Adolescent simultaneous use of alcohol and marijuana by trends in cigarette and nicotine vaping from 2000 to 2020

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Abstract

Background—Simultaneous alcohol and marijuana (SAM) use is associated with adverse consequences for youth. While SAM use is overall declining among youth, prior studies indicate increasing marijuana use among US adolescents who ever used cigarettes, suggesting possible moderation of the alcohol-marijuana relationship by cigarette use.

Methods—We included 43,845 12-th grade students participating in Monitoring the Future data (2000-2020). A 5-level alcohol/marijuana measure was used, including past-year SAM, alcohol-only, marijuana-only, non-simultaneous alcohol and marijuana, or no use. Multinomial logistic regressions estimated associations between time periods (categorized based on sample size: 2000-2005, 2006-2009, 2010-2014, 2015-2020) and the 5-level alcohol/marijuana measure. Models adjusted for sex, race, parental education and survey mode and included interactions of time periods and lifetime cigarette or vaped nicotine use.

Results—While overall SAM among 12th graders decreased from 23.65% to 18.31% between 2000 and 2020, SAM increased among students who never used cigarettes or vaped nicotine (from 5.42% to 7.03%). Among students who ever used cigarettes or vaped nicotine, SAM increased from 39.2% in 2000-2005 to 44.1% in 2010-2014 then declined to 37.8% in 2015-2020. Adjusted models controlling for demographics indicated that among students with no lifetime cigarette or vaped nicotine use, students in 2015-2020 had 1.40 (95% C.I. 1.15-1.71) times the odds of SAM, and 5.43 (95% C.I. 3.63-8.12) times the odds of marijuana-only (i.e., no alcohol use) compared to students who used neither in 2000-2005. Alcohol-only declined over time in both students who ever and never used cigarettes or nicotine vape products.

Conclusion—Paradoxically, while SAM declined in the overall adolescent US population, the prevalence of SAM increased among students who have never smoked cigarettes or vaped nicotine. This effect arises because of a substantial decline in the prevalence of cigarette smoking; smoking is a risk factor for SAM, and fewer students smoke. Increases in vaping are offsetting these changes, however. Preventing adolescent use of cigarettes and nicotine vaped products could have extended benefits for other substance use, including SAM.

Keywords

Alcohol; Marijuana; Cigarettes; Nicotine Vaping; Simultaneous Use

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1. Introduction

Simultaneous alcohol and marijuana (SAM) use, often defined as use of alcohol and marijuana together so that their effects overlap, is associated with acute injury (Duckworth and Lee, 2019; Gonçalves et al., 2022; Jackson et al., 2020; Terry-McElrath et al., 2014)

and adverse interpersonal consequences (Lee et al., 2020; Linden-Carmichael et al., 2020; Subbaraman and Kerr, 2015), as well as long-term increased risk of substance use disorders (Conway et al., 2020; Lee et al., 2022; Terry-McElrath et al., 2013). In a typical year, approximately one fifth to one fourth of 12th grade students report past-year SAM, and 6-7% report frequent SAM (Lee et al., 2022). However, SAM prevalence began to decline in recent years among adolescents (Keyes et al., 2022a) while remaining stable or increasing among young adults (Terry-McElrath and Patrick, 2018).

The role of time trends in cigarette and nicotine use have potential implications for interpreting trends in SAM use. Lifetime cigarette use by the 12th grade peaked in the late 1970s, with 75.7% of high school seniors reporting at least some lifetime cigarette use at that time (Johnston et al., 2019). Over the next 40 years, cigarette use markedly declined, and as of 2020, only 24.0% of high school seniors have ever smoked cigarettes (Johnston et al., 2019). These time trends have implications for time trends in other substance use, because adolescents who use cigarettes and nicotine are a high risk group for subsequent alcohol and marijuana use (Keyes et al., 2016, 2019; Roche et al., 2019). As cigarette prevalence has declined, more adolescents are in a lower risk group (those who do not use cigarettes) compared to a higher risk group (those who use cigarettes), thus lowering the risk of subsequent in alcohol and marijuana use through cigarette use (Miech et al., 2020, 2017).

Over the same time period, when examining the whole US adolescent population, alcohol use prevalence has substantially declined, and marijuana use has remained relatively stable (Johnston et al., 2019). Part of the mechanism underlying alcohol and marijuana use trends is the decline in cigarette use (Fleming et al., 2022, 2016; Miech et al., 2017). Specifically, a greater proportion of adolescents are at lower risk for alcohol and marijuana use because cigarette smoking has declined. Thus, this suggests that cigarette use may be suppressing what would have been less of a decline for alcohol use, and even potential increases in prevalence for marijuana. Indeed, among adolescents who have used cigarettes, marijuana use prevalence is increasing; and among adolescents who have never used cigarettes, marijuana use prevalence is also increasing (Miech et al., 2017). These observed increases are suppressed when examining the overall US adolescent population because of the shift in composition of adolescents from high risk (ever used cigarettes) to low risk (never used cigarettes) (Miech et al., 2017).

Several issues remain unresolved with respect to SAM and overall patterns of alcohol and marijuana use, however, due to changing trends in other substances. The public health successes of reduced cigarette use have been partially offset by increases in nicotine use and nicotine use disorder among adolescents through vaping devices (Miech et al., 2021,2019) since approximately 2015. Vaped nicotine use, like cigarette use, is associated with increased risk and frequency of subsequent alcohol and marijuana use (Evans-Polce et al., 2020; Park et al., 2020; Silveira et al., 2018). Thus, adolescents who vape nicotine may now again be shifting to a higher risk group for alcohol and marijuana use, and, potentially, SAM. Second, the extent to which cigarette and nicotine use may influence trends in SAM, as well as alcohol and marijuana use that is not used simultaneously, are complicated by other dynamics. Alcohol use has been declining among adolescents for decades (Jager et al., 2022; Platt et al., 2021), and recent declines in SAM use parallel

declines in alcohol use (Lee et al., 2022). Thus, variation in trends examining SAM use, alcohol use without simultaneous marijuana use, and marijuana use without simultaneous alcohol use may exhibit heterogeneous trends by cigarette and vaped nicotine use. Overall, changes in more recent years when nicotine use has increased due to vaping (Miech et al., 2021), remain understudied.

In summary, SAM use remains prevalent and concerning for adolescent public health, especially in the context of underlying divergent trends in overall alcohol and marijuana use. The extent to which cigarette and nicotine use trends modify trends in SAM, as they do for marijuana and other substance use, has not been evaluated. Further, the extent to which trends in SAM use differ from trends in non-simultaneous alcohol and cannabis use remains understudied. The present paper: a) examines time trends in SAM use, and non-simultaneous use, from 2000 to 2020 among US 12th grade students controlling for demographics; and b) tests whether trends are modified by lifetime cigarette use or nicotine vaping, both together and separately. We examine SAM in the context of other patterns of alcohol and marijuana use given their disparate trends, providing a full account of alcohol-only (adolescents who have used alcohol but never marijuana); marijuana-only (adolescents who have used marijuana but never alcohol); non-simultaneous use (adolescents who have used both alcohol and marijuana, but never simultaneously); and no use (adolescents who have never used alcohol or marijuana).

2. Methods

2.1. Sample

Data were drawn from Monitoring the Future (MTF) cross-sectional surveys conducted each year in the contiguous US. Annually, ~400 US public and private high schools are selected using a multi-stage random sampling design to participate in MTF for 2 years; declining schools are replaced matching for school size, geographic location, and urbanicity (Johnston et al., 2019; Bachman et al., 2015). Students were instructed that responses in the MTF self-administered questionnaire are confidential.

We focused on 12th grade students participating between 2000-2020. Data collection in 2020 occurred through March, before collection was halted due to COVID-19 restrictions. Response rates ranged from 79% to 85% during the study period; non-response was largely due to school absenteeism on the day of the survey, less than 1% of students refused to participate (Johnston et al., 2019). We use sampling weights provided by MTF in all estimates to account for differing inclusion probabilities and nonresponse. We analyzed data from a total of 43,845 out of 48,068 students who received survey items assessing SAM (see tables/figures for the sample size for each model).

2.2. Measures

Alcohol use and Marijuana use.—Past-year alcohol and marijuana use were assessed (separately) as the number of occasions of use (0 occasions, 1-2, 3-5, 6-9, 10-19, 20-39, 40+ occasions). Responses were dichotomized as any occasion versus none.

Simultaneous alcohol and marijuana (SAM) use.—Among students who reported alcohol and marijuana use, SAM use was assessed in the past year querying the number of times the adolescent used marijuana and alcohol together with the instruction "so that their effects overlapped." Ordinal responses from "not at all" to "every time" were offered, dichotomized as no SAM use vs. any SAM use.

A 5-level nominal variable was then created: SAM, alcohol-only (past-year alcohol use and no report of past-year marijuana or simultaneous use), marijuana-only (past-year marijuana use and no report of past-year alcohol or simultaneous use), non-simultaneous alcohol and marijuana (past-year marijuana and alcohol use, but not simultaneously), or no use.

Cigarette and vaped nicotine use. Cigarette use.—Students are asked about lifetime frequency of any cigarette use, with response options range from 'never' to 'regularly now'. We dichotomized any lifetime cigarette use vs. no lifetime use. *Vaped nicotine use.* Questions on nicotine vaping were introduced into the survey in 2017. In 2017-2018, the vaping item was "On how many occasions (if any) have you vaped nicotine... in your lifetime?" with options ranging from 0 occasions, 1-2x, 3-5x, 6-9x, 10-19x, 20-39x, 40+. In 2019-2020, the vaping item was "On how many days (if any) have you vaped nicotine in your lifetime?" with options ranging from 0, 1-2, 3-5, 6-9, 10-19, to 20+ days. Combination variables were created that indicated any lifetime cigarette use or vaped nicotine use, as well as any lifetime cigarette use (regardless of vaped nicotine use), and any vape use (regardless of cigarette use).

Sociodemographics and other covariates.—Self-reported socio-demographics included sex (male vs. female), race/ethnicity (non-Hispanic white, non-Hispanic Black, other), and respondent-reported parental education (at least one parent finished college or more, finished high school or some college, or had some high school or lower). We controlled for survey mode of administration (paper vs. tablet); starting in 2019, all schools were randomized to a paper (2019; 47.6%) or electronic tablet (2019; 52.4%) survey condition and response prevalence for drug use varied by survey mode. Survey years 2000-2020 were categorized in groups (2000-2005, 2006-2009, 2010-2014, 2015-2020) to balance the need for granularity while still providing sufficient sample sizes across the 5-level substance use outcome.

2.3. Statistical analysis

Missing data ranged from 10% (race and ethnicity) to 13% (parental education). Multiple imputation using fully conditional specification (FCS MI) method was conducted to handle missing data, implemented using the FCS statement in "proc mi" in SAS version 9.4 ("Multiple Imputation in SAS Part 1" n.d.) with 15 imputations incorporated in all analyses.

First, we assessed the population prevalence across the time periods (2000-2005, 2006-2009, 2010-2014, 2015-2020) of SAM, alcohol-only, marijuana-only, non-simultaneous alcohol and marijuana, and no use, both overall and stratified by lifetime cigarette or vaped nicotine use. Trends were assessed within the categorized year groups as there was not sufficient sample sizes within one-year groups for analysis. In supplementary analyses, we also assessed these trends by lifetime cigarette use (regardless of vaped nicotine use), and for

years 2017 to 2020, any lifetime vaped nicotine use (regardless of cigarette use). Second, we used multinomial logistic regression models to assess the association between survey year groups and the 5-level substance use outcome as a categorical (nominal) outcome variable. Multinomial logistic regression was implemented as it allows for the estimation of probabilities of each level of the outcome variable compared to a referent group while simultaneously controlling for multiple predictor variables (Agresti, 2012). We controlled for sex, parental education, race/ethnicity, and survey mode (tablet vs paper); models then also controlled for lifetime cigarette or vaped nicotine use. Third, we assessed the interaction between lifetime cigarette or vaped nicotine use and survey year groups on the 5-level substance use outcome using cross-product interaction terms, and then reported stratified multinomial regression models among adolescents with and without lifetime cigarette and vaped nicotine use. All analyses incorporated the complex survey designs and the multiple imputations. Data management and analysis was conducted in SAS("SAS Help Center" n.d.).

3.   Results

Trends in alcohol and marijuana use, overall and stratified by lifetime cigarette and vaped nicotine use

Figure 1 shows the overall trend in past-year SAM, alcohol-only, marijuana-only, and non-simultaneous alcohol and marijuana. Overall, SAM use declined from 23.65% in 2000-2005 to 18.31% in 2015-2020. Alcohol-only declined from 38.11% in 2000-2005 to 27.89% in 2015-2020. Past-year use of marijuana and alcohol (not simultaneously) increased from 10.58% in 2000-2005 to 12.42% in 2015-2020, and past-year use of marijuana-only (no past year alcohol use) increased from 0.86% in 2000-2005 to 3.63% in 2015-2020. Sample sizes by outcome and time period, across lifetime cigarette and vaped product use, are provided in Online Table 1.

When stratified by lifetime cigarette or vaped nicotine use (vaped nicotine use measured beginning in 2017), different patterns emerged. Among those with lifetime cigarette or vaped nicotine use (Figure 1), SAM was the most common pattern of substance use, and increased from 39.24% in 2000-2005 to 44.14% in 2010-2014 then declining to 37.83% in 2015-2020. Alcohol-only declined from 35.25% in 2000-2005 to 26.71% in 2015-2020. Past-year use of marijuana and alcohol (not simultaneously) increased from 15.67% in 2000-2005 to 20.84% in 2015-2020, and past-year use of marijuana-only (no past year alcohol use) increased from 1.16% in 2000-2005 to 4.01% in 2015-2020.

Among those with no lifetime cigarette or vaped nicotine use (Figure 1), past-year alcohol-only was the most common pattern of substance use, and decreased from 41.63% in 2000-2005 to 29.01% in 2015-2020. SAM use increased from 5.42% in 2000-2005 to 7.03% in 2015-2020. Past-year use of marijuana and alcohol (not simultaneously) increased from 4.52% in 2000-2005 to 7.76% in 2015-2020, and past-year use of marijuana-only (no past year alcohol use) increased from 0.44% in 2000-2005 to 3.02% in 2015-2020.

Online Figure 1 shows the trends in lifetime cigarette or vaped nicotine use over time. Lifetime cigarette use decreased from 61.17% in 2000 to 24.50% in 2020 whereas lifetime

nicotine vaping increased from 24.01% in 2017 to 42.14% in 2020. Lifetime nicotine vaping or cigarette use decreased from 61.17% in 2000 to 27.91% in 2016, and increased to 45.92% in 2020.

Online Figures 2 and 3 separate trends by lifetime cigarette use (regardless of vaped nicotine use, Online Figure 2), and lifetime vaped nicotine use (regardless of cigarette use, Online Figure 3). For lifetime vaped nicotine use, trends begin in 2017 as measures were consistent for the years 2017 to 2020. Trends stratified by lifetime cigarette use were similar to Figure 1. For vaped nicotine use, however, there were some differences. Among those who have ever vaped nicotine, simultaneous use slightly declined from 2017 to 2020, from 41.02% in 2017-2018 to 33.66% in 2019-2020, and marijuana-only slightly increased, from 3.58% in 2017-2018 to 4.14% in 2019-2020. Among those who had never vaped nicotine, all substance use outcomes declined from 2017-2018 to 2019-2020, except marijuana-only which increased from 3.32% in 2017-2018 to 4.04% in 2019-2020.

Associations between survey year, cigarette and vaped nicotine use, and alcohol and marijuana use

Table 1 shows the association between the five-level categorical alcohol/marijuana over time controlling for sex, parental education, race/ethnicity, and survey mode (tablet versus paper). Our categorical outcome reference category was no past-year alcohol or marijuana use. Results indicated declines in simultaneous use over time relative to no use; students in 2015-2020 had 0.58 times the odds of simultaneous use vs. no use compared with students in 2000-2005 (95% C.I. 0.51, 0.66).

Past year alcohol-only (2015-2020 vs. 2000-2005: OR=0.54, 95% C.I. 0.49-0.60) and past-year alcohol and marijuana use but not simultaneously (2015-2020 vs. 2000-2005: OR=0.85, 95% C.I. 0.75-0.96) also declined across time, compared to no use. The odds of marijuana-only increased; students in 2015-2020 had 2.66 times the odds of marijuana-only vs. no use compared with students in 2000-2005 (95% C.I. 2.04, 3.47).

In the overall adolescent population, female adolescents were more likely to use alcohol-only compared with male adolescents (OR=1.12, 95% C.I. 1.06-1.19), whereas males were overrepresented in SAM use (OR for females compared with males=0.82, 95% C.I. 0.77-0.88). Students with high school or some college parental education were overrepresented in SAM use compared with finished college or higher (OR=1.11, 95% C.I. 1.03-1.20), as well non-simultaneous alcohol and cannabis use (OR=1.17, 95% C.I. 1.07-1.23). Black and other race (compared with White) students were less likely to engage with SAM use, alcohol-only, and alcohol and cannabis use not simultaneously, but over-represented in marijuana-only use (see Table 1).

Interaction between survey year and cigarette and vaped nicotine use in association with alcohol and marijuana use

There were interactions between survey year and lifetime cigarette or vaped nicotine use, both unadjusted (F=2.71, numerator df=12, denominator df=1318, p=0.001), and adjusted for sex, parental education, race/ethnicity, and survey mode (F=1.97, numerator df=12, denominator df=1318, p=0.02). Because of these interactions, Tables 2 and 3 present

associations between survey year and alcohol and marijuana use stratified by lifetime cigarette or vaped nicotine use.

Among those with lifetime cigarette or vaped product use (Table 2), SAM use (OR=0.62, 95% C.I. 0.51-0.76) and alcohol-only (OR=0.50, 95% C.I. 0.41-0.61) declined in 2015-2020 compared with 2000-2005, whereas marijuana-only increased (OR=2.12, 95% C.I. 1.41-3.18). Demographic correlates were largely similar to the overall adolescent sample, with the exception that lower parental education was inversely associated with SAM and alcohol-only use.

Among those with no lifetime cigarette or vaped product use (Table 3), SAM use (OR=1.40, 95% C.I. 1.15-1.71), marijuana-only (OR=5.43, 95% C.I. 3.63-8.12), and concurrent alcohol and marijuana use (OR=1.72, 95% C.I. 1.40-2.11) increased in 2015-2020 compared with 2000-2005, whereas alcohol-only declined (OR=0.68, 95% C.I. 0.61-0.76). Demographic correlates were largely similar to the overall adolescent sample, with the exception that Black and other race students had similar odds of SAM and alcohol-only use compared with white students; Black and other race students were more likely than white students to report marijuana-only (Black students OR=3.12, 95% C.I. 2-17-4.48; other race students OR=1.80, 95% C.I. 1.29, 2.53) and alcohol and marijuana concurrent use (Black students OR=1.27, 95% C.I. 1.05, 1.53).

Online Tables 2 and 3 provide the associations stratified by lifetime cigarette use (regardless of vaped nicotine use), and Online Tables 4 and 5 provide the associations stratified by lifetime vaped nicotine use from 2017 to 2020 (regardless of lifetime cigarette use). Among students with lifetime cigarette use, the odds of past year marijuana use increased over time (2015-2020 vs. 2000-2005: OR= 2.33, 95% C.I. 1.50-3.61).

4. Discussion

Whereas overall, SAM use declined among US adolescents from 2000 to 2020, its prevalence increased among adolescents who have never vaped nicotine or smoked cigarettes, and has remained largely stable among those who have ever vaped nicotine or smoked cigarettes. Additionally, the prevalence of SAM use remains orders of magnitude higher among 12th graders who have ever vaped or smoked than among those who have not. The overall decrease in lifetime nicotine vaping or cigarette use from 2000 to 2020 explains why SAM use declined over time when not stratified by cigarette/vaping use, and why SAM use increased when stratified nicotine vaping or cigarette use from 2000 to 2020: it is because SAM use is higher among those who use cigarettes/vape, and the prevalence of cigarettes use is declining. In contrast, past-year marijuana-only (i.e., no alcohol use) is substantially increasing among 12th grade students. Among those who have never used cigarettes or nicotine, for example, marijuana-only more than quadrupled from 0.44% in 2000-2005 to 3.02% in 2015-2020. Taken together, these results indicate that continued efforts to reduce adolescent use of cigarettes and vaped nicotine may yield health benefits that extend to use of other substances, and that new approaches may be needed to reduce adolescent marijuana use specifically.

The observed in trends in SAM, with declines in the whole adolescent population but increases among those with no history of cigarette/vaped use, occurred partially because adolescent cigarette use has dramatically declined over time; cigarette use increases the likelihood of other substance use (Keyes et al., 2016; Purcell et al., 2021). Our results are consistent with other studies showing that cigarette use among adolescents strongly predicts subsequent substance use, particularly for marijuana (Roche et al., 2019). Indeed, substantial research has documented "tri" use of alcohol, cannabis and nicotine as a substance use pattern of particular concern (Linden-Carmichael et al., 2022; Roche et al., 2019). When stratified by cigarette use, findings suggest increases in marijuana use prevalence within the stratified groups, even while the overall prevalence is relatively flat or declining (Fielding-Singh et al., 2021; Bachman et al., 2015). Stratified results focusing on vaped nicotine use suggest a relative flattening of trends from 2018 to 2020, especially among those who have vaped nicotine. These results underscore a need for focused public health efforts on reducing nicotine vaping, and a continued focus on maintaining low rates of cigarette use. Vaping prevalence among youth increased in the wake of well-funded advertising campaigns portraying vaped nicotine delivery as alluring and low risk (Marynak et al., 2019; Park et al., 2019; Vogel et al., 2021). While regulations of vaped nicotine and access among youth are becoming more restrictive, additional efforts to provide accurate information to youth on the health risks of vaped nicotine use are needed (Baker and Campbell, 2020; Graham et al., 2020; Liu et al., 2020; Noar et al., 2020, 2019), as well as continued efforts to ensure that cigarette use remains at low levels.

Marijuana-only (no concurrent or simultaneous alcohol use) is increasing both among those who have used cigarettes or vaped nicotine and those who have not. Nationally, the expansion of marijuana product availability and declining legal and social sanctions associated with use may underlie these increases in youth use (Sarvet et al., 2018b), although adolescents who live in states that have passed medical and recreational marijuana laws largely (although not uniformly across studies) do not have increased rates of marijuana use compared to those in states without these laws (Bhatia et al., 2022; Sarvet et al., 2018a). There is also an overall national increase in perceptions that marijuana poses little danger to health (Sarvet et al., 2018b), and an increase in exposure to marijuana messaging, advertising, and products (Cavazos-Rehg et al., 2016; Moreno et al., 2022). Among adolescents who have used marijuana and alcohol by the 12th grade, marijuana is now more likely to be used before alcohol than vice versa, reversing a historical and consistent trend in substance use initiation patterns (Keyes et al., 2019). While the plurality of adolescents ages 12-17 perceived marijuana to both have high risk and be unavailable in 2002-2018 (Levy et al., 2021), and cannabis products vary substantially in health risks (Chadi et al., 2020; Spindle et al., 2019), providing timely and accurate information about marijuana to adolescents is critical as marijuana availability continues to expand in the US.

Moreover, among the trends assessed, marijuana-use only increased in the overall adolescent population while SAM use, alcohol and marijuana use not simultaneously, and alcohol-use only declined. This suggests that trends in alcohol and marijuana co-occurrence, whether use simultaneously or concurrently, are following overall trends in alcohol use rather than marijuana use. Explanations of the reasons adolescent alcohol and marijuana co-use followed alcohol trends rather than marijuana trends remain speculative at this point.

Certainly, alcohol use remains significantly more prevalent than cannabis use in the overall adolescent population, thus declines in use have a greater population-level impact and affect more youth than increases in cannabis use. Given the documented correlation between alcohol and marijuana use (Jackson et al., 2008), we speculate that continued declines in alcohol use, may also reduce overall marijuana use for a substantial portion of adolescents. However, the extent to which offsetting increases in marijuana-use only will disrupt this pattern remain to be seen.

The links between cigarette use and nicotine vaping with subsequent marijuana use remain to be disentangled. Mechanisms may involve increased opportunities to use marijuana after cigarette or nicotine onset given exposure to smoking peer groups (Van Etten and Anthony, 1999; Wagner et al., 2002), as well as lowering inhibitions to trying intoxicating substances. Further, adolescents who vape nicotine are at particularly high risk of vaping marijuana products. Marijuana vaping has also increased, and there is substantial overlap in marijuana and nicotine vaping among adolescents (Dai, 2020; Farsalinos et al., 2021; Keyes et al., 2022b; Patrick et al., 2020; Trivers et al., 2018). Indeed, similar modes of administration of nicotine and marijuana may drive SAM use among adolescents who have vaped nicotine use. Simultaneous or overlapping substance use amplifies the odds for other substance use. In a 2017 sample in the UK, 93% of adolescents who used e-cigarettes reported past-month tobacco, alcohol, or marijuana use, and 48% reported use of all three (Staff et al., 2020). As polysubstance use grows, bolstered by trends in vaping and especially in young adult cohorts (Terry-McElrath and Patrick, 2018), adolescents will have more opportunities for SAM use. Interventions to reduce simultaneous use of marijuana and alcohol will need to account for vaping and its co-occurring impact on other substance use. Vaping smoking interventions that utilize text-based motivations and information are promising avenues for prevention and intervention efforts (Baker and Campbell, 2020; Graham et al., 2020; Noar et al., 2019).

Finally, we note that demographic predictors of substance use patterns were observed and are largely consistent with prior literature. Black and other race students were underrepresented in SAM use and alcohol-only (Patrick et al., 2018), but were more likely to use marijuana-only (Wu et al., 2016), and students with more highly educated parents were more likely to use substances (Patrick et al., 2012). However, emergent racial and ethnic disparities in SAM use by college age (Hai et al., 2022) suggest that continued surveillance across broader developmental periods is necessary. Notably, female adolescents are emerging as a high-risk group for alcohol use, consistent with other data sources (Cheng and Anthony, 2018). This emergent sex difference is primarily due to faster declines in alcohol use among males compared with females. While reasons that alcohol use is not declining at the same rate among female adolescents remain largely speculative, available evidence suggests that changes in social expectations by gender and sex roles are shifting in recent decades for both adolescent and adults, which may partially mediate the converging sex differences in drinking (Keyes et al., 2021).

Data limitations included that the MTF only includes school-attending adolescents, thus may not generalize to students who dropped out or are otherwise not attending school. Adolescents who are school absentees are more likely to engage in substance use (Bray et al., 2000; Roebuck et al., 2004); adolescents not captured in MTF may have higher

substance use than non-participants. Self-reported data may have misclassification, and are not validated with drug testing. However, MTF rates of substance use, capture in school, are higher than other national estimates where students are interviewed at home (Gfroerer et al., 1997; Kann et al., 2002), suggesting that school-based assessment is an important context for drug use assessment. MTF did not measure vaped product use before 2017. Other national surveys that have estimated prevalence of vaped product use since approximately 2014 indicate that approximately 10-15% of high school seniors reported e-cigarette use from 2014-2016 (Sun et al., 2021; CDC, 2015). Our findings may underestimate trends in vaped product use, to the extent that some adolescents in those years did not use cigarettes as well. However, we expect this misclassification to be minimal given the overlap between e-cigarette and combustible cigarette use, and the lower average prevalence of e-cigarette use in 2014-2016 compared with later years.

In sum, overall decreases in adolescent simultaneous alcohol and marijuana use are primarily driven by declines in cigarette use. Indeed, among adolescents who have both used and not used cigarettes, prevalence of simultaneous use has increased. Marijuana use, especially marijuana use without any concurrent or simultaneous cigarette or vaped nicotine use, is increasing among US adolescents; as product availability continues to increase through the US, concerted prevention efforts are warranted. Future changes may be further potentiated by increases in nicotine vaping. As prevalence of nicotine vaping has been dynamic across recent history, its potential impact on the prevalence of substance use should be monitored.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Role of Funding Sources

Abbreviations:

MTF   Monitoring the Future Survey

aOR   Adjusted Odds ratio

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Highlights

- From 2000-2020, SAM increased among students who have never smoked cigarettes or vaped nicotine, despite declining overall

- Smoking and vaping increase the risk for simultaneous alcohol and marijuana use, and despite declines in smoking, increase in vaping threaten to reverse trends in simultaneous alcohol and marijuana use

- Marijuana use, both with concurrent alcohol use and without, is increasing in US adolescents, whereas alcohol-use-only is declining, and is now more prevalent among adolescents who have never vaped or smoked cigarettes
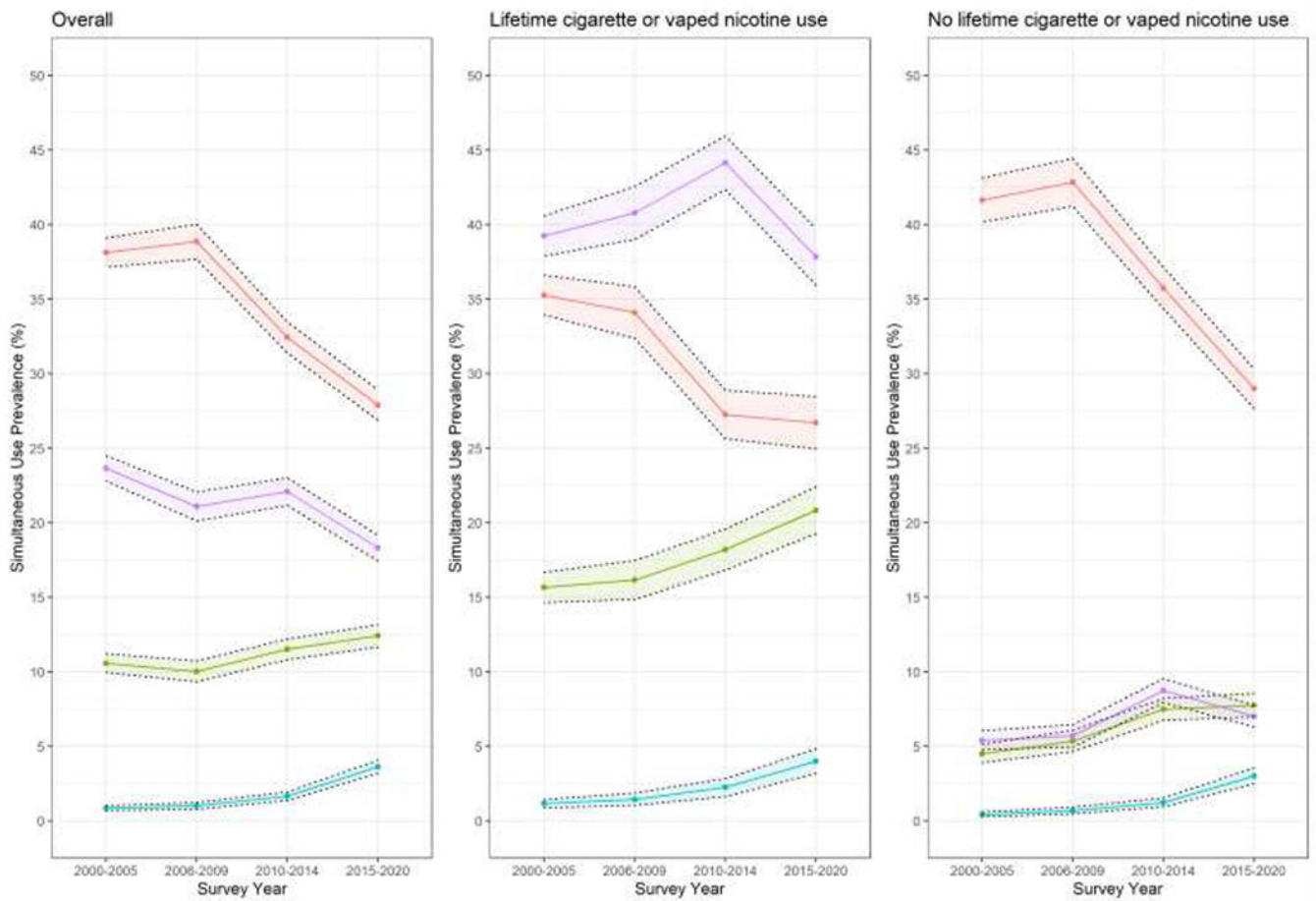
Figure 1.
Trends (prevalence [95% confidence intervals]) in past-year simultaneous alcohol and marijuana (SAM) use, alcohol-only, marijuana-only, and non-simultaneous alcohol and marijuana use among 12th graders from 2000-2020, by lifetime cigarette or vaping* use
*Nicotine vaping assessed from 2017 onward

Table 1.

Multinomial logistic regression of past-year simultaneous alcohol and marijuana (SAM) use, alcohol-only, marijuana-only, and non-simultaneous alcohol and marijuana use among 12th graders from 2000-2020

	Past-year simultaneous use Vs. no use	Past-year alcohol-only Vs. no use	Past-year marijuana-only Vs. no use	Past-year alcohol and marijuana use but not simultaneously Vs. no use
	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]
Survey year (ref=2000-2005)				
2006-2009	0.83 [0.73, 0.95]	0.94 [0.84, 1.05]	1.08 [0.79, 1.49]	0.88 [0.76, 1.02]
2010-2014	0.78 [0.70, 0.88]	0.71 [0.65, 0.78]	1.56 [1.18, 2.06]	0.91 [0.80, 1.02]
2015-2020	0.58 [0.51, 0.66]	0.54 [0.49, 0.60]	2.66 [2.04, 3.47]	0.85 [0.75, 0.96]
Sex (ref=male)				
Female	0.82 [0.77, 0.88]	1.12 [1.06, 1.19]	0.85 [0.71, 1.01]	1.07 [0.99, 1.16]
Parental education (ref=finished college or more)				
Some high school or lower	0.98 [0.86, 1.13]	0.95 [0.85, 1.07]	1.18 [0.83, 1.66]	1.05 [0.90, 1.23]
Finished high school or some college	1.12 [1.04, 1.21]	1.04 [0.98, 1.11]	1.22 [0.99, 1.49]	1.17 [1.07, 1.23]
Race/ethnicity (ref=white)				
Black	0.50 [0.44, 0.56]	0.61 [0.55, 0.67]	1.95 [1.52, 2.50]	0.80 [0.70, 0.90]
Other	0.72 [0.65, 0.78]	0.85 [0.79, 0.92]	1.54 [1.23, 1.94]	0.93 [0.84, 1.03]

Note: aOR=Adjusted odds ratio. Alcohol-only is defined as past-year alcohol use and no report of past-year marijuana or simultaneous use. Marijuana-only is defined as past-year marijuana use and no report of past-year alcohol or simultaneous use.

Model adjusts for survey year, sex, parental education, race/ethnicity, and also adjusted for survey mode (not shown)

Table 2.

Among students reporting lifetime cigarette or nicotine vape use, multinomial logistic regression of past-year simultaneous alcohol and marijuana (SAM) use, alcohol-only, marijuana-only, and non-simultaneous alcohol and marijuana use among 12th graders from 2000-2020

Covariate	Past-year SAM use Vs. no use	Past-year alcohol-only Vs. no use	Past-year marijuana-only Vs. no use	Past-year alcohol and marijuana use but not simultaneously Vs. no use
	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]
Survey year (ref=2000-2005)				
2006-2009	1.05 [0.86, 1.28]	0.98 [0.81, 1.20]	1.24 [0.81, 1.90]	1.04 [0.85, 1.27]
2010-2014	1.03 [0.85, 1.25]	0.74 [0.61, 0.89]	1.72 [1.14, 2.59]	1.06 [0.87, 1.29]
2015-2020	0.62 [0.51, 0.76]	0.50 [0.41, 0.61]	2.12 [1.41, 3.18]	0.82 [0.66, 1.02]
Sex (ref=male)				
Female	0.84 [0.74, 0.95]	1.07 [0.94, 1.22]	0.94 [0.71, 1.23]	1.13 [0.98, 1.31]
Parental education (ref=finished college or more)				
Some high school or lower	0.58 [0.47, 0.72]	0.63 [0.50, 0.79]	0.71 [0.42, 1.18]	0.61 [0.47, 0.78]
Finished high school or some college	0.80 [0.69, 0.92]	0.80 [0.68, 0.94]	0.86 [0.63, 1.17]	0.85 [0.72, 1.01]
Race/ethnicity (ref=white)				
Black	0.38 [0.31, 0.47]	0.41 [0.34, 0.51]	1.18 [0.82, 1.71]	0.58 [0.46, 0.73]
Other	0.73 [0.63, 0.86]	0.81 [0.69, 0.95]	1.48 [1.05, 2.07]	1.00 [0.84, 1.18]

Note: aOR=Adjusted odds ratio. Alcohol-only is defined as past-year alcohol use and no report of past-year marijuana or simultaneous use. Marijuana-only is defined as past-year marijuana use and no report of past-year alcohol or simultaneous use.

Model adjusts for survey year, sex, parental education, race/ethnicity, and also adjusted for survey mode (not shown)

Table 3.

Among students reporting no lifetime cigarette or nicotine vape use, multinomial logistic regression of past-year simultaneous alcohol and marijuana (SAM) use, alcohol-only, marijuana-only, and non-simultaneous alcohol and marijuana among 12th graders from 2000-2020

Covariate	Past-year SAM Vs. no use	Past-year alcohol-only Vs. no use	Past-year marijuana-only Vs. no use	Past-year alcohol and marijuana use but not simultaneously Vs. no use
	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]
Survey year (ref=2000-2005)				
2006-2009	1.11 [0.89, 1.37]	1.08 [0.94, 1.23]	1.46 [0.89, 2.40]	1.22 [0.96, 1.54]
2010-2014	1.48 [1.22, 1.80]	0.87 [0.78, 0.97]	2.58 [1.69, 3.94]	1.58 [1.29, 1.94]
2015-2020	1.40 [1.15, 1.71]	0.68 [0.61, 0.76]	5.43 [3.63, 8.12]	1.72 [1.40, 2.11]
Sex (ref=male)				
Female	0.87 [0.78, 0.99]	1.18 [1.10, 1.26]	0.80 [0.63, 1.03]	1.05 [0.93, 1.18]
Parental education (ref=finished college or more)				
Some high school or lower	0.81 [0.64, 1.02]	0.97 [0.84, 1.12]	1.20 [0.75, 1.92]	1.08 [0.84, 1.39]
Finished high school or some college	1.06 [0.93, 1.21]	1.05 [0.98, 1.14]	1.29 [0.97, 1.71]	1.16 [1.01, 1.33]
Race/ethnicity (ref=white)				
Black	0.98 [0.80, 1.19]	0.75 [0.67, 0.85]	3.12 [2.17, 4.48]	1.27 [1.05, 1.53]
Other	0.89 [0.76, 1.04]	0.92 [0.85, 1.01]	1.80 [1.29, 2.53]	0.96 [0.81, 1.13]

Note: aOR=Adjusted odds ratio. Alcohol-only is defined as past-year alcohol use and no report of past-year marijuana or simultaneous use. Marijuana-only is defined as past-year marijuana use and no report of past-year alcohol or simultaneous use.

Model adjusts for survey year, sex, parental education, race/ethnicity, and also adjusted for survey mode (not shown)