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Past-month cannabis use among U.S. individuals from 2002–2015: An age-period-cohort analysis

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Abstract

Background—Cannabis is the most commonly used illicit drug among U.S. adolescents and adults, but little is known about factors that drive trends in cannabis use prevalence. To better understand drivers of these trends, we aimed to estimate age, period, and cohort effects on past-month cannabis use among U.S. individuals age 12 and older from 2002 to 2015.

Methods—We conducted an age-period-cohort analysis on past-month cannabis use among participants ages 12 and older using National Survey on Drug Use and Health (NSDUH), an annual cross-sectional nationally-representative survey of drug use. Additionally, we examined how age, period, and cohort effects differed across gender. Participants (n=779,799) self-reported cannabis patterns using a computer-assisted telephone interview (CATI).

Results—Past-month cannabis use in this population increased from 6.0% in 2002 to 8.1% in 2015. Distinct age, period, and cohort effects were observed. Compared to participants ages 12–13, participants ages 18–21 (PR: 16.8, 95% CI: 15.6, 18.1) and 22–25 (PR: 13.2, 95% CI: 12.2, 14.4) had dramatically higher prevalence of past-month cannabis use. Compared to participants in 2002, participants in 2014 (PR: 1.2, 95% CI: 1.1, 1.4) and 2014 (PR: 1.2, 95% CI: 1.1, 1.4) had slightly higher prevalence of past-month cannabis use. Compared to the 1940s birth cohort, the 1950s birth cohort (PR: 1.8, 95% CI: 1.5, 2.2) had higher prevalence of past-month cannabis use.

Conclusions—Past-month cannabis use is prevalent and increasing among U.S. adults. Distinct age, period, and cohort effects are at play, though age effects are strongest.

Keywords

cannabis; marijuana; substance use trends; age-period-cohort

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1. Introduction

Cannabis is the most commonly used illicit drug among adolescents and adults in the United States (U.S.) (Haberstick et al.; Tice, 2014; Volkow, Baler, Compton, & Weiss, 2014). As of 2015, an estimated 1 in 5 young adults (aged 18–25) were current users of cannabis (SAMHSA, 2016c). However, less is known about how trends of cannabis use are changing in the context of changing social norms and state-level policies in the U.S. Understanding trends in cannabis use among U.S. individuals is an essential step toward developing health policy, health education, and targeted interventions to mitigate potential adverse health effects from cannabis use (Wilkinson, 2016).

Prevalence of recent cannabis use (defined as at least one occurrence in the past month) has increased among adults aged 18 to 25 from 16% in 2004 to 20% in 2014 (Tice, 2014). Moreover, attitudes among younger cohorts continue to move towards greater acceptance of cannabis, with the percentage of teenagers who perceive “great risk from regular use” significantly declining in the past decade (Johnston, 2015; Okaneku, Vearrier, McKeever, LaSala, & Greenberg, 2015). Policies on cannabis legality are also rapidly changing. To date, 29 states have legalized medical use, and eight states and the District of Columbia have legalized recreational use (Wu, Zhu, & Swartz, 2016). Disentangling the effects of age, policy period, and cohort is critical to understanding changes in cannabis use over time, as these three parameters are inextricably correlated over time but may have independent, potentially modifiable effects.

Three studies have previously investigated age, period, and cohort effects of cannabis use among U.S. populations. Two older studies found strong age and cohort effects of past-year cannabis use, some of which differed across gender (W. G. Kerr, TK; Bond, J; Ye, Y, 2007; Miech & Koester, 2012). Only one study examined age, period, and cohort effects after the first U.S. states legalized recreational use of cannabis in 2012; authors found strong age effects and growing period effects of past-year cannabis use (W. C. L. Kerr, C.; Ye, Y., 2017). These increasing period effects suggest that changing policies and social norms may be an important driver of cannabis use trends. However, all previous studies looked only at past-year cannabis use prevalence. No studies have examined age, period, and cohort effects on measures of more recent or chronic cannabis use prevalence.

Therefore we conducted an age-period-cohort (APC) analysis to estimate the independent effects of age, period, and cohort on past-month cannabis use among U.S. men and women age 12 and older from 2002 to 2014 using nationally-representative survey data. We also investigated potential differences in cannabis use trends by gender.

2. Material and methods

2.1 Study population

We analyzed data from the National Survey on Drug Use and Health (NSDUH). Conducted by the Department of Health and Human Services since 1972, the NSDUH uses a repeated annual cross-sectional survey design to measure tobacco, alcohol, and illicit drugs use. In

addition to drug use patterns, the survey also covers mental health conditions, behavioral disorders, and attitudes towards drug use.

The survey uses multistage clustered sampling to ascertain a nationally-representative sample of U.S. households (SAMHSA, 2015). Professional interviewers visit selected household to conduct the computer-assisted interviews (SAMHSA, 2015). All participants were age 12 or older at time of interview. Monetary compensation for study participation began in 2002 and resulted in increased participation; thus, we restricted our sample to 2002 onwards. We merged publicly-available NSDUH data across survey years 2002 to 2015 for a total analytic sample of 779,799 participants.

2.2 Measures

The cannabis survey questions were asked using audio computer-assisted self-interviewing (ACASI), during which the respondent listens to pre-recorded questions on headphones and enters his/her own response. This survey method has been shown to improve response accuracy, since the question is not asked face-to-face by an interviewer, thereby reducing perceived stigma and potential misreporting (Aquilino, 1992; Newman et al., 2002). During this section, the respondent were first briefed on different formats and names for cannabis (e.g. marijuana, hash, pot, grass, joints) that are considered exchangeable in the survey. Respondents were then asked: “How long has it been since you last used marijuana or hash?” with the following possible responses: (1) Within past 30 days, (2) More than 30 days ago but within past 12 months, (3) More than 12 months ago, or (4) Never used. Our primary outcome of interest for this analysis was any cannabis use in the past 30 days; thus, we combined response categories to create a dichotomous variable indicating *use in the past 30 days* vs. *use more than 30 days ago or never use* (referent group for all analyses).

Socio-demographic characteristics, tobacco, alcohol, and other illicit drug use were also ascertained from the NSDUH survey. Socio-demographic questions were asked by the trained interviewer, while more sensitive questions pertaining to substance use were ascertained using the ACASI method described above.

For most variables, missing or ambiguous values were imputed by NSDUH statisticians using a methodology called predictive mean neighborhoods (PMN), described elsewhere (SAMHSA, 2016a).

2.3 Statistical Analysis

We examined the distribution of socio-demographic characteristics, tobacco, alcohol, and other drug use stratified by individual-level past-month cannabis use in our study sample (see Table 1).

First we created age-period contingency tables, overall and stratified by gender, for the proportion of past-month cannabis use for each age category and study year. Birth year was calculated by subtracting age from study year. For confidentiality reasons, publicly-available NSDUH data provided some ages categorically (e.g. 30–34). In these cases, we used the median age (e.g. 32) for each category to calculate birth year. We then categorized birth year in 10-year intervals to represent birth cohorts by generation (e.g. 1960, 1970, etc.)

We used log-linear multivariable models to estimate adjusted prevalence ratios (aPR) and 95% confidence intervals (CI) for associations between age, period, and cohort and proportion of individuals reporting past-month cannabis use. The conventional age-by-period array of aggregate outcomes categorize age and period in equal interval lengths, thereby creating the exact linear dependency between the independent variables (period = age + cohort) that leads to the model identification problem (Yang, 2013). However, in our data, cohort was categorized in 10-year intervals - conventional in demographic studies of population based data - to represent potential generational effects. Age was categorized in unequal intervals based on NSDUH statisticians' recommendations to best represent age-related changes in drug use. Period was categorized in 1-year intervals to assess potential year-by-year changes in cannabis use, in the context of changing legislation during the study period. We therefore used the differential time interval groupings to break the exact linear dependency between the three variables.(Yang, 2013)

Descriptive models included confidential survey weight and variance estimation stratum from the NSDUH to account for sampling, non-response, and variance adjustment. Weighted results are meant to be generalizable to the target population of U.S. adults age 12 and older. No additional covariates were included in the age-period-cohort models, since no potential confounders were identified using a directed acyclic graph (Bandoli, Palmsten, Flores, & Chambers; Williamson et al.). This approach is consistent with previous age-period-cohort analysis of substance use (Giordano et al., 2014; W. C. L. Kerr, C.; Ye, Y., 2017; Miech & Koester, 2012; Piontek, Kraus, & Pabst, 2011). No interaction terms were included in the model, since cohort effects can be conceptualized as an interaction between age and period. In other words, cohort effects capture how age effects vary by time period.

Analyses were conducted using R 2.14.0 and SAS 7.3.

3. Results

3.1 Sociodemographic Characteristics

Overall, 6.4% of the study population reported past-month cannabis use. Past-month use varied greatly by age, with prevalence as high as 17.3 % for 18–25 year olds and as low as 2.0% for 50 years and older (see Table 1). Compared to those reported no cannabis use in the past month, past-month users were more likely to be male, unemployed, and unmarried. Past-month users did not differ substantially in terms of family income, educational attainment, and overall health status. Past-month cannabis use was associated with current cigarette smoking, past-month binge drinking, and ever-use of cocaine, heroin, LSD, methamphetamines, and non-medical use of painkillers (see Table 1).

3.2 Trends from 2002–2015

The overall prevalence of past-month cannabis use increased from 6.0% in 2002 to 8.1% in 2015. While the absolute prevalence remained higher for males through the study period, the overall trend appeared similar for males and females (see Figure 1).

3.3 Age, Period, Cohort Effects

By simultaneously modeling age, period, and cohort effects on proportion of individuals reporting past-month cannabis use, we estimated each independent effect while holding the other two factors constant. Note that Figures 2–4 have varying y-axis limits to best depict results. Age had considerably stronger effects on proportion of past-month cannabis use than period or cohort. The strongest age effects were observed for 18–21 year olds (aPR: 16.8, 95% CI: 15.6, 18.1) and 22–25 year olds (aPR: 13.2, 95% CI: 12.2, 14.4), compared to the 12–13 year old referent group (see Figure 2). Cohorts born in the 1950s, 1980s, and 1990s had slightly higher proportions of past-month use compared to the 1940s birth cohort referent group, with the strongest cohort effect for 1950 (PR: 1.8, 95% CI: 1.5, 2.2) (see Figure 3). We observed a small but consistently increasing period effect for study years 2009 to 2015 compared to 2002 (see Figure 4). Most confidence intervals included the null; however, period effects for 2013 (aPR: 1.1, 95% CI: 1.0, 1.2), 2014 (aPR: 1.2, 95% CI: 1.1, 1.4), and 2015 (aPR: 1.2, 95% CI: 1.1, 1.4) were more pronounced.

3.4 Gender Differences

Prevalence of past-month cannabis use was higher among males than females for all study years. However, the overall increasing trend in past-month use from 2002 to 2015 was similar across gender.

Age effects were stronger for males, most notably for the 18–21 age group (aPR for females: 13.8, 95% CI: 12.3, 15.5; aPR for males: 19.9, 95% CI: 18.2, 21.6) (see Figure 2). Cohort and period effects were overall similar across gender (see Figures 3 and 4). However, significant period effects were observed for study years 2010 through 2015 among males, but only for study year 2014 and 2015 among females. The magnitude of period effects were slightly stronger among males, with the exception of study year 2015, where period effects appeared slightly stronger among females.

4. Discussion

4.1 Overall

This was the second study to examine age, period, and cohort effects on cannabis use in the United States since the first states legalized recreational use of cannabis in 2012 and the first study to do so using NSDUH data. This was also the first APC study to consider past-month cannabis use, a more sensitive marker for regular cannabis use and potentially related health effects (King et al. 2015, Toennes et al. 2010).

Cannabis use was somewhat prevalent in this study population, with approximately 6% of participants reporting past-month use. We observed a meaningful increase in past-month cannabis use prevalence from 6.0% in 2002 to 8.1% in 2015. While past-month cannabis use prevalence was almost twice as high among males as compared to females, time trends were consistent across gender, which counter recent reports of gender convergence of past-year or any cannabis use prevalence (Chapman et al., 2017). While we found distinct age, period, and cohort effects on past-month cannabis use, age was the strongest independent source of variation, especially for the 18–21 and 22–25 age groups, which is consistent with current

literature on risk factors for cannabis use. Age was a stronger correlate of cannabis use prevalence among men when estimating prevalence ratios. However these gender differences were mitigated when estimating prevalence differences, likely because the baseline prevalence differed across gender, thus resulting in differing ratio estimates. We therefore conclude that age effects are strong for both men and women, and the magnitude of effects are largely similar by gender.

A consistent increase in use across periods suggests that time-dependent socio-cultural factors may influence past-month cannabis use. Notably, the overall period effect was strongest for study years 2013, 2014, and 2015, which reflect the time period immediately after Colorado and Washington legalized recreational cannabis use in 2012.

State-level legalization in 2012 could influence national period effects in past-month cannabis use through multiple pathways (M. Cerdá, Wall, Feng, & et al., 2017; Cerda, Wall, et al., 2017; Estoup, Moise-Campbell, Varma, & Stewart, 2016). First, individuals may have increased access to cannabis; this would primarily affect individuals living in states with legalization (Cerda, Sarvet, et al., 2017; M. W. Cerdá, M; Keyes, KM; Galea, S; Hasin, D, 2012). Second, legalization may reduce risk perception and change social norms surrounding acceptance and use of cannabis. Significant decreases in the risk perception surrounding cannabis use in US populations from 2002 to 2014 have been documented (Okaneku et al., 2015). Drug use patterns are known to be strongly influenced by social norms and other group-level processes (M. Cerdá et al., 2017; Johnson & Fendrich, 2005; Reynoso-Vallejo, 2011; Roditis, Delucchi, Chang, & Halpern-Felsher, 2016). Future research could assess these potential mediators, and how effects differ for medical versus recreational cannabis use (Roy-Byrne et al., 2015). We cannot necessarily infer that state-level legalization caused this period effect because we were unable to account for other time-varying factors during this period that may influence cannabis use. Moreover, more time may need to elapse before we see the true period effects from state-level legalization (Dills, 2016). Interestingly, the increasing period effect we observed in past-month use is consistent with recent reports of strengthening period effects in national support of cannabis legalization in the past decade (Schwadel & Ellison) (Campbell, Twenge, & Carter, 2017).

Three earlier studies found strong age effects with a peak in young adulthood, consistent with our findings (W. C. L. Kerr, C.; Ye, Y., 2017; W. G. Kerr, TK; Bond, J; Ye, Y, 2007; Miech & Koester, 2012; Piontek et al., 2011). Kerr et. al. reported a decline in past-year cannabis use among men, but stable use among women from 1984 to 2000 (W. G. Kerr, TK; Bond, J; Ye, Y, 2007). More recently, we observed distinct patterns by gender, but increased use among both men and women from 2002–2015. Consistent with our results, Kerr et al. also found that age effects were stronger for women than for men (W. G. Kerr, TK; Bond, J; Ye, Y, 2007). Miech et al found a distinct period effect in study years 2000–2009 across all ages and cohorts (Miech & Koester, 2012), speculating trends may have reflected changing social norms and attitudes towards cannabis use (Miech & Koester, 2012). Similarly, we observed a distinct increasing period effect, but of more consistent magnitude and precision than was observed by Miech et al. This may suggest that period effects were already emerging in the US from 2000–2009 but have since become stronger in 2002–2014, perhaps due to even stronger social norms or legislation changes. Consistent with our findings, Kerr

et al. found strong age effects and increasing period effects during their study period of 1984–2015 (W. C. L. Kerr, C.; Ye, Y., 2017). However, Kerr et al. used data from the National Alcohol Survey, which only surveys the U.S. population every five years, as compared to the annual survey frequency of NSDUH. Kerr et al.'s results for past-year use were mostly consistent with the trends we observed in past-month use, though the magnitude of our age effects were notably larger. Our findings of stronger period effects for study years 2013, 2014, and 2015 were consistent with Kerr et al's period effect for study year 2015, suggest the increasing period effect holds true for past-year and past-month cannabis use.

Laws and social norms have changed drastically since the most APC studies reported on trends (Dills, 2016; Estoup et al., 2016; Okaneku et al., 2015). The most notable change was in 2012 with the first state legalization of recreational cannabis use, so it is timely to examine time trends and drivers those trends over the past seven years (M. Cerdá et al., 2017). Our efforts to understand trends among individuals of reproductive age are crucial to public health guidelines and planning, especially in light of the growing evidence of adverse reproductive health effects of cannabis use. Moreover, we have investigated past-month use, which provides a more temporally relevant measure of use with regard to health effects than would be available from previous studies that evaluated past-year cannabis use (Fischer et al., 2010; Silins et al., 2013; Temple E.C., 2015; Johnson, 2015).

4.2 Limitations

Self-report of cannabis may be under-reported, and the extent of measurement error may differ by age and gender. Moreover, our results could be vulnerable to time-varying changes in reporting accuracy either by all participants or by participants of specific age groups: if study participants in later years are more comfortable reporting true cannabis use, we may mistake increased reporting for increases in actual prevalence. These concerns may be mitigated by measures taken within the NSDUH data collection protocol to improve the accuracy of self-report, including: anonymous reporting without face-to-face interactions with the interviewer, reminders of anonymity, and a repeated follow-up approach to minimize non-response.

By restricting to a 14-year period (2002 to 2015), we are 'capturing' each birth cohort at specific ages. For example, individuals born in 1965 would be captured in our study at ages 37 to 49, whereas individuals born in the 1990 would be captured at ages 17 to 29. Since cannabis use is most prevalent among young adults, we may be missing the heaviest cannabis use for the 1960 and 1970 birth cohorts. We adjusted for period and age in the cohort effect estimates, which may mitigate this issue by providing cohort trends averaged over all period and age groups, but generalization of our results beyond this sample is limited. Longer study periods could help corroborate estimates of cohort effects in past-month cannabis use. Additionally, we may be susceptible to potential measurement error for age and cohort effects, since the publicly-available NSDUH data only provided categories for older ages. Future studies with more exact age, and therefore cohort, measurement should replicate our results.

Finally, we were unable to investigate effect-measure modification by state because the public-access NSDUH files do not include data on participants' residence. Many states decriminalized possession and legalized medical and/or recreational use of cannabis over the study period. Future studies could look at state-specific data to elucidate how period effects differ geographically and by type of legislation change.

5. Conclusions

Cannabis use is prevalent and increasing among U.S. adults aged 12 and older, with approximately 6.4% reporting past-month use during the 2002–2015 study period. Age, period, and cohort each have independent effects on past-month cannabis use, with age having the strongest influences. When holding age and cohort constant, small but consistent period effects were observed. Most notably, period effects – which arose from time-dependent socio-cultural factors – were strongest for 2014 and 2015. State-level cannabis legalization in 2012 may partly explain these recent national period effects, though recent period effects also fit a larger trend of steady increases in cannabis use in the past decade.

Cannabis use is common and increasing among U.S. adolescents and adults. Understanding trends in cannabis use among U.S. adolescents and adults is an essential step toward developing health policy, health education, and targeted interventions to mitigate potential adverse effects from cannabis use.

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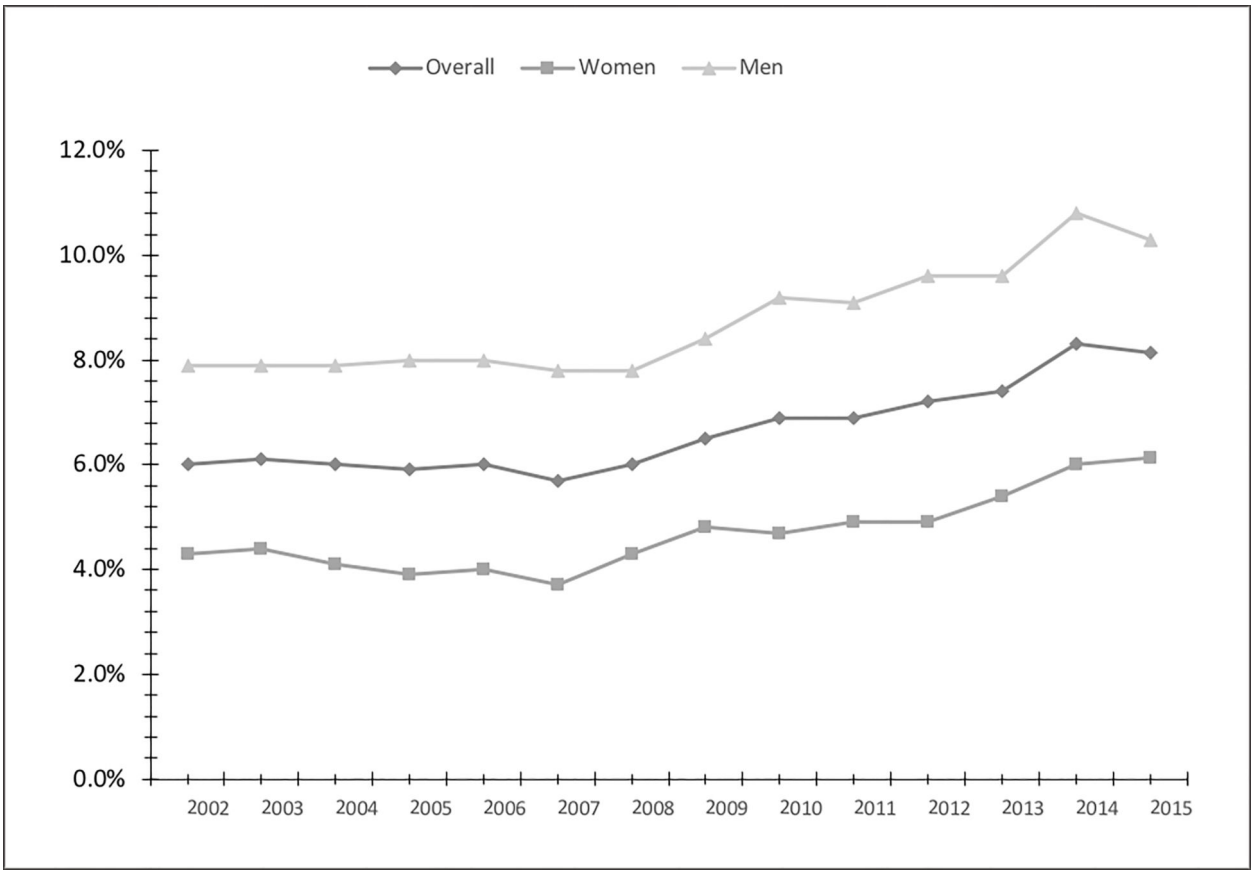

Figure 1.
Trends in past-month cannabis use among U.S. men and women ages 12 and older, from 2002–2015

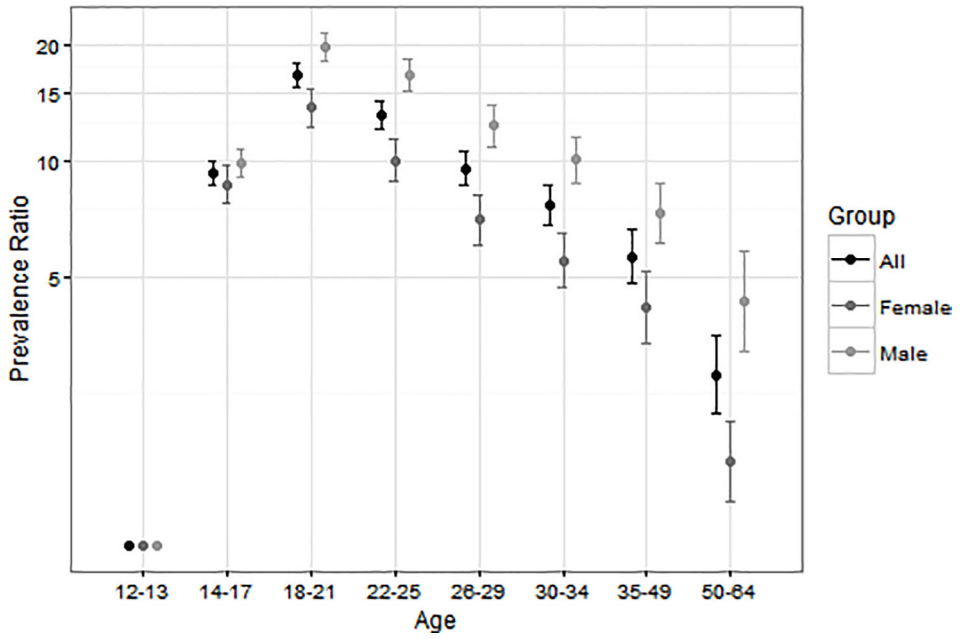

Figure 2.
Age effects on prevalence of past-month cannabis use

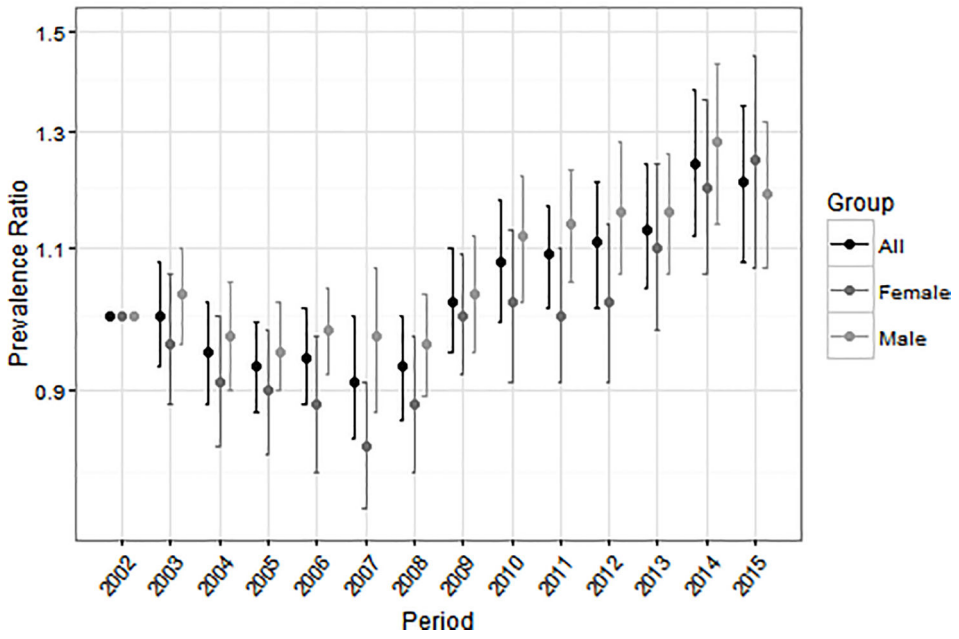

Figure 3.
Period effects on prevalence of past-month cannabis use

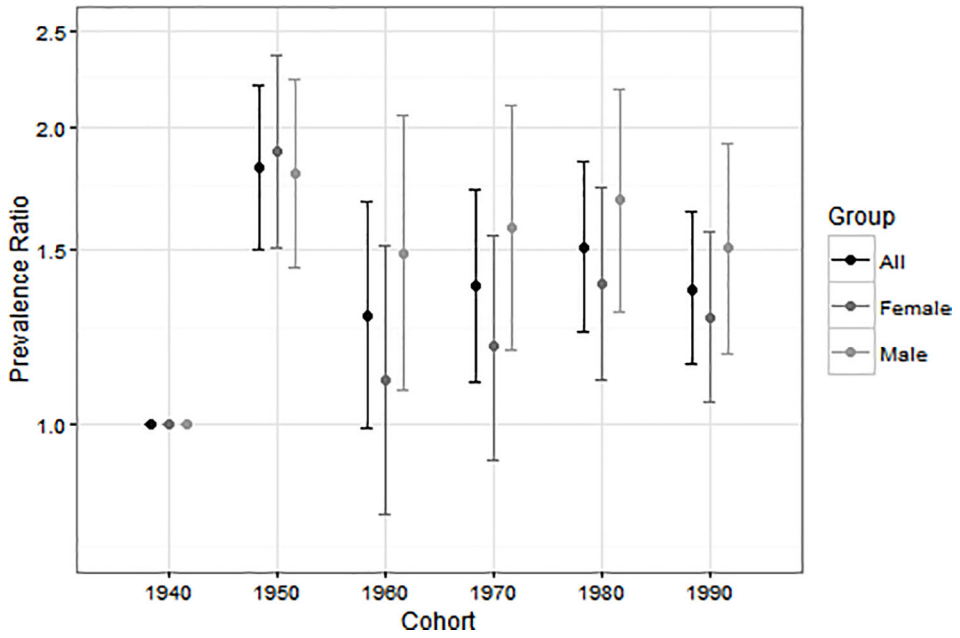

Figure 4.
Cohort effects on prevalence of past-month cannabis use

Table 1.

Study population characteristics by past-month cannabis use

	Past-month cannabis use (%)	
	No	**Yes**
Overall	90.1	9.9
Age		
15–17	87.8	12.2
18–21	80.3	19.7
22–25	84.1	15.9
26–29	88.8	11.2
30–34	91.5	8.5
35–49	94.6	5.4
Gender		
Female	92.8	7.2
Male	87.3	12.7
Race/ethnicity		
Non-hispanic black	88.6	11.4
Non-hispanic white	89.1	10.9
Hispanic	93.1	6.9
Asian	96.8	3.2
More than one race	83.5	16.5
Native american/AK native	87.1	12.9
Native HI/Pacific Islander	90.6	9.4
Education		
17 or younger	87.8	12.2
Less than high school	88.0	12.0
High school graduate	89.1	10.9
Some college	89.2	10.8
College graduate	93.8	6.2
Marital status		
Married	95.7	4.3
Not married	85.6	14.4
Employed		
Full-time	91.6	8.4
Part-time	87.4	12.6
18 or younger	87.8	12.2
Unemployed	83.3	16.7
Other	90.4	9.6
Family income		
< $20,000	86.0	14.0
$20,000-$49,999	89.4	10.6
$50,000-$74,999	91.5	8.5

	Past-month cannabis use (%)	
	No	Yes
≥ $75,000	92.5	7.5
Cigarette smoking status		
Current	78.2	21.8
Former	93.2	6.9
Never	97.5	2.5
Binge drink in past month[b]		
Yes	79.1	20.9
No	94.8	5.2
Chewing tobacco		
Never	91.4	8.6
Ever	82.4	17.6
Cocaine		
Never	93.9	6.1
Ever	72.5	27.5
Crack		
Never	91.2	8.8
Ever	65.8	34.2
Heroin		
Never	90.6	9.4
Ever	63.6	36.4
Ecstasy		
Never	92.9	7.1
Ever	60.3	39.7
LSD		
Never	92.9	7.1
Ever	68.7	31.3
Methamphetamine		
Never	91.1	8.9
Ever	71.2	28.8
Painkiller (non-medical use)		
Never	93.9	6.1
Ever	73.0	27.0
Overall health		
Excellent	92.6	7.4
Very good	89.8	10.2
Good	88.5	11.5
Fair	87.6	12.4
Poor	87.6	12.4

[a] Frequencies are weighted for NSDUH sampling structure and reflect combined NSDUH 2002–2014 data

[b] Binge-drinking is defined as 5 or more drinks in one setting