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Trends Among US High School Seniors in Recent Marijuana Use and Associations with Other Substances: 1976 to 2013

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Abstract

Purpose—To describe historical trends in rates of recent substance use, and associations between marijuana and other substances, among United States high school seniors by race and gender.

Methods—Data from Monitoring the Future (1976–2013; n=599,109) were used to estimate historical trends in alcohol use, heavy episodic drinking, cigarette use, and marijuana use. We used time-varying effect models to flexibly estimate changes in associations of substance use behaviors.

Results—Past-month marijuana use rates peaked in the 1970s, declined through 1990, then rose again to reach levels of use of more than 20% for both Black and White participants. Recent years show increasing disparities across groups such that males, and in particular Black youth, are on a trajectory toward higher use. This rise in marijuana use is particularly concerning among Black youth, with rates far exceeding those for cigarette use and heavy episodic drinking. The association of marijuana use with both cigarette use and heavy episodic drinking is particularly high in recent years among Black adolescents.

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Conclusions—Substance use recently declined among high school seniors, except for marijuana use, particularly among Black youth. The increasing association between marijuana and other substances among Black adolescents suggests future amplification in critical health disparities.

Keywords

marijuana use; adolescent substance use; time-varying effect model

Marijuana is the most common illicit drug used by adolescents in the United States.¹ Marijuana use is associated with multiple problems, including early school dropout, increased use of other illicit substances, and adult cannabis and alcohol use disorders, respiratory problems, and neurocognitive problems.^{2–7} Adolescent marijuana use often co-occurs with use of other substances, such as alcohol and tobacco.⁸ Harmful effects of these substances may be heightened when marijuana is also used. For example, respiratory problems are more common among those who use both marijuana and cigarettes than those who use either substance alone.^{5–7} Adolescents who engage in heavy drinking and marijuana use show different neural deficits compared to adolescents who only engaged in heavy drinking.⁹ In addition, understanding whether use of alcohol or tobacco is associated with marijuana use can help researchers determine whether prevention programs aimed at single or multiple substances may be more appropriate.⁸ Thus, when examining trends of marijuana use, it is important to document not only rates of use, but trends in associations with other substances. This paper uses a novel analytic approach, the time-varying effect model (TVEM),¹⁰ to examine historical trends in marijuana, alcohol, and cigarette use for United States high school students; changes in associations of marijuana use with other substances over time; and differences by race and gender.

Marijuana use among adolescents peaked in the late 1970s, with half of high school seniors having used marijuana in the past year.^{11,12} Marijuana use in this population decreased to about 20% in the early 1990s, increased to about 40% in 1997, and then declined to about 31% in 2006. Use among high school seniors has begun to rise again recently, with an annual prevalence of 36% in 2013.¹ Although there has been some research examining simultaneous use of substances (for example, that use of marijuana and alcohol at the same time has decreased in recent years¹³), relatively little is known about how trends of associations between substances has changed over time (for example, whether individuals who engage in heavy drinking more likely to use marijuana and is this association increasing or decreasing in recent years).

Differences in use of marijuana and other drugs by race/ethnicity and gender have been documented. Generally White adolescents have higher rates of substance use, including alcohol, cigarette and marijuana use, than Black adolescents, and these differences have persisted over time.^{1,14} Among twelfth graders, male students generally have greater odds of substance use than female students, although this difference has decreased over time, and there have been only small gender differences in daily cigarette use.¹⁵ However, less is known about how trends associations between use of these substances may differ over time, and how these trends differ by gender and race.

In this study we examine historical trends in rates of and associations between marijuana and other substance use among high school seniors by applying TVEM, a flexible method for modeling dynamic associations between two variables as they unfold in continuous time, to data on substance use reported by high school seniors from Monitoring the Future (MTF).¹ We address the following questions:

1. How do trends in the rates of recent marijuana, alcohol, and cigarette use among high school seniors from 1976 through 2013 differ by race and gender?
2. How do associations between marijuana use and alcohol use, heavy episodic drinking (HED), and cigarette use change from 1976 to 2013 for White and Black adolescents, and for male and female adolescents? What specific behavior patterns underlie these time-varying associations?

METHODS

Design and Sample

We analyzed data from MTF, an ongoing, annual, cross-sectional survey of high school seniors conducted via in-school surveys. The sample was drawn through a multi-stage, school-based random sampling strategy. Sampling weights are used to correct for unequal probability of selection and to ensure representativeness for the 48 contiguous states. Across years of data collection the response rate ranged from 77% to 86%.¹

We used data from high school seniors surveyed between 1976 and 2013, resulting in an overall sample size of $n=599,109$ (48.7% male; 12.2% Black, 67.0% White, 20.8% other/missing; 65.6% 18 years old or older). The sample size available each year ranged from 13,180 (in 2013) to 18,924 (in 1978). Note that coding of the race variable in the MTF public-use data changed over time. Prior to 1983, only White and non-White options were coded. From 1983 to 2004, only White and Black race options were coded; all others, including Hispanic, were coded as missing. Beginning in 2005, a third category for Hispanic was available, but was recoded as missing for the current study to be as consistent as possible across study years. Also, beginning in 1997, the only age variable available to the public was an indicator for whether the participant was 18 and over.

Measures

Alcohol use was assessed by a questionnaire item asking on how many occasions during the last 30 days (if any) a participant drank alcoholic beverages. Response options ranged from 1 for “0 occasions” to 7 for “40 or more.” HED was assessed by asking how many times over the last two weeks a participant had five or more drinks in a row. Response options ranged from 1 for “None” to 6 for “10 or more times.” Cigarette use was measured with a questionnaire item asking how frequently they smoked cigarettes during the past 30 days. Response options ranged from 1 for “Not at all” to 7 for “Two packs or more per day.” Marijuana use was assessed by a questionnaire item asking on how many occasions (if any) they used marijuana or hashish during the last 30 days. Response options ranged from 1 for “0 occasions” to 7 for “40 or more.” Because of the large right skew in the original reported

data, we treated each substance use measure as a dichotomous item: 1 = any reported behavior during the time frame, 0 = none.

Statistical Analysis

Descriptive statistics were conducted in SAS using survey procedures to handle weighted data. To estimate prevalence rates and odds ratios (ORs) that vary smoothly as a function of historical time, we conducted analyses in R software¹⁶ by specifying a weighted logistic TVEM similar to the unweighted logistic TVEM in SAS.^{17–18} This approach estimates the log-odds of an event (e.g., recent marijuana use) as a function of covariates. TVEM differs from ordinary logistic regression in that *the intercept and slope coefficients are estimated as a function of time*. Because time is treated as continuous, coefficients are not presented in tables but rather in figures that express the *coefficient functions*, along with point-wise confidence intervals. The coefficient functions are free to vary smoothly with time and are not assumed to follow any parametric form such as linear or quadratic.

Our analytic strategy was as follows. First, to examine historical trends, intercept-only TVEMs were fit for recent marijuana use over time separately by gender, and then race, effectively allowing these variables to flexibly moderate the continuous effect of time on substance use. In addition, similar models for alcohol use, HED, and cigarette use were estimated so that their historical trends could be compared to that of marijuana use. Second, indicators of alcohol use, HED, and cigarette use were included as time-varying covariates with time-varying effects in separate models to predict marijuana use. That is, the associations between alcohol use and marijuana use, HED and marijuana use, and cigarette use and marijuana use varied as a function of historical year, and could be moderated by race and gender. Third, to further elucidate these time-varying associations, we coded indicators of particular substance use combinations and fit intercept-only models to show historical trends in patterns of use. More information on using TVEM to model behavior over time appears elsewhere.¹⁹

RESULTS

Historical Trends in Substance Use Behavior Across Race Groups

Figure 1 presents, separately for $n=401,296$ White and $n=73,036$ Black adolescents, the estimated prevalence for each substance use behavior as a function of time. The rates of missing data on these variables were 3.5% and 11.2% for alcohol use, 3.8% and 11.4% for HED, 1.2% and 3.7% for cigarette use, and 1.8% and 6.2% for marijuana use, among White and Black respondents, respectively.

The estimated rate of recent marijuana use among White high school seniors has fluctuated considerably between 1976 and 2013 (Figure 1 top panel, dotted line). Use peaked around 1978, with 38% reporting recent use; this was followed by smooth, steady decline until the rates reached 14% in 1991. Prevalence then rose again to approximately 20%, remaining there for over a decade. Marijuana use among White youth has been rising very slightly since 2006. The estimated rate of recent cigarette use (solid line) dropped during the late 1970s to slightly over 30% in 1980, after which the rate of smoking stayed nearly constant

for over a decade while the rate of marijuana use fell. Cigarette use increased to an all-time high of 41% in the late 1990s but has since declined steadily. The estimated rates of recent alcohol use and recent HED show an identical pattern over time, with overall rates of alcohol use at nearly double those for HED at all years (dashed lines). That is, over half of all high school seniors who drink alcohol recently engaged in HED. Rates of HED peaked in the late 1970s, with 76% reporting any alcohol use and 44% reporting HED. These rates fell through the early 1990s, when 54% (as of 1994) used alcohol and 31% engaged in HED. After a moderate rise in the late 1990s, rates dropped steadily to their lowest levels in 2013, when 43% of high school seniors reported recent alcohol use and 25% reported HED. Rates of both behaviors appear to be on a downward trajectory.

The estimated rate of recent marijuana use for Black youth (Figure 1, bottom panel, dotted line) followed a similar pattern of fluctuations as the rate among White youth, but the peak rate during the late 1970's only reached 29% (compared to 38% for White youth) and the lowest rate, in 1990, fell to just 6% (versus 15% for White youth). Just as for White youth, the rate among Black youth from 1995 to 2005 held steady at around 20%. However, marijuana use among Black adolescents has been increasing rapidly, in contrast to the very slight increase among White youth after 2005. The trend in the rate of cigarette use among Black adolescents (solid line) is quite different from that among Whites. For both groups, the rate of cigarette use was approximately 40% in 1976. However, despite persistent high cigarette use among White adolescents, the rate of use among Black youth dropped dramatically and steadily until 1992, when the rate was only 10%. Their rate of cigarette use has held fairly constant since then. Rates of both alcohol use and HED (dashed lines) have been consistently lower for Black compared to White adolescents from 1976 to 2013, although this gap is narrowing due to a steady decrease in the rate among Whites. In 2013, the rate of HED was about 12% for Black adolescents and 25% for White adolescents. The rate of marijuana use has surpassed that of cigarette use among Black adolescents since about 1993, but White adolescents did not show this crossover until 2011. Among Black youth, the rate of marijuana use also surpassed that of HED, except during the years 1986 to 1994.

Gender Differences in Historical Trends of Substance Use Behavior

Figure 2 presents, separately for $n=277,024$ male and $n=291,664$ female adolescents, the estimated prevalence (and corresponding 95% confidence interval) for each substance use behavior as a function of time. Missingness rates were 5.4% and 5.0% for alcohol, 6.1% and 4.8% for HED, 1.8% and 1.5% for cigarettes, and 3.1% and 2.3% for marijuana for males and females, respectively. Overall, the estimated rate of recent use of each substance shows a similar pattern of fluctuations over time across gender, except that males had consistently higher rates for alcohol, HED, and marijuana use than females (Figure 2). Rates of these three behaviors peaked around 1978, then declined fairly steadily until the early 1990's with marijuana use showing the fastest decline (from 42% to 15% among males, and from 32% to 10% among females). During the late 1990's rates of alcohol use and HED increased slightly and then continued the downward trend for both males and females, with all-time low levels for the entire study period in 2013. However, during the mid-1990's the rate of marijuana use nearly doubled for both male and female adolescents, and since 2005 the

trend again reflects increasing use, with 26% of males and 19% of females using marijuana as of 2013.

The estimated rate of recent cigarette use shows a similar time-varying trend for male and female adolescents, with a few exceptions (Figure 2, solid lines). Female youth had slightly higher rates in the early 1980's (with 27% of males and 32% of females reporting cigarette use in 1983), but very recently male youth report cigarette use at higher rates (19% of males and 13% of females in 2013). The recent trend, particularly for females, is a fairly steep and steady decline. By 2013 the rate of marijuana use exceeded that of cigarette use. This crossover occurred around 2008 for male adolescents, and around 2010 for female adolescents. Figures 1 and 2 clearly show the extent to which, in contrast with the other substances, marijuana use is on the rise among high school students.

Associations among marijuana and other substance use

Associations among substance use behaviors were then modeled to explore the extent to which use of other substances was associated with marijuana use, and how those associations changed over 37 years. Race and gender were examined as moderators of the time-varying association of alcohol use, HED, and cigarette use with marijuana use (i.e., associations among substances varied as a function of time as well as race and gender). Large odds ratios indicate that individuals are likely to use either both substances or neither, but not just one. When they decrease, this represents a weakening of this association, indicating a trend for more individuals to specialize in one substance or another.

Race as a Moderator of Time-Varying Associations—The top and bottom panels of Figure 3 show the time-varying effects (as ORs) of these behaviors on the rate of marijuana use for White and Black adolescents, respectively. For White adolescents, marijuana use was more strongly associated with alcohol use than cigarette use across all years. For example, in 1976, White adolescents who reported any alcohol use had an estimated 14.7 times greater odds of reporting marijuana use compared to those not reporting alcohol use. This OR decreased slowly and steadily to 9.5 throughout the study years. Among White adolescents, HED and cigarette use were significantly and consistently associated with marijuana use across all years (estimated OR ranging between 5.6 and 8.1 across years and substances).

The pattern across years is more complicated for Black adolescents. In 1976, alcohol use, HED, and cigarette use were associated with marijuana use at similar levels (estimated ORs 7.8 for alcohol, 5.5 for HED, and 5.5 for marijuana). In the subsequent 15 years, however, the association of marijuana with alcohol use increased rapidly (OR=14.6 in 1990). The historical trends in associations among substances for Black adolescents began to shift after 1990. Figure 3 shows that the association of marijuana use with alcohol use diminished considerably, but the association with HED has strengthened since 2008.

Gender as a Moderator of Time-Varying Associations—The top and bottom panels of Figure 4 show the time-varying effects (as ORs) of recent alcohol use, HED, and cigarette use on the rate of marijuana use for male and female adolescents, respectively. The strongest

associations between substances were for marijuana and alcohol use; adolescents who reported any alcohol use had as much as 15 times greater odds of reporting marijuana use.

Across all years, HED was consistently associated with marijuana use (OR ranging between 6.3 and 8.1 over years for males and between 6.3 and 8.3 for females). The association between cigarette and marijuana use also has been fairly consistent across years for females, with estimated ORs between 7.0 and 10.3. While this association was typically weaker among males, the association between cigarette and marijuana use has slowly strengthened over time, with the OR increasing from 4.7 in 1976 to 7.6 in 2007, although it then fell to 5.9 by 2013.

Historical Trends in Particular Substance Use Combinations—Figure 5 shows the time-varying prevalence of different combinations of marijuana with other substance use behaviors. The first panel depicts trends in combinations of marijuana use and HED; the prevalence of both substances (solid line) declined through 1990 and has been flat in recent years at just over 10%. The rate of using either one of these two substances alone is equal, at around 10%, despite large historical differences suggesting greater specialization toward HED but not marijuana for over 20 years. The second panel presents trends in combinations of marijuana and cigarette use; despite increasing use of marijuana in recent year, use of cigarettes alone (dotted line) or with marijuana (solid line) have declined since the late 1990's. The third panel shows trends in combinations across all three substances; findings from the most recent years highlight the increase of marijuana use, either alone (dotted line) or with HED (uneven dashed line), in this population.

DISCUSSION

The decline in rates of cigarette and alcohol use, including HED – particularly during the most recent decade – suggests that behavioral interventions and public policies focused on reducing adolescent use of legal substances have been effective for each subgroup of adolescents examined in this study. Such policies have included tax increases and enforcement of minimum age laws, policies which have been shown to be efficacious.²⁰ However, these reductions could also be due to other factors, such as economic or social attitudinal changes.

Despite these declines in alcohol and cigarette use, overall rates of marijuana use among high school seniors have increased in recent years, particularly among Blacks and males. Use of both marijuana and cigarettes in the past 30-days is declining, whereas use of marijuana without cigarettes and use of marijuana and HED without cigarettes is increasing. This is consistent with increasing knowledge of the risks of cigarette use along with increasing acceptance and push for decriminalization of marijuana in recent years.²¹ The increases in marijuana use were larger for black and male adolescents, and associations between use of the substances showed some difference by subgroup. Most notably, the strength of the relationship between marijuana use and HED has increased in the last few years among Black, but not white, adolescents. Despite Black adolescents' overall lower levels of use, this finding is particularly concerning given the higher likelihood of Black adolescents to progress from early use to later abuse and dependence.^{22,23} Interventions

targeting black and male adolescents, particularly those who engage in heavy drinking, may be important in reducing marijuana use. Further, the increasing association in recent years between marijuana use and HED among Black adolescents indicates the possibility for increased health disparities between Black and White adolescents, particularly because Black adolescents who initiate HED and marijuana use may be more likely to become chronic users than their White counterparts.²⁴

Limitations

Several limitations of this study merit discussion. First, between 1976 and 2013 the coded race categories provided by MTF permitted comparison only between Black and White adolescents. Furthermore, the coding of race changed across study years. Specifically, prior to 1983 race categories were defined as White and non-White. Beginning in 1983, the categories were specifically defined as White and Black. Thus, the relative composition of the group labeled as Black may have shifted somewhat between 1982 and 1983. However, an empirical investigation of this issue showed no significant curve shifts at 1983, which may lessen this concern. Another limitation is missing data. For Figures 1 and 2, we essentially assumed noninformative missingness, which may be unrealistic. If nonresponders are considered to be especially likely to be users, the estimated rates might be slightly higher. For Figures 3 and 4, we performed listwise deletion of individuals missing either race or gender respectively, or any of the four items, thus excluding 29% or 14% of the sample respectively.

Conclusions

Despite these limitations, this study provides a nuanced description of changing behavior patterns across historical time and a description of population subgroups that exhibit particular behavioral trends of public health concern. This study is the first to apply TVEM to examine historical trends in rates of different substance use behaviors and their associations. It sets the stage for future research incorporating additional data, for example on policy changes, to help elucidate other important factors contributing to rising rates of marijuana use and its increasingly strong associations with other substances for some subgroups of adolescents.

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Abbreviations

HED	heavy episodic drinking
MTF	Monitoring the Future
OR	odds ratio

TVEM time-varying effect model[ing]

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Highlights

- Cigarette and alcohol use by high school seniors are stable or declining, but marijuana use in high school seniors is rising, especially for Blacks.
- Time-varying effect modeling, which describes changes in regression coefficients, enabled a study of changing associations between marijuana use and other substance use from 1976 to 2013.
- Odds ratios among substance use behaviors have changed during past decades in different ways for different demographic groups.
- Recent years show an increase in the number of youth engaging in just marijuana use, and in both marijuana use and heavy episodic drinking.

Implications and Contribution

Time-varying effect modeling (TVEM), a new methodology allowing regression coefficients to be estimated as smooth functions of time, is used to describe the changing rates and associations of marijuana, alcohol, and cigarette use among US high school seniors as they have changed over 37 years. Race and gender differences in these historical time-varying effects are examined. The increasing association between marijuana use and other substance use among Black adolescents suggests future amplifications in critical health disparities.

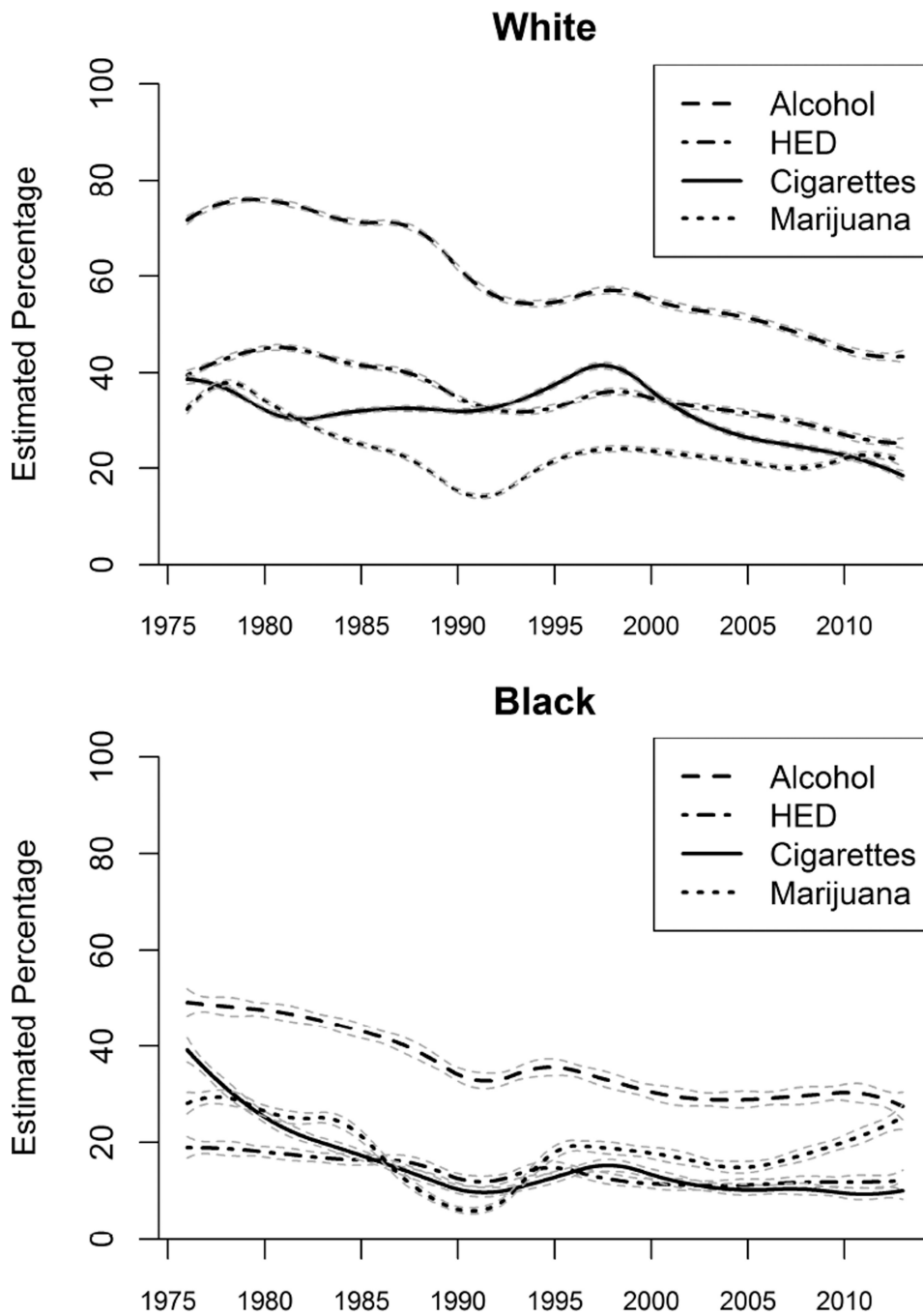


Figure 1. Estimated percentages (with 95% confidence intervals) of White and Black adolescents reporting recent alcohol use, heavy episodic drinking (HED), cigarette use, and marijuana use as a function of historical time.

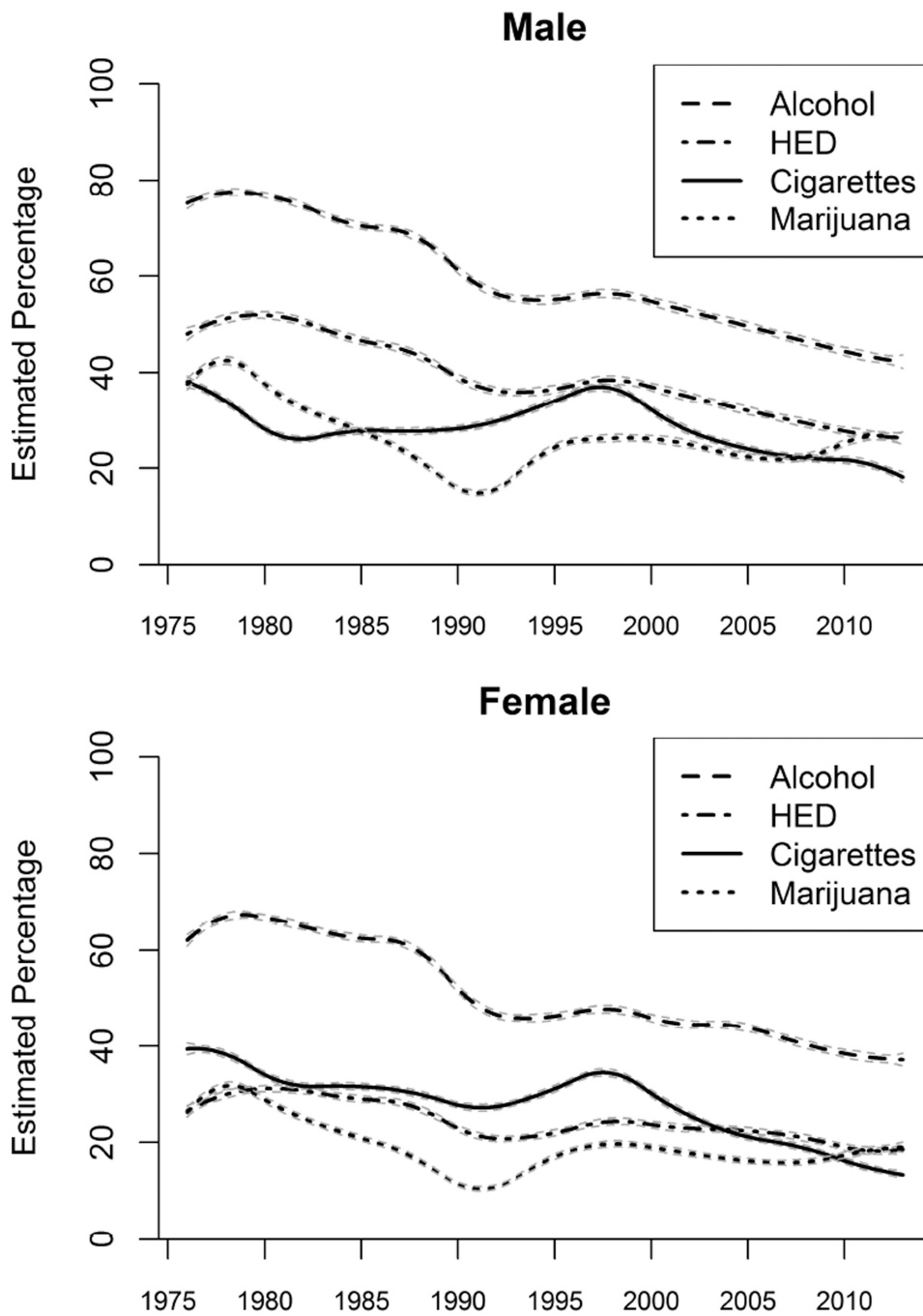


Figure 2. Estimated percentages (with 95% confidence intervals) of male and female adolescents reporting recent alcohol use, heavy episodic drinking (HED), cigarette use, and marijuana use as a function of historical time.

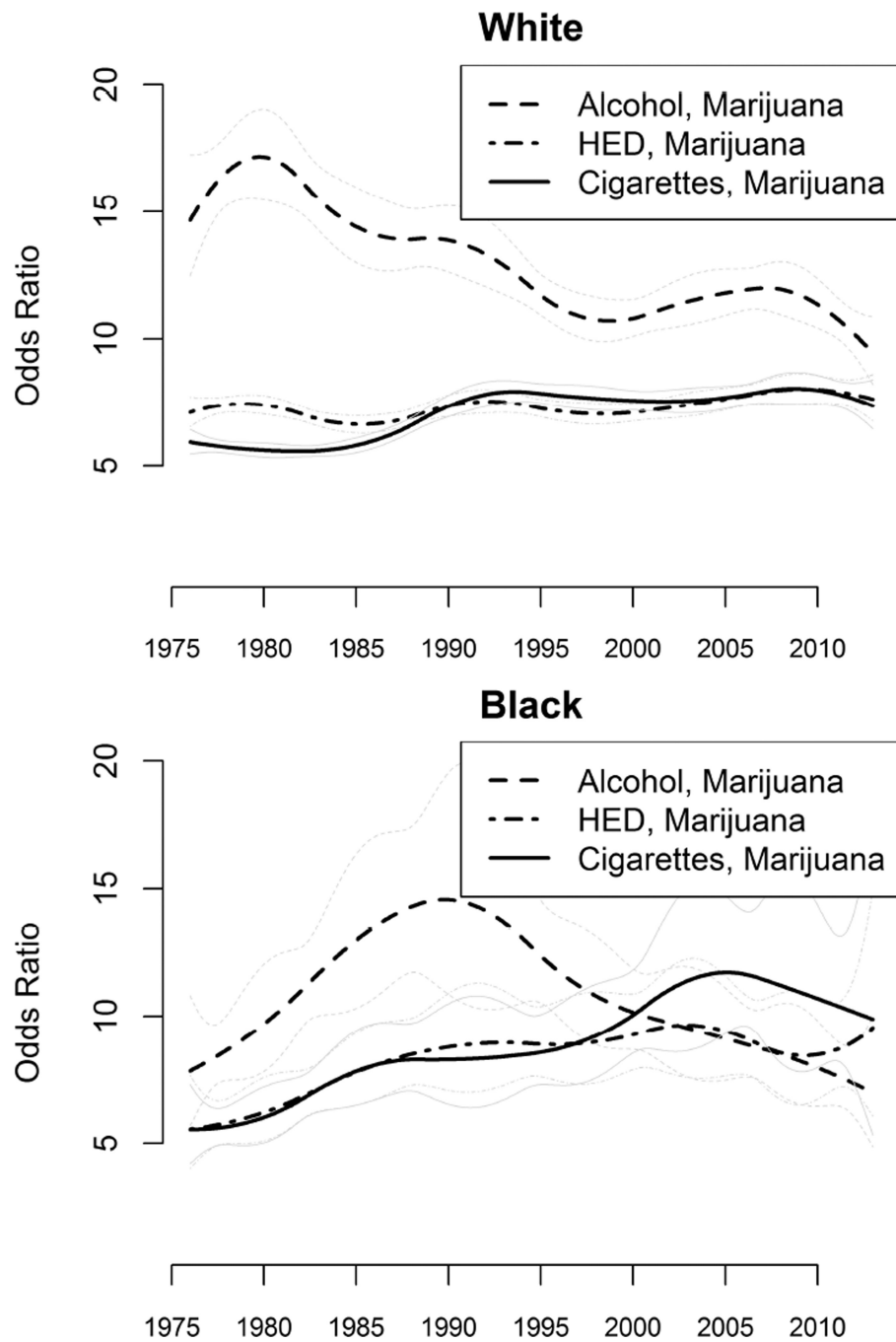


Figure 3. Estimated increase in odds (with 95% confidence intervals) of recent marijuana use associated with recent alcohol use, heavy episodic drinking (HED), and cigarette use for Black and White adolescents as a function of historical time.

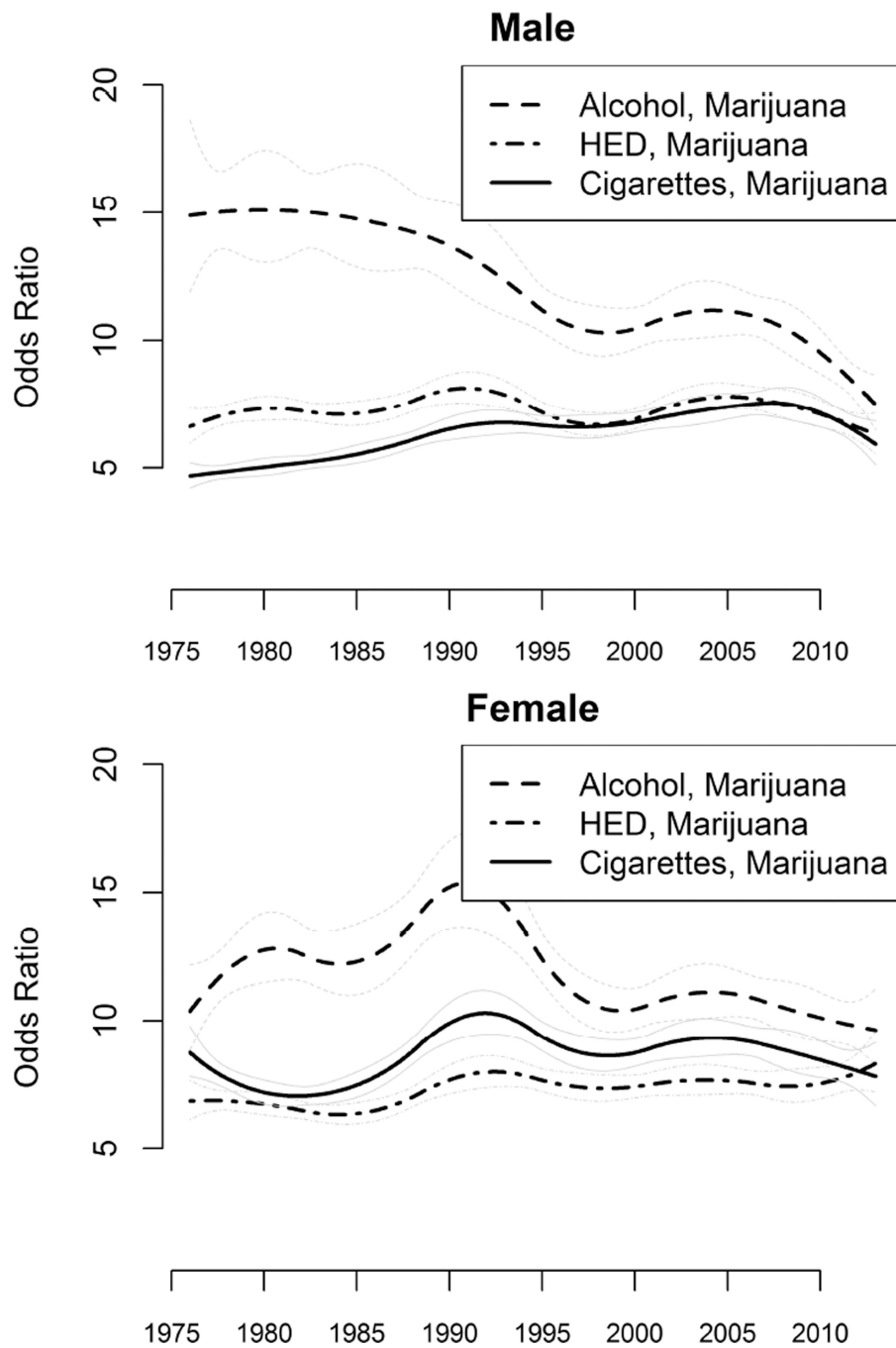
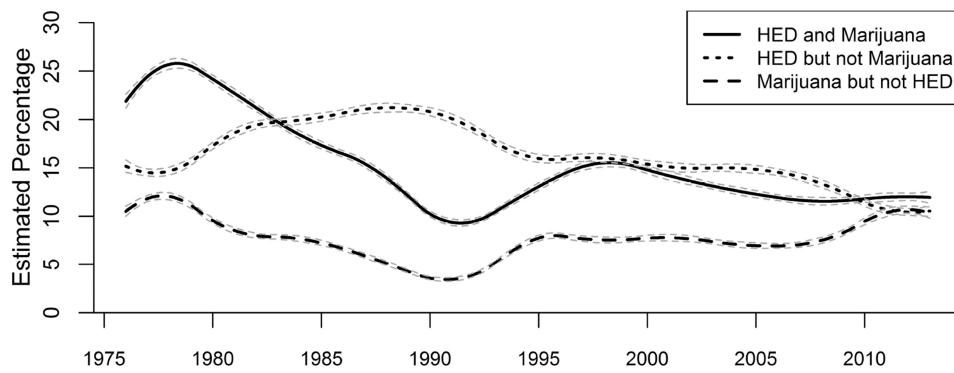
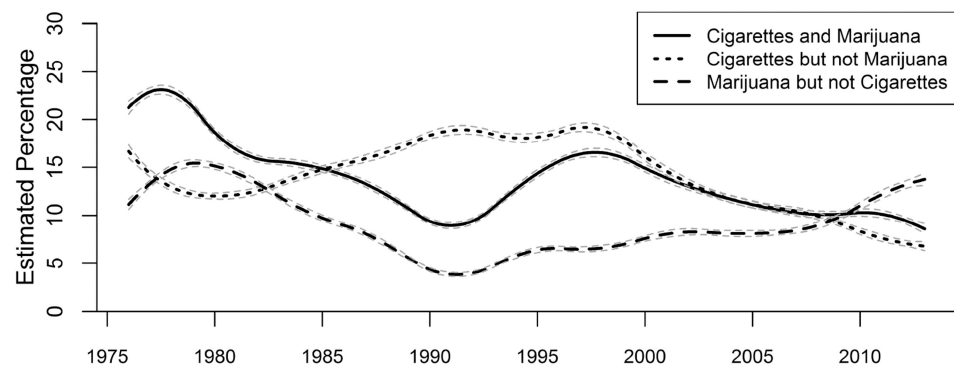


Figure 4. Estimated increase in odds (with 95% confidence intervals) of recent marijuana use associated with recent alcohol use, heavy episodic drinking (HED), and cigarette use for male and female adolescents as a function of historical time.

Patterns of Marijuana Use and Heavy Episodic Drinking (HED)



Patterns of Marijuana and Cigarette Use



Patterns of Marijuana Use, HED, and Cigarette Use

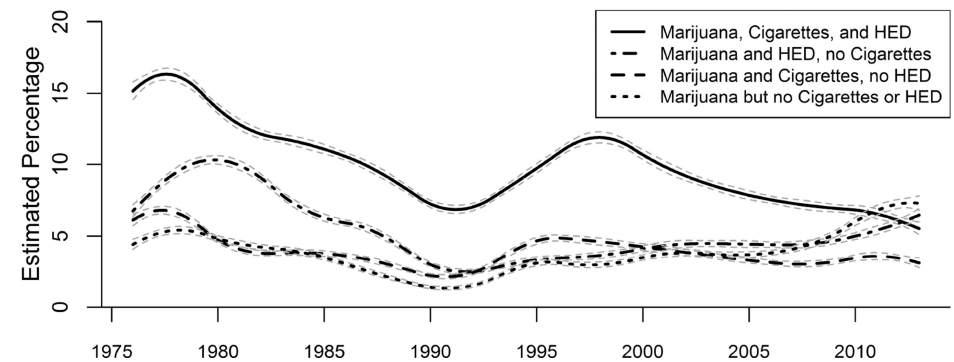


Figure 5. Estimated percentages (with 95% confidence intervals) of specific combinations of recent marijuana and other substance use as a function of historical time.