HHS Public Access

Author manuscript

Drug Alcohol Depend. Author manuscript; available in PMC 2019 October 01.

Published in final edited form as:

Drug Alcohol Depend. 2018 October 01; 191: 203–209. doi:10.1016/j.drugalcdep.2018.07.002.

The end of convergence in developmental patterns of frequent marijuana use from ages 18 to 30: An analysis of cohort change from 1976–2016

Yvonne M. Terry-McElrath[a,*], **Megan E. Patrick**[b], **Patrick M. O'Malley**[a], and **Lloyd D. Johnston**[a]

[a]Institute for Social Research, University of Michigan, PO Box 1248, Ann Arbor, MI 48106-1248, USA

[b]Institute for Translational Research in Children's Mental Health, Institute of Child Development, University of Minnesota, 1100 Washington Ave S., Suite 101, Minneapolis, MN 55414, USA

Abstract

Background: This study examines the extent to which the developmental pattern of frequent marijuana use prevalence from ages 18 to 30 (overall and by gender) has varied across historical time (cohort groups) using data from a national sample of US young adults.

Methods: Self-reported data on frequent marijuana use (use on 20+ occasions in the past 30 days) from modal ages 18 to 30 were obtained from 58,059 individuals from 29 sequential cohorts (graduating high school classes of 1976–2004) participating in the Monitoring the Future study. Time-varying effect modeling was used to model cohort group differences in developmental patterns of frequent use overall and by gender.

Results: Developmental patterns of frequent marijuana use prevalence varied meaningfully across cohort groups. Frequent use at age 18 differed significantly across cohort groups as expected based on national data. Among earlier cohort groups (reaching age 30 during 1987–2008), developmental patterns converged by age 30 to relatively low frequent marijuana use prevalence. In contrast, among cohort groups reaching age 30 during 2008–2016, frequent marijuana use at age 30 was significantly higher than all previous cohort groups. Observed cohort differences did not vary significantly by gender.

Conclusions: Cross-cohort convergence in developmental patterns of frequent marijuana use prevalence by age 30 was not observed among recent cohort groups, among whom age 30 frequent marijuana use prevalence was at the highest levels observed since the study began. Higher frequent

*Corresponding author.

Contributors

All authors contributed to the design and execution of this study. P.M. O'Malley, M.E. Patrick, and L.D. Johnston are co-investigators on the study that collected the data. Y.M. Terry-McElrath developed the initial research aims and scope of analyses, conducted analyses, and developed the initial manuscript. All authors assisted with writing and approved the final manuscript.

Conflict of interest

None.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.drugalcdep.2018.07.002.

marijuana use prevalence in late young adulthood has meaningful health risk and service provision implications.

Keywords

Frequent marijuana use; Time-varying effect modeling; Young adult; Developmental pattern; Developmental trajectory

1. Introduction

Previous research has shown that marijuana use prevalence typically increases from late adolescence through the early years of young adulthood (roughly ages 21/22) and then decreases thereafter (Bachman et al., 1997; Substance Abuse and Mental Health Services Administration, 2017 Schulenberg et al., 2005, 2017; Terry-McElrath and O'Malley, 2011). Trends in age-specific marijuana use prevalence clearly indicate marked changes across historical time (Centers for Disease Control and Prevention [CDC], 2015; Johnson et al., 2015; Miech et al., 2017;Substance Abuse and Mental Health Services Administration, 2017 Schulenberg et al., 2017), but few studies have examined the extent to which the typical developmental pattern of marijuana use prevalence across age changes over historical time. One study investigated historical change in the developmental pattern of marijuana use from ages 18 through 22 using data from 1976 to 2004 (Jager et al., 2013) and found evidence of a modest increase in the growth rate for past 30-day marijuana use frequency from ages 18 through 22 across cohorts of 12th graders followed into young adulthood. However, the study did not examine variation in the developmental pattern of marijuana use after age 22.

Possible historical change in the developmental pattern of higher-frequency marijuana use is particularly important. Those who use marijuana frequently are at heightened risk for many negative outcomes including addiction (Volkow et al., 2014), cognitive impairment (Gordon et al., 2013; Becker et al., 2014; Whitlow et al., 2004), some cancers (Gordon et al., 2013), and other health issues (Hézode et al., 2008; Ishida et al., 2008). Chronic higher-frequency marijuana use extending into the 30s or beyond is associated with particularly poor outcomes including increased anxiety symptoms, crime involvement, sexual risk behaviors, and abuse/dependence symptoms for marijuana, alcohol, and tobacco by age 33 (Epstein et al., 2015), lower verbal memory measured during the mid-40s to mid-50s (Auer et al., 2015), and higher likelihood of past 30-day cognitive health problems, past 12-month psychological visits, and lifetime psychiatric, drug, and alcohol problems by age 50 (Terry-McElrath et al., 2017). Thus, a developmental pattern that is consistent across historical time reflecting decreasing higher-frequency marijuana use from the mid-20 s onward is desirable from a public health viewpoint.

National data (Miech et al., 2017) show that use of marijuana on 20 or more occasions in the past 30 days (hereafter referred to as frequent marijuana use) among high school seniors reached a high of 10.7% in 1978, decreased over time to 1.9% in 1992, increased to 5.8% by 1997, and then remained between 5.0% and 6.6% from 1998 through 2016 (see Fig. 1). To the extent that the developmental pattern of frequent marijuana use from ages 18 through 30 has remained generally stable in form across cohorts (i.e., increasing from late adolescence

through roughly ages 21/22 and then decreasing thereafter), one would expect frequent marijuana use to remain highest through age 30 among individuals in high school cohorts of the late 1970s and early 1980s (cohorts with the highest age 18 frequent marijuana use) and to remain lowest for individuals in high school cohorts of the early 1990s (cohorts with the lowest age 18 frequent marijuana use). If, however, the developmental pattern has varied significantly across cohorts, the prevalence of frequent marijuana use by age 30 may not be accurately estimated based on use at age 18. Recent data show that frequent marijuana use among young adults is at historically high prevalence levels, including among those aged 27–30 (Schulenberg et al., 2017). Such historically high prevalence levels may indicate meaningful changes in the developmental pattern of frequent marijuana use across age.

There are recognized gender differences in marijuana use throughout adolescence and young adulthood. Marijuana use prevalence (including frequent use prevalence) is typically significantly higher for men than women from late adolescence throughout adulthood (Chen and Jacobson, 2012; Johnston et al., 2017, 2018; Miech et al., 2017; Substance Abuse and Mental Health Services Administration, 2016). Men increase marijuana use from mid- to late adolescence at a faster rate than women (Kuhn, 2015) and reach peak use at slightly later ages than women (Chen and Jacobson, 2012). Jager et al. (2013) found an increase over time in the growth rate for past 30-day marijuana use frequency for both men and women, but potential gender differences in the historical stability of the developmental pattern of marijuana use (particularly frequent marijuana use) from ages 18 through 30 have not been examined. The observed historically high prevalence levels of frequent marijuana use among those aged 27–30 have been found for both men and women (Schulenberg et al., 2017).

The current study adds to the marijuana use epidemiology literature by using longitudinal data from 29 national cohorts of high school seniors (classes of 1976–2004; data collected from 1976 to 2016) to examine the extent to which both overall and gender-specific developmental patterns of frequent marijuana use from ages 18 through 30 have varied across cohorts.

2. Methods

2.1. Sample

Analyses used data from the Monitoring the Future (MTF) study; detailed methodology is available elsewhere (Bachman et al., 2015; Miech et al., 2017; Schulenberg et al., 2017). Briefly, US nationally-representative samples of approximately 15,000 12th graders (modal age 18) from about 130 public and private schools in the contiguous 48 states have been surveyed annually since 1975. Students complete self-administered surveys, typically during a normal class period. Since 1976, a sub-sample of about 2400 12th graders has been selected from each annual sample for longitudinal follow-up (with drug users sampled at a higher rate). A random half of the follow-up sample receives a series of biennial follow-ups beginning one year after their senior year (model age 19); the other half receives a series of biennial follow-ups beginning two years after their senior year (modal age 20). Mailed questionnaires are used to collect data at six follow-up time points: modal ages 19/20, 21/22, 23/24, 25/26, 27/28, and 29/30. The resulting data include responses at all modal ages from

18 through 30 (although individual respondents provide data at a maximum of 7 modal ages). A University of Michigan Institutional Review Board approved the study.

Analysis was limited to cohorts who had the opportunity to complete all baseline and follow-up surveys through age 29/30 as of the date of analysis. The decision to focus on ages 18 through 30 was based on (a) the importance of the developmental period recognized as young adulthood (Institute of Medicine, National Research Council, 2015), (b) the fact that historically high prevalence levels for frequent marijuana use have recently been observed across the ages of 19–22, 23–26, and 27–30 (Schulenberg et al., 2017), and (c) expansion past the age of 30 would reduce the number of cohorts that could be included in analysis. Thus, the analytic sample was limited to 12th grade cohorts from 1976 to 2004 (age 29/30 data were collected during 2001–2016). A total of 70,843 individuals were selected for follow-up participation from relevant cohorts. Cases were limited to 58,076 respondents (82.0% of the original sample) who participated in baseline data collection and at least one of the six follow-up data collection efforts. Of these respondents, 58,059 (99.97%) provided data on frequent marijuana use on at least one occasion. The mean number of responses regarding frequent marijuana use per respondent in the resulting analytic dataset was 5.3 (range of 1–7). Males constituted 46.4% of respondents. Attrition adjustments are discussed below.

2.2. Measures

On each survey, respondents were asked, “On how many occasions (if any) have you used marijuana or hashish during the last 30 days?” (0, 1–2, 3–5, 6–9, 10–19, 20–39, and 40 or more occasions). In sensitivity analyses, two dichotomies were examined in regards to the study research questions: use on 20+ occasions versus use on 40+ occasions in the past 30 days. Results were not substantively different. For the current study, individuals who reported using on 20 or more occasions in the past 30 days were classified as frequent users. Gender was coded as male or female. Cohort (indicating year of baseline survey) was coded into seven non-overlapping groups sharing common patterns of change over historical time in age 18 frequent marijuana use prevalence described in the Introduction and shown in Fig. 1. A total of seven cohort groups were used to ensure (1) roughly equal numbers of cohorts per group and (2) that cohorts within each group reflected similar trends in age 18 frequent marijuana use prevalence. The specific cohort groups were: 1976–1979 (cohorts with highest age 18 frequent marijuana use prevalence); 1980–1983, 1984–1987, and 1988–1991 (cohorts reflecting rapidly decreasing prevalence); 1992–1996 (cohorts with increasing prevalence); and 1997–2000 and 2001–2004 (years of generally stable prevalence but well below 1976–1980 prevalence levels). The modal age of respondents at the 12th grade survey was 18; modal age increased with each year following the 12th grade survey with final values of 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, and 30. Hereafter, modal age will be referred to simply as age.

2.3. Analysis

Analyses were conducted using SAS 9.4. The research questions of interest in the current study focused on temporal change: how the effect of cohort group on frequent marijuana use varied across age both overall and by gender. Thus, traditional analytic methods such as

growth curve modeling were not used because the effect of cohort group would be assumed to be constant across age if cohort was used as a covariate, or, if cohort was used as a grouping variable, the growth rates would be required to be modeled using parametric assumptions across cohort groups. Instead, modeled age-varying prevalence and regression estimates were obtained using time-varying effect modeling (TVEM). TVEM was developed as a methodological technique to understand complex relations between processes that unfold over time where the associations between an outcome and one or more predictors can be modeled as time-invariant and/or time varying (Lanza et al., 2014). TVEM is a regression-based method of modeling relationships in longitudinal data between covariate(s) and an outcome over continuous time; no assumptions regarding the association's parametric form are made (Lanza et al., 2014; Li et al., 2015; Tan et al., 2012). TVEM assumes only that the relationship changes over time in a smooth manner (i.e., with no sudden break points; Tan et al., 2012). TVEM allows for inclusion of multiple time-varying and non-time-varying covariates; this was desirable due to interest in examining not only non-parametric cohort effects on frequent marijuana use across age but possible non-parametric time-varying interactions between gender and cohort group on frequent marijuana use across age. In the current analyses, no non-time-varying covariates were specified.

For the current analyses, time was operationalized as age in years as defined above. The SAS macro %WeightedTVEM (v. 2.6.0) (Dziak et al., 2017; Weighted TVEM SAS Macro, 2017) was used to fit TVEM models as shown (here predicting the log odds of any frequent marijuana use by cohort group as a continuous, smoothed function of age from 18 to 30):

$$\ln\left(\frac{P(FrequentMJUSE_{it}=1)}{1-P(FrequentMJUSE_{it}=1)}\right) = \beta_0(t) + \beta_1(t)Cohorts1980to83_i + \beta_2(t)Cohorts1984to87_i + \beta_3(t)Cohorts1988to91_i + \beta_4(t)Cohorts1992to96_i + \beta_5(t)Cohorts1997to00_i + \beta_6(t)Cohorts2001to04_i$$

where t indicates continuous age, and i denotes data for individual i. Here, β_0 (the intercept) reflects the log-odds of frequent marijuana use for individuals in the earliest cohort group (1976–1979); β_1 through β_6 are slope functions describing age-varying associations between cohort group (referent = cohort group 1976-1979) and frequent marijuana use.

The %WeightedTVEM macro allows for modeling of clustering and survey weights, supports unpenalized B-splines without random effects, and provides robust standard errors using Taylor linearization (Dziak et al., 2017). The macro uses the SAS SURVEYLOGISTIC procedure for analyses with binary outcomes (such as those modeled here). Comparison of pseudolikelihood AIC and BIC values from unpenalized B-splines are

used to select the optimal number of knots (corresponding to smoothness) for each coefficient function. Figures present coefficient functions in the form of odds ratios (ORs) and point-wise 99% confidence intervals (CIs) for each smoothed point along continuous age. For points when CIs do not contain 1.0, coefficients are significant at $p < .01$ ($p < .01$ was selected as appropriate given the large sample size).

To test for overall cohort group differences in the developmental pattern of frequent marijuana use, TVEM models regressed frequent use on dichotomous cohort group terms using 1976–1979 as the referent. To test for differences by gender in observed cohort-specific patterns, TVEM models regressed frequent use on cohort group terms (using 1976–1979 as the referent), gender (using female as the referent), and gender by cohort group interactions. Intercept-only TVEM models provided figures showing unadjusted developmental patterns of frequent marijuana use by cohort group across age overall and by gender. All analyses accounted for clustering of repeated measures within individuals. Further, all analyses were weighted using follow-up specific attrition weights, calculated as the inverse of the probability of responding at each age based on covariates measured at age 18 (gender, race/ethnicity, college plans, high school grades, number of parents in the home, religiosity, parental education, alcohol use, cigarette use, marijuana use, region of country, cohort, and sampling weight correcting for over-sampling of age 18 substance users).

3. Results

3.1. Overall cohort group differences in developmental patterns of frequent marijuana use

Fig. 2 presents the modeled estimates of frequent marijuana use by cohort group. Supplemental Fig. 1 presents odds ratios of frequent marijuana use by cohort group (referent = 1976–1979, the cohort group characterized by the highest age 18 frequent marijuana use prevalence levels). As expected based on trends reported in Fig. 1, cohort groups varied significantly in regards to prevalence at age 18. Under the assumption that developmental patterns of frequent marijuana use have remained generally stable across cohorts, we expected to observe that frequent marijuana use prevalence would remain highest through age 30 among individuals in the earliest cohorts (those with the highest age 18 frequent marijuana use) and would remain lowest for individuals in cohorts of the early 1990s (cohorts with the lowest age 18 frequent marijuana use). However, the developmental patterns for the first five cohort groups converged by age 30. That is, regardless of differences in frequent marijuana use prevalence at age 18 between the first five cohort groups, by age 30, no significant differences in prevalence remained. Among the first five cohort groups, age 18 frequent marijuana use prevalence ranged from 1.9% (99% CI 1.6, 2.2) to 8.6% (8.1, 9.2). By age 30, prevalence in these cohort groups ranged only from 2.3% (1.7, 3.0) to 3.8% (2.3, 3.8).

Among the earlier cohort groups, convergence by age 30 was possible only because of very different developmental patterns of frequent marijuana use from ages 18 to 30. While some cohort groups (e.g., 1976–1979) followed a clear pattern of increasing use during the early 20s followed by rapidly decreasing prevalence, others (e.g., 1988–1991) actually reflected higher prevalence by age 30 than was observed at age 18. These cohort group differences in

developmental patterns are likely associated with macro-level social changes affecting marijuana use at all ages. For example, individuals in the 1976–1979 cohorts reached age 30 during the years 1987–1991. Age 18 frequent marijuana use prevalence decreased strongly during these years (see Fig. 1); this trend likely helped drive prevalence down as individuals aged. In contrast, individuals in the 1988–1991 cohorts reached age 30 during 1999–2003. As Fig. 1 shows, age 18 frequent marijuana use prevalence reached its lowest levels recorded in the MTF survey during these years (1992), followed by increasing prevalence through 1997 and generally stable use thereafter. Thus, as individuals from the 1988–1991 cohorts aged, social trends may have encouraged higher prevalence over age.

The developmental patterns of frequent marijuana use among the two more recent cohort groups (1997–2000 and 2001–2004) did not reflect the age 30 convergence observed in earlier cohort groups' developmental patterns. Among these more recent cohort groups, frequent marijuana use prevalence by age 30 diverged from prior cohort groups and reached 4.0% (3.2, 5.0) for 1997–2000 and 5.1% (4.0, 6.7) for 2001–2004. In fact, the prevalence of frequent marijuana use at age 30 among individuals in the most recent cohort group (2001–2004) was significantly higher than in all prior cohort groups other than 1997–2000.

3.2. Gender and cohort group differences in the developmental pattern of frequent marijuana use

In the TVEM model regressing frequent marijuana use on gender, cohort group, and gender by cohort group interaction terms (referent = 1976–1979), none of the gender by cohort group interaction terms were statistically significant at any age, indicating that the cohort-related changes in the developmental pattern of frequent marijuana use from ages 18 to 30 did not vary significantly between men and women (figures reporting resulting non-significant coefficients not shown). Given the lack of significant interactions, Fig. 3 presents gender-specific modeled estimates of frequent marijuana use by cohort group. Men reported significantly higher prevalence of frequent marijuana use than women across ages 18 to 30 for most cohort groups (prevalence converged at age 30 for men and women in the 1980–1983, 1984–1987, and 2001–2004 cohort groups), yet the degree to which developmental patterns changed across cohorts did not differ significantly between men and women. While frequent marijuana use prevalence varied significantly at age 18 across cohort groups for both men and women, by age 30, convergence was observed in the developmental patterns for all cohort groups other than 2001–2004. By age 30, frequent marijuana use prevalence was significantly higher for men and women in the most recent cohort group (2001–2004) compared with the first cohort group (1976–1979): 6.9% (4.9, 9.7) versus 4.1% (3.1, 5.2) for men and 3.8% (2.6, 5.6) versus 1.6% (1.1, 2.3) for women.

4. Discussion

Using national samples of US high school graduates, the current study found that developmental patterns of frequent marijuana use prevalence across ages 18–30 showed meaningful variation across cohorts. Among earlier cohort groups (1976–1979, 1980–1983, 1984–1987, 1988–1991, and 1992–1996), by age 30, developmental patterns of frequent marijuana use prevalence converged regardless of significant differences in prevalence

observed from ages 18 through the early 20s. Similar convergence by age 30 was not observed for the more recent cohort groups of 1997–2000 and 2001–2004. By age 30, individuals from the more recent cohort groups reported higher frequent marijuana use prevalence levels than all other cohort groups among the sample overall. No significant differences between men and women were found in regards to cohort group differences in the developmental pattern of frequent marijuana use from ages 18 to 30.

Results from the current study indicated that developmental patterns of frequent marijuana use from ages 18 through 30 have not been consistent over historical time. Work by Jager et al. (2013) had identified meaningful cohort differences in the growth rate of marijuana use frequency from age 18 through 22. The current study found that developmental patterns of frequent marijuana use from the early 20s through age 30 exhibited significant change across cohorts. Some of the observed changes are likely attributable to broader social trends in marijuana use (as discussed in Section 3.1). However, the notable change from developmental pattern convergence by age 30 (with generally low frequent marijuana use prevalence of approximately 2%−3% for cohort groups 1976–1979 through 1992–1996) to diverging significantly higher age 30 prevalence among more recent cohort groups (approximately 4%−5% for cohort groups 1997–2000 and 2001–2004) is cause for concern. While 4%−5% may appear to represent only a small number of individuals, based on U.S. Census Bureau estimates, 4.5% of those who were 30 years of age during 2008–2016 is estimated to be approximately 1.7 million individuals (U.S. Census Bureau, 2004, 2014).

As noted previously, those who use marijuana frequently are at increased risk for addiction, cognitive impairment, and other health concerns (Becker et al., 2014; Gordon et al., 2013; Volkow et al., 2014; Whitlow et al., 2004; Hézode et al., 2008; Ishida et al., 2008), and the highest health risks are associated with chronic use that extends into age 30 and beyond (Auer et al., 2015; Epstein et al., 2015; Terry-McElrath et al., 2017). Results from the current study indicate that the number of individuals at high risk for such negative health outcomes due to frequent marijuana use at age 30 has increased markedly among recent cohorts. Increased prevalence of frequent marijuana use among those entering their 30s is also likely to increase a range of other social and economic costs associated with marijuana use including decreased job productivity (Hickox, 2012) and motor vehicle injuries and fatalities (Asbridge et al., 2012; Hartman and Huestis, 2013), etc.

The risks associated with higher frequent marijuana use prevalence for those in more recent cohort groups have also risen due to the consistently increasing potency of marijuana in the US. Analysis of illicit marijuana and related cannabis products seized by the US Drug Enforcement Administration shows that average potency (i.e., Δ^9-tetrahydrocannabinol or THC content) has increased significantly since 1992 from approximately 3% to approximately 12% in 2014 (ElSohly et al., 2000, 2016). At the same time, other compounds in marijuana such as cannabidiol or CBD (the primary therapeutic agent in marijuana for conditions such as chronic pain, etc.) have been decreasing (ElSohly et al., 2016). While CBD is believed to be neuroprotective, THC has been found to exacerbate alterations in brain regions such as the prefrontal cortex and hippocampus, and higher doses of marijuana use are particularly associated with such alterations (Lorenzetti et al., 2016). In states with legal marijuana markets (such as Washington), average THC levels for cannabis extracts

have been found to be more than three times those for cannabis flowers (Smart et al., 2017). Frequent use of high-potency marijuana has been associated with dependence severity (Freeman and Winstock, 2015), and increases in potency have been linked with increases in first-time admissions to drug treatment for problems associated with cannabis (Freeman et al., 2018). It may be that one factor influencing higher prevalence of frequent marijuana use by age 30 for individuals in the more recent cohorts is higher potency and associated higher levels of dependence.

An additional factor that may be associated with the higher prevalence of frequent marijuana use by age 30 in recent cohorts is the observed weakening of the association between perceived risk of marijuana use and actual use among recent cohorts of US young adults. Specifically, research indicates that for individuals who were high school seniors in both 1990–1994 and 1995–1999 cohort groups, the statistical association between perceived risk and marijuana use generally was consistent across ages 18 through 30, but for individuals in the 2000–2004 cohort group, the association weakened from the mid- to late 20s (Terry-McElrath et al., in press). Individuals from the more recent cohorts have experienced a much different marijuana policy landscape than those from earlier cohorts, most notably the emerging state-level legalization of adult recreational marijuana use. Change in the policy landscape toward legalization has resulted in arguably lower risks for marijuana use in regards to arrest, prosecution, penalty severity, and even social/relational risks (Terry-McElrath et al., in press). A weaker perceived risk/use association during the mid- to late 20s would be consistent with higher frequent marijuana use prevalence levels during these ages.

While the current study cannot determine the specific factors at play, the lack of continued decrease in frequent marijuana use prevalence through the end of young adulthood indicates a need for increased interventions aimed at use reduction or cessation specifically targeting individuals in their late 20s and early 30s. The current paper spans older adolescents (in their final year of high school) to young adults entering their 30s (navigating decisions and roles related to family and work). The different developmental tasks and roles of these ages have been associated with change in the likelihood of substance use in several prior publications (e.g., Bachman et al., 1997, 2002; Kandel et al., 1986; Kandel and Raveis, 1989; Staff et al., 2010). According to a lifespan developmental stage-approach to substance use programming, each developmental stage calls for unique program characteristics for successful development and implementation (Sussman, 2013). Such efforts should be targeted toward men and women equally, as the current study's findings show no significant differences between men and women in regards to observed cohort differences. While the overall number of frequent marijuana users who are men continued to be higher than women from ages 18 through 29, both genders experienced significantly higher frequent marijuana use prevalence by age 30 among recent cohorts than earlier cohorts. Among the most recent cohort group, no significant differences in frequent marijuana use prevalence were observed between men and women at age 30.

4.1. Strengths and limitations

While the current study has several notable strengths (including large representative samples, consistent measurement over 40 years, longitudinal data spanning ages 18 through 30, and use of an innovative analytical methodology), the results should be considered within their limitations. Given that the sample for this study involved high school seniors, results may not generalize to individuals who drop out of high school before 12th grade; lower educational attainment has been found to be significantly associated with higher marijuana and other substance use (Tice et al., 2017). Data were based on self-reports; however, such data have been found to be reasonably reliable and valid under conditions provided in the MTF study (Brener et al., 2003; Miech et al., 2017; O'Malley et al., 1983). While attrition may also have affected generalizability, the use of attrition weighting has been found to provide reasonable adjustment for nonresponse in other school-based samples (McGuigan et al., 1997). Finally, the current analyses utilize a single measure of marijuana use reflecting use on 20+ occasions in the past 30 days. More detailed measures of marijuana use (e.g., further differentiating the number of days of use and number of use occasions per day of use or measures of heavier use) would be informative. These limitations notwithstanding, the current study provides important results that contribute significantly to available knowledge on the developmental patterns of frequent marijuana use among US young adults in recent decades.

5. Conclusions

Developmental patterns of frequent marijuana use from ages 18 through 30 exhibited meaningful change across cohorts for both men and women. While earlier cohort groups evidenced convergence in frequent marijuana use prevalence by age 30, more recent cohort groups exhibited significantly higher prevalence levels of frequent marijuana use prevalence by age 30. There is a growing number of adults (both men and women) at high risk for the negative effects associated with frequent marijuana use.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Role of the funding source

This work was supported by the National Institute on Drug Abuse (DA001411, DA016575, and DA037902). The National Institute on Drug Abuse had no further role in the study design; in the collection, management, analysis, and interpretation of the data; in the writing of the manuscript; or in the decision to submit the paper for publication. The views expressed in this article are those of the authors and do not necessarily reflect the views of the funders.

References

Asbridge M, Hyden JA, Cartwright JL, 2012 Acute cannabis consumption and motor vehicle collision risk: systematic review of observational studies and meta-analysis. BMJ 344 e536. [PubMed: 22323502]

Auer R, Vittinghoff E, Yaffe K, Künzi A, Kertesz SG, Levine DA, Albanese E, Whitmer RA, Jacobs DR Jr., Sidney S, Glymour M, Pletcher MJ, 2015 Association between lifetime marijuana use and cognitive function in middle age: The Coronary Artery Risk Development in Young Adults (CARDIA) study. JAMA Intern. Med. 176, 352–361.

Bachman JG, Wadsworth KN, O'Malley PM, Johnston LD, Schulenberg J, 1997 Smoking, Drinking and Drug Use in Young Adulthood: the Impacts of New Freedoms and New Responsibilities. Lawrence Erlbaum Associates, Mahwah, NJ.

Bachman JG, O'Malley PM, Schulenberg JE, Johnston LD, Bryant AL, Merline AC, 2002 The Decline of Substance Use in Young Adulthood: Changes in Social Activities, Roles, and Beliefs. Lawrence Erlbaum Associates, Mahwah, NJ.

Bachman JG, Johnston LD, O'Malley PM, Schulenberg JE, Miech RA, 2015 The Monitoring the Future Project After Four Decades: Design and Procedures (Monitoring the Future Occasional Paper No. 82) Institute for Social Research, University of Michigan, Ann Arbor, MI.

Becker MP, Collins PF, Luciana M, 2014 Neurocognition in college-aged daily marijuana users. J. Clin. Exp. Neuropsychol. 36, 379–398. [PubMed: 24620756]

Brener ND, Billy JOG, Grady WR, 2003 Assessment of factors affecting the validity of self-reported health-risk behavior among adolescents: evidence from the scientific literature. J. Adolesc. Health 33, 436–457. [PubMed: 14642706]

Centers for Disease Control and Prevention [CDC], 2015 Trends in the Prevalence of Marijuana, Cocaine, and Other Illegal Drug Use National YRBS: 1991-2015 Fact Sheet. Centers for Disease Control and Prevention. Atlanta.

Chen P, Jacobson KC, 2012 Developmental trajectories of substance use from early adolescence to young adulthood: gender and racial/ethnic differences. J. Adolesc. Health 50, 154–163. [PubMed: 22265111]

Dziak JJ, Li R, Wagner AT, 2017 Weighted TVEM SAS Macro Users' Guide (Version 2.6). The Methodology Center, Penn State, University Park, PA.

ElSohly MA, Ross SA, Mehmedic A, Arafat R, Yi B, Banahan III BF, 2000 Potency trends of Δ^9-THC and other cannabinoids in confiscated marijuana from 180– 1997. J. Forensic Sci. 43, 24–30.

ElSohly MA, Mehmedic Z, Foster S, Gon C, Chandra S, Church JC, 2016 Changes in cannabis potency over the last 2 decades (1995–2014): analysis of current data in the United States. Biol. Psychiatry 79, 613–619. [PubMed: 26903403]

Epstein M, Hill KG, Nevell AM, Guttmannova K, Bailey JA, Abbott RD, Kosterman R, Hawkins JD, 2015 Trajectories of marijuana use from adolescence into adulthood: environmental and individual correlates. Dev. Psychol. 51, 1650–1663. [PubMed: 26389603]

Freeman TP, Winstock AR, 2015 Examining the profile of high-potency cannabis and its association with severity of cannabis dependence. Psychol. Med. 45, 3181–3189. [PubMed: 26213314]

Freeman TP, van der Pol P, Kuijpers W, Wisselink J, Das RK, Rigter S, van Laar M, Griffiths P, Swift W, Niesink R, Lynskey MT, 2018 Changes in cannabis potency and first-time admissions to drug treatment: a 16-year study in the Netherlands. Psychol. Med. 31 (January), 1–7. 10.1017/S0033291717003877.

Gordon AJ, Conley JW, Gordon JM, 2013 Medical consequences of marijuana use: a review of current literature. Curr. Psychiatry Rep. 15, 419. [PubMed: 24234874]

Hartman RL, Huestis MA, 2013 Cannabis effects on driving skills. Clin. Chem. 59, 478–492. [PubMed: 23220273]

Hezode C, Zafrani ES, Roudot-Thoraval F, Costentin C, Hessami A, Bouvier-Alias M, Medkour F, Pawlostky J-M, Lotersztajn S, Mallat A, 2008 Daily cannabis use: a novel risk factor of steatosis severity in patients with chronic hepatitis C. Gastroenterology 134, 432–439. [PubMed: 18242211]

Hickox SA, 2012 Drug testing of medical marijuana users in the workplace: an inaccurate test of impairment. Hofstra Lab. Emp. L. J. 29, 273–341.

Institute of Medicine, National Research Council, 2015 Investing in the Health and Well-being of Young Adults. The National Academies Press, Washington, DC.

Ishida JH, Peters MG, Jin C, Louie K, Tan V, Bacchetti P, Terrault NA, 2008 Influence of cannabis use on severity of hepatitis C disease. Clin. Gastroenterol. Hepatol. 6, 69–75. [PubMed: 18166478]

Jager J, Schulenberg JE, O'Malley PM, Bachman JG, 2013 Historical variation in drug use trajectories across the transition to adulthood: the trend towards lower intercepts and steeper, ascending slopes. Dev. Psychopathol. 25, 527–543. [PubMed: 23627961]

Johnson RM, Fairman B, Gilreath T, Xuan Z, Rothman EF, Parnham T, Furr-Holden CDM, 2015 Past 15-year trends in adolescent marijuana use: differences by race/ethnicity and sex. Drug Alcohol Depend. 155, 8–15. [PubMed: 26361714]

Johnston LD, Schulenberg JE, O'Malley PM, Bachman JG, Miech RA, Patrick ME, 2017 Demographic Subgroup Trends Among Young Adults in the Use of Various Licit and Illicit Drugs, 1988–2016 (Monitoring the Future Occasional Paper 89). Institute for Social Research, University of Michigan, Ann Arbor, MI.

Johnston LD, Miech RA, O'Malley PM, Bachman JG, Schulenberg JE, Patrick ME, 2018 Demographic Subgroup Trends Among Adolescents in the Use of Various Licit and Illicit Drugs, 1975–2017 (Monitoring the Future Occasional Paper No. 90). Institute for Social Research, University of Michigan, Ann Arbor, MI.

Kandel DB, Raveis VH, 1989 Cessation of illicit drug use in young adulthood. Arch. Gen. Psychiatry 46, 109–116. [PubMed: 2913970]

Kandel D, Simcha-Fagan O, Davies M, 1986 Risk factors for delinquency and illicit drug use from adolescence to young adulthood. J. Drug Issues 16, 67–90.

Kuhn C, 2015 Emergence of sex differences in the development of substance use and abuse during adolescence. Pharmacol. Ther. 153, 55–78. [PubMed: 26049025]

Lanza ST, Vasilenko SA, Liu X, Li R, Piper ME, 2014 Advancing the understanding of craving during smoking cessation attempts: a demonstration of the time-varying effect model. Nicotine Tob. Res. 16, S127–S134. [PubMed: 23975881]

Li R, Dziak JJ, Tan X, Huang L, Wagner AT, Yang J, 2015 TVEM (Time-varying Effect Modeling) SAS Macro Users' Guide (Version 3.1.0). The Methodology Center, Penn State, University Park, PA.

Lorenzetti V, Solowij N, Yücel M, 2016 The role of cannabinoids in neuroanatomic alterations in cannabis users. Biol. Psychiatry 79, e17–e31. [PubMed: 26858212]

McGuigan KA, Ellickson PL, Hays RD, Bell RM, 1997 Adjusting for attrition in school-based samples. Eval. Rev. 21, 554–567.

Miech RA, Johnston LD, O'Malley PM, Bachman JG, Schulenberg JE, Patrick ME, 2017 Monitoring the Future National Survey Results on Drug Use, 1975-2016: Volume I, Secondary School Students. Institute for Social Research, The University of Michigan, Ann Arbor.

O'Malley PM, Bachman JG, Johnston LD, 1983 Reliability and consistency of self-reports of drug use. Int. J. Addict. 18, 805–824. [PubMed: 6605313]

Schulenberg JE, Merline AC, Johnston LD, O'Malley PM, Bachman JG, Laetz VB, 2005 Trajectories of marijuana use during the transition to adulthood: the big picture based on national panel data. J. Drug Issues 35, 255–279. [PubMed: 16534532]

Schulenberg JE, Johnston LD, O'Malley PM, Bachman JG, Miech RA, Patrick ME, 2017 Monitoring the Future National Survey Results on Drug Use, 1975-2016: Volume II, College Students and Adults Ages 19-55. Institute for Social Research, The University of Michigan, Ann Arbor.

Smart R, Caulkins JP, Kilmer B, Davenport S, Midgette G, 2017 Variation in cannabis potency and prices in a newly legal market: evidence from 30 million cannabis sales in Washington state. Addiction 112, 2167–2177. [PubMed: 28556310]

Staff J, Schulenberg JE, Maslowsky J, Bachman JG, O'Malley PM, Maggs JL, Johnston LD, 2010 Substance use changes and social role transitions: proximal developmental effects on ongoing trajectories from late adolescence through early adulthood. Dev. Psychopathol. 22, 917–932. [PubMed: 20883590]

Substance Abuse and Mental Health Services Administration, 2016 Results From the 2015 National Survey on Drug Use and Health: Detailed Tables Substance Abuse and Mental Health Services Administration, Center for Behavioral Health Statistics and Quality, Rockville, MD.

Substance Abuse and Mental Health Services Administration, 2017 Key Substance Use and Mental Health Indicators in the United States: Results From the 2016 National Survey on Drug Use and Health (HHS Publication No. SMA 17-5044, NSDUH Series H-52) Substance Abuse and Mental

Health Services Administration, Center for Behavioral Health Statistics and Quality, Rockville, MD.

Sussman S, 2013 A lifespan developmental-stage approach to tobacco and other drug abuse prevention. ISRN Addict., 745783.

Tan X, Shiyko MP, Li R, Li Y, Dierker L, 2012 A time-varying effect model for intensive longitudinal data. Psychol. Methods 17, 61–77. [PubMed: 22103434]

Terry-McElrath YM, O'Malley PM, 2011 Substance use and exercise participation among young adults: parallel trajectories in a national cohort-sequential study. Addiction 106, 1855–1865. [PubMed: 21561496]

Terry-McElrath YM, O'Malley PM, Johnston LD, Bray BC, Patrick ME, Schulenberg JE, 2017 Longitudinal patterns of marijuana use across ages 18-50 in a US national sample: a descriptive examination of predictors and health correlates of repeated measures latent class membership. Drug Alcohol Depend. 171, 70–83. [PubMed: 28024188]

Terry-McElrath YM, Patrick ME, O'Malley PM, 2018 Stability and change in perceived risk associations with binge drinking and marijuana use among US young adults: a national study, 1990–2016. in press Terry-McElrath YM, VanderWaal CJ, Baltazar AM, Trim DJB (Eds.), Promoting the Public Good: Policy in the Public Square and the Church. Avondale Academic Press, Cooranbong; Office of Archives, Statistics and Research, General Conference of Seventh-Day Advenstists.

Tice P, Lipari RN, Van Horn SL, 2017 Substance Use Among 12th Grade Aged Youths, by Dropout Status Substance Abuse and Mental Health Services Administration, Center for Behavioral Health Statistics and Quality, Rockville, MD.

U.S. Census Bureau, 2004 U.S. Interim Projections by Age, Sex, Race, and Hispanic Origin. U.S. Census Bureau, Washington, D.C.

U.S. Census Bureau, 2014 Projected Population by Single Year of Age, Sex, Race, and Hispanic Origin for the United States: 2014 to 2060, 2014 National Population Projections. U.S. Census Bureau, Washington, D.C.

Volkow ND, Baler RD, Compton WM, Weiss SRB, 2014 Adverse health effects of marijuana use. N. Engl. J. Med. 370, 2219–2227. [PubMed: 24897085]

Weighted TVEM SAS Macro, 2017 (Version 2.6.0) [Software]. The Methodology Center, Penn State, University Park, PA.

Whitlow CT, Ligouri A, Livengood LB, Hart SL, Mussat-Whitlow BJ, Lamborn CM, Laurienti PJ, Porrino LJ, 2004 Long-term heavy marijuana users make costly decisions on a gambling task. Drug Alcohol Depend. 76, 107–111. [PubMed: 15380295]

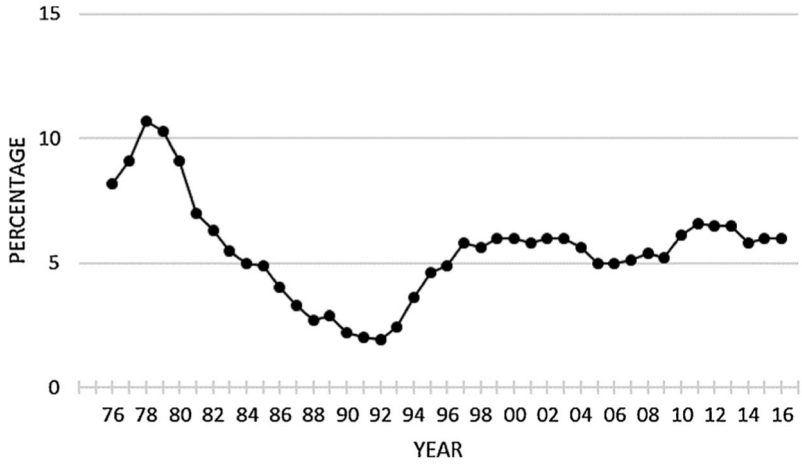

Fig. 1.

Historical trends in prevalence of past 30-day frequent marijuana use in grade 12.

Note: Frequent use defined as use on 20 or more occasions in the last 30 days. *Source*: The Monitoring the Future Study, the University of Michigan (Miech et al., 2017).

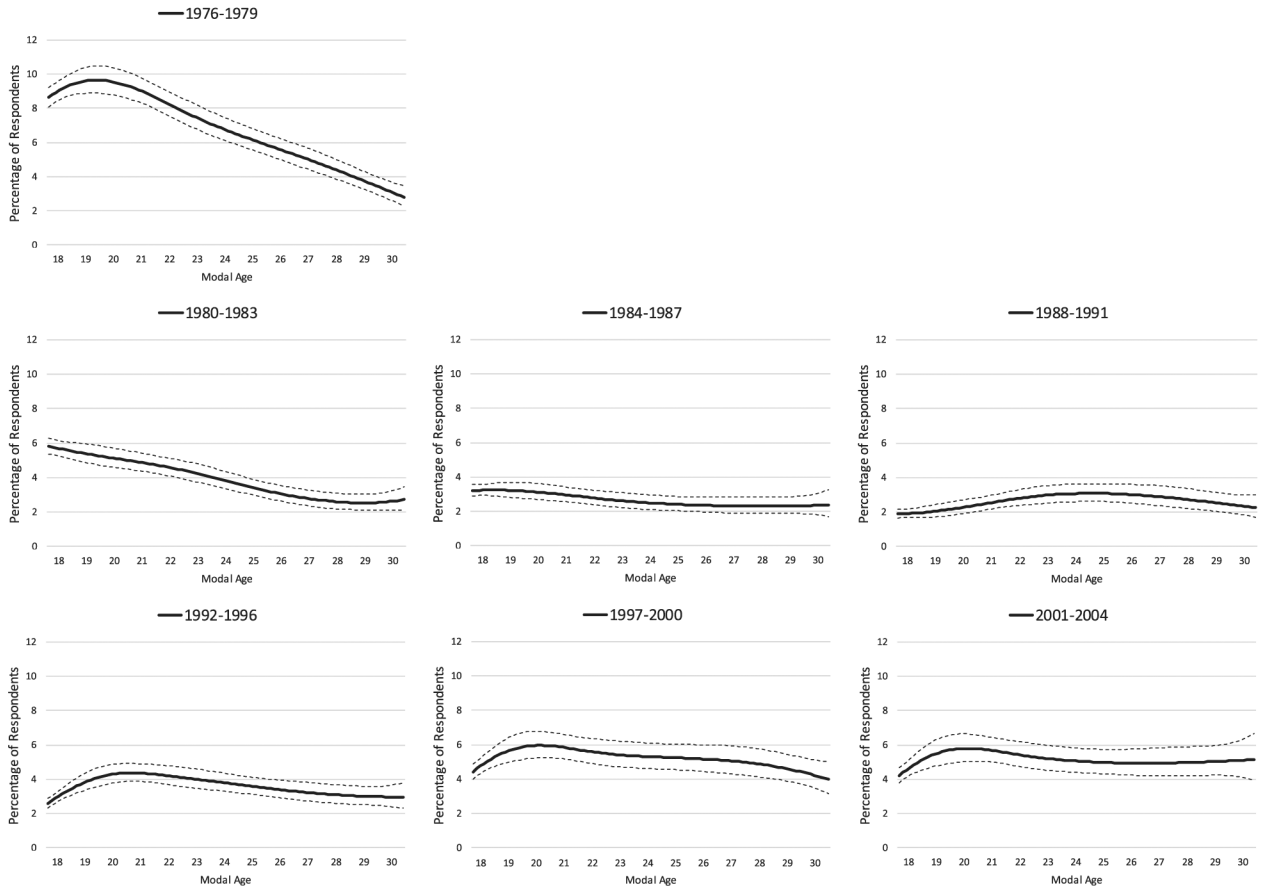

Fig. 2.

Modeled prevalence of frequent marijuana use among US young adults aged 18 through 30 by cohort groups.

Notes: N (unwtd.) = 310,197 time points from 58,059 individuals. Estimates obtained from time-varying effect models. Dotted lines indicate 99% confidence intervals. Frequent marijuana use defined as using on 20 or more occasions in the past 30 days.

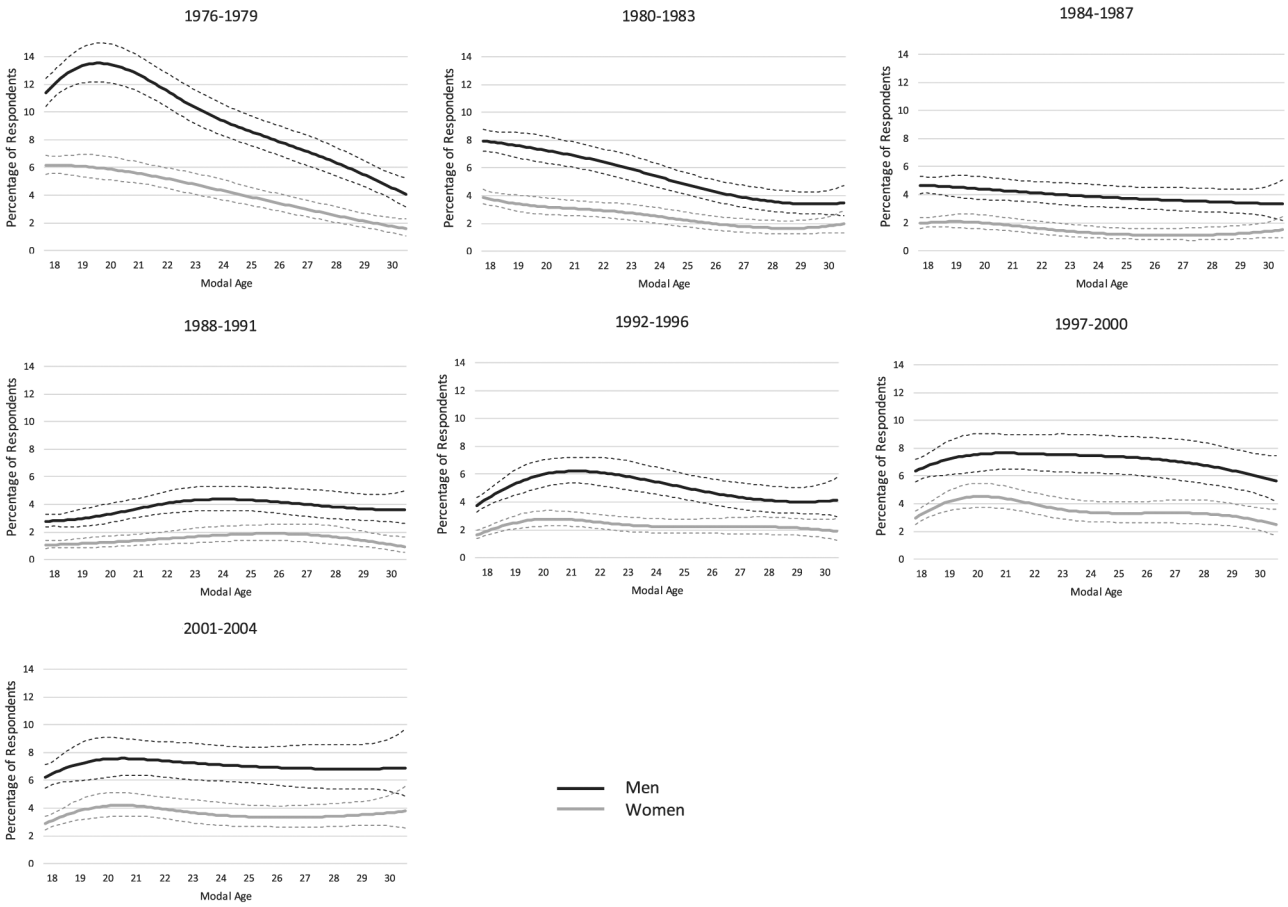

Fig. 3.

Modeled prevalence of frequent marijuana use among US young adults aged 18 through 30 by gender and cohort groups.

Notes: N (unwtd.) = 173,029 time points from 31,148 women; 137,168 time points from 26,911 men. Estimates obtained from time-varying effect models. Dotted lines indicate 99% confidence intervals. Frequent marijuana use defined as using on 20 or more occasions in the past 30 days.