finding of disproportionate MO use among racial/ethnic minority adolescents is racial/ethnic differences in sequencing of substance use initiation and regular use. For example, African American youth have been found more likely than White youth to end substance use initiation and regular substance use with marijuana (White et al., 2007), which would contribute to their overrepresentation in the MO user typology.

Additionally, several studies have shown that the sequencing of substance initiation during adolescence differs by race/ethnicity with African American and Hispanic adolescents being more likely to use marijuana before alcohol and cigarettes, and Whites being more likely to use alcohol and cigarettes before marijuana (Aung et al., 2004; Guerra et al., 2000; Kandel and Yamaguchi, 2002; Sartor et al., 2013; Vaughn et al., 2008; White et al., 2007; Young and Harrison, 2001). Thus, the disproportionate representation of racial/ethnic minorities in the MO category may be due to a greater likelihood of initiating marijuana use first among these populations.

Furthermore, the “atypical” sequence of concurrent substance use initiation (i.e., marijuana use before licit substances) has been associated with a more rapid progression to symptoms of cannabis use disorder than the typical sequence (i.e., licit substances before marijuana) among concurrent users (Sartor et al., 2013). Thus, racial/ethnic minorities may be at higher risk for consequences associated with concurrent use than their White peers with the same substance-use typology. Taken with evidence that rates of marijuana and cigarette use increase among African American and Hispanic adolescents to converge with those of Whites by early adulthood (Keyes et al., 2015), these findings point for the need for more research examining the transition from single to concurrent use, whether this transition differs by race/ethnicity, and how this transition contributes to racial/ethnic disparities in substance-related problems.

4.1 Limitations

The present study's limitations should be considered. Firstly, the data is comprised of self-report conducted in a home-based setting. Although they are computer assisted, the responses could be open to an under-reporting bias. Secondly, the study used past 30-day use to create substance use categories; frequency and quantity of substances used was not considered. Thus, substance use risk could vary widely among adolescents in the same substance-use typology. Thirdly, the results among Native American youth must be interpreted with caution as they represent a small percentage of the population and estimates including this group were characterized by large confidence intervals. Finally, the NSDUH does not assess for religious beliefs, which have been shown to predict substance choice among adolescents and young adults (Thorens et al., 2016).

5. Conclusion

The current study described the national prevalence of single and concurrent typologies of adolescent substance use by sex and race/ethnicity. We found that the largest category of substance-use typology was AO (37.84%), with nearly three times the prevalence of the next largest category. Yet, concurrent substance use is also prevalent in the U.S., making up over 40% of past-month substance use. Among current substance-users, White, male adolescents report the highest rates of concurrent substance use. However, significant within- and between-group differences regarding substance-use typologies warrant further attention. Firstly, minority groups were more likely to be MO users than their White counterparts, with African Americans having markedly high rates of this typology, as shown with previous national data (Moss et al., 2014). Secondly, although rates of cigarette use (Miech et al., 2016) and concurrent use of cigarettes and other substances are declining (Lanza et al., 2015), the current results suggest that Native

American adolescents remain at increased risk for cigarette use—and thus, adverse health consequences from use—relative to other groups. Thirdly, although African American adolescents are less likely to belong to most concurrent substance use typologies than their White peers, they are at increased risk of A+M, which is concerning given the higher likelihood of progression from early use to chronic use and dependence among African Americans relative to Whites (Finlay et al., 2012; Swendsen et al., 2012). In summary, results from this nationally-representative study suggest that future research examining substance use outcomes among adolescents should consider all typologies of use rather than only single-substance exposures. Moreover, examining variation in risk based on both sex and race/ethnicity is imperative as typologies of use appear to differ significantly across groups, which has implications for health disparities in the progression to SUD and comorbid problems across development.

Author Disclosures

Contributors

DB conceived of the study and led on all aspects of the analysis and writing. AR wrote sections of the manuscript with input from DB and TZ. PM conducted the statistical analyses and wrote sections of the manuscript. TZ critically revised drafts of the manuscript. All authors contributed to and approved the final draft of the manuscript.

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Conflict of Interest

No conflict declared.

References

- Aung, A.T., Pickworth, W.B., Moolchan, E.T., 2004. History of marijuana use and tobacco smoking topography in tobacco-dependent adolescents. *Addict. Behav.* 29, 699-706. [http:// dx.doi.org/10.1016/j.addbeh.2004.02.012](http://dx.doi.org/10.1016/j.addbeh.2004.02.012)
- Boys, A., Farrell, M., Taylor, C., Marsden, J., Goodman, R., Brugha, T., Bebbington, P., Jenkins, R., Meltzer, H., 2003. Psychiatric morbidity and substance use in young people aged 13–15 years: Results from the Child and Adolescent Survey of Mental Health. *Br. J. Psychiatry* 182, 509-517. [http:// dx.doi.org/10.1192/bjp.182.6.509](http://dx.doi.org/10.1192/bjp.182.6.509)
- Chun, T.H., Spirito, A., Hernández, L., Fairlie, A.M., Sindelar-Manning, H., Eaton, C.A., Lewander, W.J., 2010. The significance of marijuana use among alcohol-using adolescent emergency department patients. *Acad. Emerg. Med.* 17, 63-71. [http:// dx.doi.org/10.1111/j.1553-2712.2009.00615.x](http://dx.doi.org/10.1111/j.1553-2712.2009.00615.x)
- Chung, T., Kim, K.H., Hipwell, A.E., Stepp, S.D., 2013. White and Black adolescent females differ in profiles and longitudinal patterns of alcohol, cigarette, and marijuana use. *Psychol. Addict. Behav.* 27, 1110-1121. <http://dx.doi.org/10.1037/a0031173>
- Collins, R.L., Ellickson, P.L., Bell, R.M., 1998. Simultaneous polydrug use among teens: Prevalence and predictors. *J. Subst. Abuse* 10, 233-253. [http://dx.doi.org/10.1016/S0899-3289\(99\)00007-3](http://dx.doi.org/10.1016/S0899-3289(99)00007-3)
- Connell, C.M., Gilreath, T.D., Aklin, W.M., Brex, R.A., 2010. Social-ecological influences on patterns of substance use among non-metropolitan high school students. *Am. J. Community Psychol.* 45, 36-48. <http://dx.doi.org/10.1007/s10464-009-9289-x>

- Connell, C.M., Gilreath, T.D., Hansen, N.B., 2009. A multiprocess latent class analysis of the co-occurrence of substance use and sexual risk behavior among adolescents. *J. Stud. Alcohol Drugs* 70, 943-951. <http://dx.doi.org/10.15288/jsad.2009.70.943>
- Conway, K.P., Vullo, G.C., Nichter, B., Wang, J., Compton, W.M., Iannotti, R.J., Simons-Morton, B., 2013. Prevalence and patterns of polysubstance use in a nationally representative sample of 10th graders in the United States. *J. Adolesc. Health* 52, 716-723. <http://dx.doi.org/10.1016/j.jadohealth.2012.12.006>
- Finlay, A.K., White, H.R., Mun, E.-Y., Cronley, C.C., Lee, C., 2012. Racial differences in trajectories of heavy drinking and regular marijuana use from ages 13 through 24 among African-American and White males. *Drug Alcohol Depend.* 121, 118-123. <http://dx.doi.org/10.1016/j.drugalcdep.2011.08.020>
- Gilreath, T.D., Astor, R.A., Estrada, J.N., Benbenishty, R., Unger, J.B., 2014. School victimization and substance use among adolescents in California. *Prev. Sci.* 15, 897-906. <http://dx.doi.org/10.1007/s11121-013-0449-8>
- Gilreath, T.D., Astor, R.A., Estrada, J.N., Johnson, R.M., Benbenishty, R., Unger, J.B., 2015. Substance use among adolescents in California: A latent class analysis. *Subst. Use Misuse* 49, 116-123. <http://dx.doi.org/10.3109/10826084.2013.824468>
- Green, K.M., Musci, R.J., Johnson, R.M., Matson, P.A., Reboussin, B.A., Ialongo, N.S., 2016. Outcomes associated with adolescent marijuana and alcohol use among urban young adults: a prospective study. *Addict. Behav.* 53, 155-160. <http://dx.doi.org/10.1016/j.addbeh.2015.10.014>

- Guerra, L.M., Romano, P.S., Samuels, S.J., Kass, P.H., 2000. Ethnic differences in adolescent substance initiation sequences. *Arch. Pediatr. Adolesc. Med.* 154, 1089-1095.
<http://dx.doi.org/10.1001/archpedi.154.11.1089>
- Guxens, M., Nebot, M., Ariza, C., 2007. Age and sex differences in factors associated with the onset of cannabis use: a cohort study. *Drug Alcohol Depend.* 88, 234-243.
<http://dx.doi.org/10.1016/j.drugalcdep.2006.10.018>
- Hoffman, J.H., Welte, J.W., Barnes, G.M., 2001. Co-occurrence of alcohol and cigarette use among adolescents. *Addict. Behav.* 26, 63-78. [http://dx.doi.org/10.1016/S0306-4603\(00\)00089-7](http://dx.doi.org/10.1016/S0306-4603(00)00089-7)
- Jacobsen, L.K., Pugh, K.R., Constable, R.T., Westerveld, M., Mencl, W.E., 2007. Functional Correlates of verbal memory deficits emerging during nicotine withdrawal in abstinent adolescent cannabis users. *Biol. Psychiatry* 61, 31-40.
<http://dx.doi.org/10.1016/j.biopsych.2006.02.014>
- Johnson, P.B., Richter, L., 2002. The relationship between smoking, drinking, and adolescents' self-perceived health and frequency of hospitalization: Analyses from the 1997 National Household Survey on Drug Abuse. *J. Adolesc. Health* 30, 175-183.
[http://dx.doi.org/10.1016/S1054-139X\(01\)00317-2](http://dx.doi.org/10.1016/S1054-139X(01)00317-2)
- Johnson, R.M., Fairman, B., Gilreath, T., Xuan, Z., Rothman, E.F., Parnham, T., Furr-Holden, C.D.M., 2015. Past 15-year trends in adolescent marijuana use: Differences by race/ethnicity and sex. *Drug Alcohol Depend.* 155, 8-15.
<http://dx.doi.org/10.1016/j.drugalcdep.2015.08.025>

- Kandel, D.B., Yamaguchi, K., 2002. Stages of drug involvement in the US population. In: Kandel, D.B. (Ed.), *Stages and pathways of drug involvement: Examining the gateway hypothesis*. Cambridge University Press, New York. pp. 65-89.
- Kelly, A.B., Chan, G.C.K., Mason, W.A., Williams, J.W., 2015a. The relationship between psychological distress and adolescent polydrug use. *Psychol. Addict. Behav.* 29, 787-793. <http://dx.doi.org/10.1037/adb0000068>
- Kelly, A.B., Evans-Whipp, T.J., Smith, R., Chan, G.C.K., Toumbourou, J.W., Patton, G.C., Hemphill, S.A., Hall, W.D., Catalano, R.F., 2015b. A longitudinal study of the association of adolescent polydrug use, alcohol use and high school non-completion. *Addiction* 110, 627-635. <http://dx.doi.org/10.1111/add.12829>
- Keyes, K.M., Vo, T., Wall, M., Caetano, R., Suglia, S.F., Martins, S.S., Galea, S., Hasin, D., 2015. Racial/ethnic differences in use of alcohol, tobacco, and marijuana: Is there a cross-over from adolescence to adulthood? *Soc. Sci. Med.* 124, 132-141. <http://dx.doi.org/10.1016/j.socscimed.2014.11.035>
- Lanza, S.T., Patrick, M.E., Maggs, J.L., 2010. Latent transition analysis: Benefits of a latent variable approach to modeling transitions in substance use. *J. Drug Issues* 40, 93-120. <http://dx.doi.org/10.1177/002204261004000106>
- Lanza, S.T., Vasilenko, S.A., Dziak, J.J., Butera, N.M., 2015. Trends among U.S. high school seniors in recent marijuana use and associations with other substances: 1976–2013. *J. Adolesc. Health* 57, 198-204. <http://dx.doi.org/10.1016/j.jadohealth.2015.04.006>
- Leatherdale, S.T., Ahmed, R., 2010. Alcohol, marijuana, and tobacco use among canadian youth: Do we need more multi-substance prevention programming? *J. Prim. Prev.* 31, 99-108. <http://dx.doi.org/10.1007/s10935-010-0211-y>

- Malone, P.S., Northrup, T.F., Masyn, K.E., Lamis, D.A., Lamont, A.E., 2012. Initiation and persistence of alcohol use in United States Black, Hispanic, and White male and female youth. *Addict. Behav.* 37, 299-305. <https://doi.org/10.1016/j.addbeh.2011.11.010>
- Miech, R.A., Johnston, L.D., O'Malley, P.M., Bachman, J.G., Schulenberg, J.E., 2016. *Monitoring the Future national survey results on drug use, 1975–2015: Volume I, Secondary school students*. Institute for Social Research, The University of Michigan, Ann Arbor.
- Moss, H.B., Chen, C.M., Yi, H.-y., 2014. Early adolescent patterns of alcohol, cigarettes, and marijuana polysubstance use and young adult substance use outcomes in a nationally representative sample. *Drug Alcohol Depend.* 136, 51-62.
<http://dx.doi.org/10.1016/j.drugalcdep.2013.12.011>
- Orlando, M., Tucker, J.S., Ellickson, P.L., Klein, D.J., 2005. Concurrent use of alcohol and cigarettes from adolescence to young adulthood: an examination of developmental trajectories and outcomes. *Subst. Use Misuse* 40, 1051-1069.
<http://dx.doi.org/10.1081/JA-200030789>
- Patton, G.C., Coffey, C., Lynskey, M.T., Reid, S., Hemphill, S., Carlin, J.B., Hall, W., 2007. Trajectories of adolescent alcohol and cannabis use into young adulthood. *Addiction* 102, 607-615. <http://dx.doi.org/10.1111/j.1360-0443.2006.01728.x>
- Ramo, D.E., Liu, H., Prochaska, J.J., 2012. Tobacco and marijuana use among adolescents and young adults: A systematic review of their co-use. *Clin. Psychol. Rev.* 32, 105-121.
<http://dx.doi.org/10.1016/j.cpr.2011.12.002>
- Sartor, C.E., Agrawal, A., Lynskey, M.T., Duncan, A.E., Grant, J.D., Nelson, E.C., Madden, P.A.F., Heath, A.C., Bucholz, K.K., 2013. Cannabis or alcohol first? Differences by

- ethnicity and in risk for rapid progression to cannabis-related problems in women. *Psychol. Med.* 43, 813-823. <http://dx.doi.org/10.1017/S0033291712001493>
- Substance Abuse and Mental Health Services Administration, 2012. National Survey on Drug Use and Health, 2011. Inter-university Consortium for Political and Social Research (ICPSR) [distributor]. <http://dx.doi.org/10.3886/ICPSR34481.v4>
- Substance Abuse and Mental Health Services Administration, 2013. National Survey on Drug Use and Health, 2012. Inter-university Consortium for Political and Social Research (ICPSR) [distributor]. <http://dx.doi.org/10.3886/ICPSR34933.v3>
- Substance Abuse and Mental Health Services Administration, 2014. National Survey on Drug Use and Health, 2013. Inter-university Consortium for Political and Social Research (ICPSR) [distributor]. <http://dx.doi.org/10.3886/ICPSR35509.v3>
- Substance Abuse and Mental Health Services Administration, 2015a. 2014 National Survey on Drug Use and Health: Methodological summary and definitions. U.S. Department of Health and Human Services, Rockville, MD.
- Substance Abuse and Mental Health Services Administration, 2015b. National Survey on Drug Use and Health, 2014. Inter-university Consortium for Political and Social Research (ICPSR) [distributor]. <http://dx.doi.org/10.3886/ICPSR36361.v1>
- Substance Abuse and Mental Health Services Administration, 2015c. Results from the 2014 National Survey on Drug Use and Health: Detailed Tables. U.S Department of Health and Human Services, Rockville, MD.
- Shillington, A.M., Clapp, J.D., 2002. Beer and bongs: Differential problems experienced by older adolescents using alcohol only compared to combined alcohol and marijuana use. *Am. J. Drug Alcohol Abuse* 28, 379. <http://dx.doi.org/10.1081/ada-120002980>

- Suris, J.C., Akre, C., Berchtold, A., Jeannin, A., Michaud, P.A., 2007. Some go without a cigarette: characteristics of cannabis users who have never smoked tobacco. *Arch. Pediatr. Adolesc. Med.* 161, 1042-1047. <http://dx.doi.org/10.1001/archpedi.161.11.1042>
- Swendsen, J., Burstein, M., Case, B., Conway, K.P., Dierker, L., He, J., Merikangas, K.R., 2012. Use and abuse of alcohol and illicit drugs in US adolescents: results of the National Comorbidity Survey–Adolescent Supplement. *Arch. Gen. Psychiatry* 69, 390-398. <http://dx.doi.org/10.1001/archgenpsychiatry.2011.1503>
- Terry-McElrath, Y.M., O'Malley, P.M., Johnston, L.D., 2013. Simultaneous alcohol and marijuana use among US high school seniors from 1976–2011: Trends, reasons, and situations. *Drug Alcohol Depend.* 133, 71-79. <http://dx.doi.org/10.1016/j.drugalcdep.2013.05.031>
- Thorens, G., Rothen, S., Gmel, G., Khazaal, Y., Achab, S., Zulino, D., 2016. Association between religious beliefs and drugs of choice in a swiss male sample. *J. Addict. Behav. Ther. Rehabil.* <http://dx.doi.org/10.4172/2324-9005.1000153>
- Tomczyk, S., Isensee, B., Hanewinkel, R., 2016. Latent classes of polysubstance use among adolescents—A systematic review. *Drug Alcohol Depend.* 160, 12-29. <http://dx.doi.org/10.1016/j.drugalcdep.2015.11.035>
- Vaughn, M., Wallace, J., Perron, B., Copeland, V., Howard, M., 2008. Does marijuana use serve as a gateway to cigarette use for high-risk African-American youth? *Am. J. Drug Alcohol Abuse* 34, 782-791. <http://dx.doi.org/10.1080/00952990802455477>
- Victoir, A., Eertmans, A., Van den Bergh, O., Van den Broucke, S., 2007. Association of substance-use behaviours and their social-cognitive determinants in secondary school students. *Health Edu. Res.* 22, 81-94. <http://dx.doi.org/10.1093/her/cyl050>

- Wallace, J.M., Bachman, J.G., O'Malley, P.M., Johnston, L.D., Schulenberg, J.E., Cooper, S.M.,
2002. Tobacco, alcohol, and illicit drug use: Racial and ethnic differences among U.S.
high school seniors, 1976-2000. *Public Health Rep.* 117, S67-S75.
<http://dx.doi.org/10.2105/ajph.81.3.372>
- Wallace, J.M., Bachman, J.G., O'Malley, P.M., Schulenberg, J.E., Cooper, S.M., Johnston, L.D.,
2003. Gender and ethnic differences in smoking, drinking and illicit drug use among
American 8th, 10th and 12th grade students, 1976–2000. *Addiction* 98, 225-234.
<http://dx.doi.org/10.1046/j.1360-0443.2003.00282.x>
- White, H.R., Jarrett, N., Valencia, E.Y., Loeber, R., Wei, E., 2007. Stages and sequences of
initiation and regular substance use in a longitudinal cohort of black and white male
adolescents. *J. Stud. Alcohol Drugs* 68, 173-181.
- Whitesell, N.R., Beals, J., Mitchell, C.M., Novins, D.K., Spicer, P., Manson, S.M., 2006. Latent
class analysis of substance use: Comparison of two American Indian reservation
populations and a national sample. *J. Stud. Alcohol* 67, 32-43.
<http://dx.doi.org/10.15288/jsa.2006.67.32>
- Young, V.D., Harrison, R., 2001. Race/ethnic differences in the sequences of drugs used by
women. *J. Drug Issues* 31, 293-324. <http://dx.doi.org/10.1177/002204260103100201>

Figure Legends

Figure 1. Probabilities of substance-use typology were computed using multinomial logistic regression with alcohol only (AO) as the reference group, and are presented here by race/ethnicity with Whites as the comparison group. Estimated probabilities are adjusted for age and income.

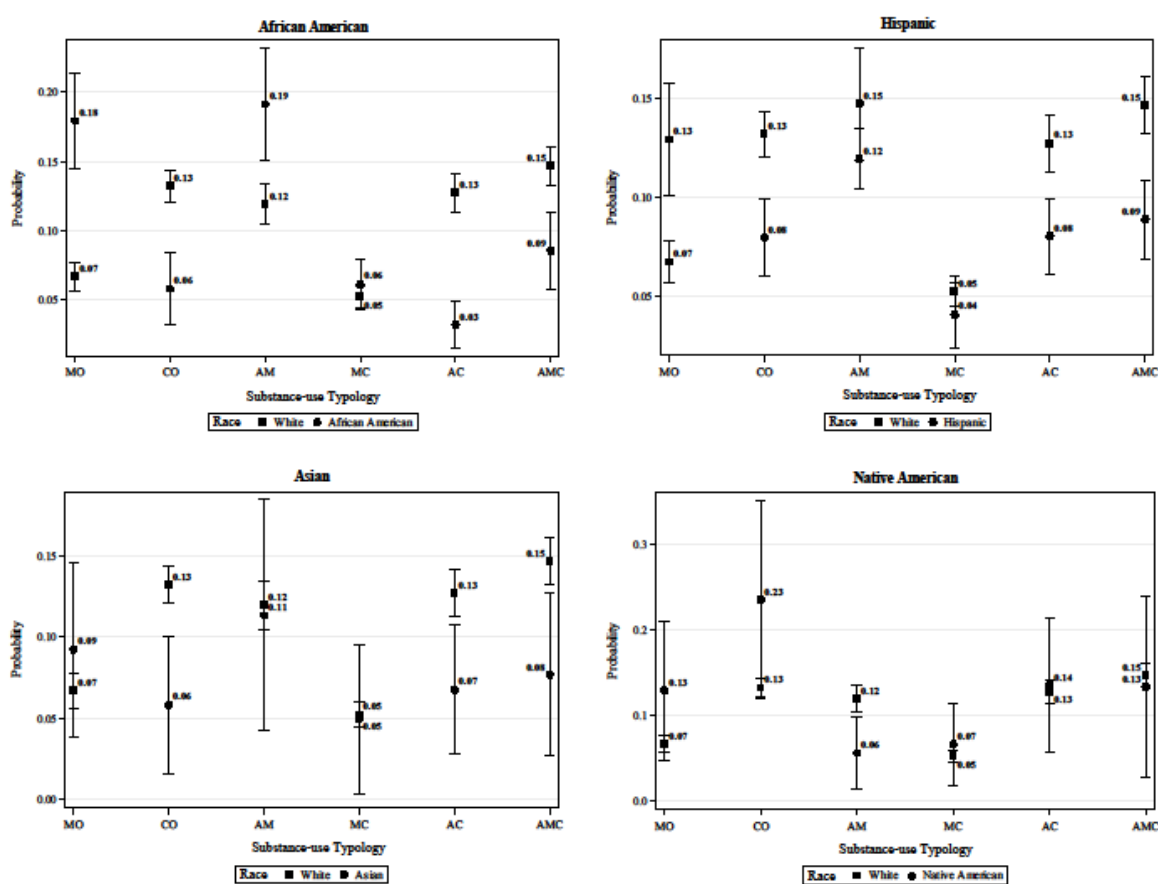


Table 1

Mean age and percentage distribution of substance use typology by sex and race/ethnicity among current adolescent substance users.

	Substance Use Typology							Total n=14,667
	AO	MO	CO	A+M	M+C	A+C	A+M+	
	n=5,494	n=1,426	n=1,649	n=1,894	n=778	n=1,551	n=1,875	
Weighted Population (%)	37.8	9.7 ^a	10.5 ^a	13.4 ^b	5.1 ^c	10.8 ^a	12.7 ^b	100
Age^d (M)	16.4 ^a	16.1	16.7 ^b	16.6 ^b	16.5 ^a	17.0 ^c	16.9 ^c	16.58
Sex^d (%)								
Male	47.4 ^a	58.8 ^b	53.6 ^b	54.1 ^b	61.2 ^b	52.2 ^a	57.9 ^b	52.61
Female	52.6 ^a	41.2 ^{bc}	46.4 ^{bc}	45.9 ^{bc}	38.8 ^c	47.8 ^{ab}	42.1 ^{bc}	47.39
Race/Ethnicity^d (%)								
White	59.8 ^a	43.4	71.4 ^b	57.4 ^a	59.8 ^a	74.2 ^b	69.9 ^b	61.94
Hispanic	23.7 ^a	28.9	16.6 ^b	23.0 ^{ac}	19.0 ^a	18.4 ^{bc}	17.3 ^{bc}	21.73
African American	12.2 ^a	24.2	8.7 ^b	17.0 ^c	17.0 ^c	4.5	10.1 ^{ab}	12.75
Asian	3.9 ^a	2.6 ^{ab}	2.1 ^{ab}	2.4 ^{ab}	2.4 ^{ab}	2.1 ^{ab}	1.9 ^b	2.89
Native American	0.5 ^{ab}	0.9 ^{ab}	1.3 ^a	0.2 ^b	0.9 ^a	0.8 ^a	0.8 ^a	0.68

^{a-c} Prevalence estimates sharing the same superscript in the same row do not differ based on 95% confidence intervals.

^d Age, sex and race/ethnicity significantly predicted substance use typology at $p < .001$.

Table 2

Results of multinomial logistic regression analyses predicting substance-use typology from sex and race/ethnicity.

	Substance-use Typology ^{a, b}					
	MO	CO	A+M	M+C	A+C	A+M+C
Sex^c						
Male	1.64 (1.39, 1.93)	1.34 (1.16, 1.55)	1.30 (1.13, 1.50)	1.82 (1.47, 2.25)	1.20 (1.03, 1.38)	1.54 (1.33, 1.79)
Race/Ethnicity^d						
Hispanic	1.58 (1.18, 2.12)	.49 (.36, .68)	1.01 (.72, 1.42)	.64 (.39, 1.04)	.52 (.37, .72)	.50 (.37, .66)
African American	2.43 (1.76, 3.35)	.40 (.25, .65)	1.46 (1.03, 2.05)	1.06 (.72, 1.57)	.23 (.13, .41)	.53 (.35, .80)
Asian	.90 (.43, 1.90)	.29 (.12, .68)	.62 (.29, 1.34)	.62 (.21, 1.86)	.35 (.18, .67)	.34 (.16, .74)
Native American	2.79 (1.09, 7.14)	2.58 (1.13, 5.88)	.68 (.28, 1.65)	1.84 (.73, 4.70)	1.54 (.67, 3.57)	1.32 (.45, 3.84)

^a Results are presented as odds ratios, with 95% confidence intervals in parentheses. Bold values indicate significant differences from the reference category.

^b Alcohol only served as the reference category for substance use typology.

^c Female served as the reference category.

^d White served as the reference category.