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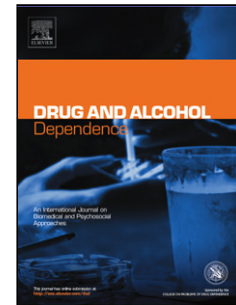
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Falling rates of marijuana dependence among heavy users

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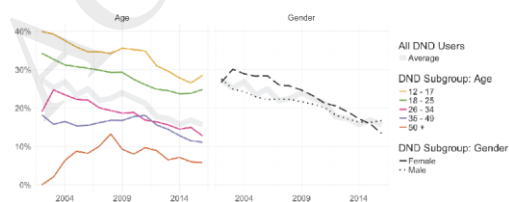
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Graphical abstract



Highlights

- For Daily/Near-Daily (DND) users, DSM-IV dependence fell from 26.5% to 16.1%
- Decreases held for all DND age and gender subgroups, save for users over 50
- No significant change in population-level dependence was detected
- Among symptomatic criterion, all but one (increasing tolerance) fell significantly
- Potential causal drivers include changing products, policies, or attitudes

Abstract

Introduction: Marijuana use has become increasingly popular in the United States since the turn of the century, and typical use patterns among past-month marijuana users have intensified, raising concerns for an increase in cannabis use disorders (CUDs). Yet the population prevalence of CUDs has mostly remained flat. We analyzed trends in DSM-IV marijuana dependence among Daily/Near-Daily (DND) users, both overall and by age and gender, and considered potential explanations.

Methods: Using data assembled from the National Survey on Drug Use and Health (2002-2016), rates of self-reported dependence and constituent symptoms are calculated for DND marijuana users; logistic regressions with pre- and post- periods (2002-2004, 2014-2016) and a Cochrane-Armitage trend test are applied to describe temporal changes.

Results: Dependence among DND users fell by 39% (26.5%-16.1%; $p<0.001$), with significant trend. No significant change is detected at the population level. Sub-group analysis shows a steep gradient for age but not for gender. Declines are robust to sub-group analysis, except for users over 50 years old. Among dependence symptoms, most showed significant declines: reducing important activities ($p<0.001$); use despite emotional, mental, or physical problems ($p<0.001$);

failing attempts to cutback ($p<0.001$); lots of time getting, using, or getting over marijuana ($p<0.01$); and failing to keep limits set on use ($p<.05$). Reported tolerance showed no significant change.

Conclusions: Though it is unclear why, the risk of dependence formation among heavy marijuana users appear to have declined since 2002. Further research is warranted regarding explanations related to state marijuana policies, product forms, or social context.

Keywords: marijuana; cannabis; dependence; United States; National Survey on Drug Use and Health; NSDUH

1. Introduction

Since the turn of the century, the United States has seen dramatic changes in marijuana policy, use, and social context. Eight states and Washington DC have legalized possession, use, production, and sale of marijuana for non-medical use; more than thirty states have legalized some form of medical marijuana, often with dispensaries. Perceptions of marijuana's risks have been falling (Pacek et al., 2015), and approval for legalization is now nearly two-thirds (Gallup, 2017). Marijuana use has also changed in other ways, e.g., increasing THC potency, an increasing acceptance and availability of marijuana for medical use, and rising popularity of alternative forms of consumption such as edibles, portable vaporizers, and "dabbing" solid concentrates (Davenport and Caulkins, 2016; Kilmer et al., 2014).

Marijuana use has been on an upward trend since roughly the mid-1990s, and intensifying since 2007 (Carliner et al., 2017). The portion of Americans 12 years or older reporting past-month marijuana use rose from 6.2% in 2002 to 8.9% in 2016 (Center for

Behavioral Health Statistics and Quality, 2017a). Even among past-month marijuana users, use habits have intensified, for instance as measured by the portion of past-month users reporting daily or near-daily (“DND”) use, i.e., use on more than 20 of the past 30 days, which tripled from one-in-nine in 1994 to one-in-three in 2014. DND users dominate the marijuana market, accounting for 68% of use days and 60% of expenditures in 2012-2013. In total, the number of days of marijuana use reported to NSDUH increased by more than half from 2002-2003 to 2012-2013 (Davenport and Caulkins, 2016).

Use disorders are an important risk of marijuana use. The Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) provides definitions of marijuana abuse and dependence, with diagnostic criteria including spending a great time using or getting marijuana, increasing tolerance, continued use despite physical or mental problems, and reduced time spent on important activities; with the notable exclusion of withdrawal symptoms, due to a lack of evidence at the time of publication (American Psychiatric Association, 2000; Hasin et al., 2013). Questions corresponding to these criteria have been asked by the National Survey on Drug Use and Health (NSDUH) for decades, allowing for the calculation of prevalence of cannabis abuse and/or dependence based on self-reported symptoms.

Though the NSDUH questionnaire remains unchanged, the DSM-V has since introduced changes relating to cannabis use disorders (American Psychiatric Association, 2013; Center for Behavioral Health Statistics and Quality, 2016). First, the DSM-V changed the diagnostic threshold for cannabis use disorder, merging cannabis abuse and dependence and changing some criteria; namely, dropping the criterion relating to legality, citing limited information gained for diagnosis and amid doubts about its use as a clinical indicator, and adding a criterion relating to cravings (Peer et al., 2013). Second, reflecting new research, the DSM-V recognized symptoms

for cannabis withdrawal, based on feelings of irritability, anger, anxiety, disturbed sleep, decreased appetite, mood, and/or energy, and at least one physical symptom causing significant discomfort, e.g., abdominal pain, tremors, fever, or headache (Hasin et al., 2008). Comparisons suggest these changes have had little effect on the measured prevalence of cannabis use disorders (Mewton et al., 2013; Peer et al., 2013).

NSDUH data suggest four million Americans suffer from DSM-IV marijuana dependence (Center for Behavioral Health Statistics and Quality, 2017a); and as a percent of the general population, marijuana abuse and dependence have remained relatively stable from 2002-2014 at 1.5% (Compton et al., 2016). The National Epidemiologic Survey on Alcohol and Related Conditions records a much larger increase, from 1.5% to 2.9% (Hasin et al., 2015), due largely to changes in NESARC methodology (Gruza et al., 2016).

One might have expected the population prevalence of marijuana dependence to have increased proportionally to the substantial increase in prevalence of marijuana use. That this did not occur presents a puzzle, which this paper seeks to elucidate. Using National Survey of Drug Use and Health (NSDUH) data, we seek to measure levels and changes in marijuana dependence and its symptomatic criteria among the heaviest users, and consider potential causes at hand.

2. Methods

2.1 Data

Questions corresponding to the DSM-IV diagnostic criteria have been asked by NSDUH since 2002, providing a consistent data source for tracking trends in the reporting of marijuana dependence diagnoses and their constituent symptomatic criteria. NSDUH is a household survey, representative of the U.S. household population aged 12 and older, with over 60,000 respondents per year. NSDUH asks respondents a range of health-related questions, including recent use of

drugs; for marijuana, respondents reporting past-year use are asked follow-up items about recent use, including a battery corresponding to DSM-IV diagnostic criteria for marijuana abuse and dependence. NSDUH has not announced changes to its question battery or re-coded variables to incorporate DSM-V criteria. We assemble these data from 2002 to 2016.

2.2 Measures

Our main outcomes are marijuana dependence and its symptomatic criteria, as indicated by the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV). In accordance with SAMHSA practices following those guidelines, dependence was coded as ‘yes’ if respondent met at least three of the six indicated criteria, presented here along with the coded variable(s) in NSDUH: 1) Spent a great deal of time over a period of a month getting, using, or getting over a substance’s effects (MRJLOTTM=1 or MRJGTOVR=1); 2) Unable to keep set limits on substance use or used more often than intended (MRJLIMIT=1 or 2, and MRJKPLMT=2); 3) Needed to use more to get desired effects or noticed lesser effect from the same amount (MRJNDMOR=1 or MRJLSEFX=1); 4) Unable to cut down or stop using at every attempt or desire (MRJCUTDN=1 or 2, and MRJCUTEV=2); 5) Continued to use despite it causing problems with emotions, nerves, mental health, or physical health (MRJEMCTD=1 or MRJPHCTD=1); and 6) Reduced or stopped participation in important activities due to substance use (MRJLSACT=1) (Center for Behavioral Health Statistics and Quality, 2017b).

2.3 Analyses

Data were weighted to reflect NSDUH’s sampling design, assembled from individual years into an omnibus dataset, and analyzed in R (3.4.2) (United States Department of Health and Human Services and Substance Abuse and Mental Health Services Administration Center for Behavioral Health Statistics and Quality, 2016). The prevalence among DND users of DSM-

IV dependence is calculated for each year of available data, first across all DND users and then by age group (12-17, 18-25, 26-34, 35+) and gender. To provide broader context, levels and changes in DND prevalence are compared to prevalence among past-year marijuana users and among the general population, but detailed results from analyses of non-DND user groups is omitted for brevity. DND prevalence is plotted without alteration. For sub-group analyses, smoothing is applied in order to reduce year-to-year variation driven by small sample sizes. A simple 5-year moving average is applied (e.g., 2008 = average for 2006-2010) where possible; to conserve data points for plotting, years near the sample's edge are presented unsmoothed (e.g., 2002, 2016) or partially but symmetrically smoothed (e.g., 2003 = average for 2002-2004). To summarize changes over the study period, data are divided into three-year pre-/post- time periods (2002-2004 and 2014-2016), and fit with a quasi-binomial regression predicting self-reported DSM-IV dependence as a function of age, race, education, gender, and time period. Statistical significance is tested by the p-value on the time dummy coefficient. Change is presented in absolute and relative terms.

Likewise, the prevalence of individual DSM-IV Marijuana Dependence criteria among DND users are calculated, plotted, and tested for statistical significance. No sub-group analysis is undertaken here, for simplicity.

3. Results

3.1 Marijuana dependence

Rates of marijuana dependence among DND users fell throughout the study period, from a high of 27.3% in 2002 (26.5%, pooling 2002-2004) to a low of 15.8% in 2014 (16.1% for 2014-2016). Among all past-year users, we observe a decline that is similar in relative terms (from 13.8% to 8.5%). Logistic regression confirms the reduction in DND dependence from

2002-2004 to 2014-2016 is statistically significant ($p < .001$). A similar model run on all NSDUH respondents, estimating the population-level prevalence, shows no significant change. From 2002-2004, 4,461 respondents reported daily/near-daily use and so were asked questions about DSM-IV dependence, and 6,190 in 2014-2016.

Figure 1 shows DND (thick, knotted black line) and sub-group dependence rates (patterned lines). Sub-group analyses show declines among all age and gender groups, except for adults over 50 years old, among whom dependence has fallen only since 2007, but was increasing beforehand. Dependence rates show a steep age gradient, with adolescent rates roughly doubling those among 26-49-year-olds, which in turn double older users' rates. Rates among females are persistently higher than male rates until crossing in 2015.

3.2 Symptom criterion

Among DND users, five of six DSM-IV marijuana dependence symptoms showed significant declines in prevalence. The biggest relative declines are in criteria related to health and lifestyle, e.g., stopping important activities and continued use despite emotional, mental, or physical problems. Reported tolerance ("needed more for the same effect") showed no significant change.

4. Conclusions

Findings from this paper emphasize that during a period of liberalizing cannabis policy, increases in past-month prevalence, and the intensification of typical use habits, there has been a marked reduction in self-reported rates of marijuana dependence among DND users, from roughly one-in-four to one-in-six. A similar decline in relative terms was observed among past-year users (13.8% to 8.5%). The net effect of these declines, along with increases in prevalence, has yielded stable rates of dependence in the broader population. Declines are robust to sub-

group analysis by age and gender, with the exception of adults over 50, who show mixed trends. Conditioning on DND use offers a fresh perspective, essentially treating prevalence as a confounder. Dependence manifests differently in men and women (Agrawal and Lynskey, 2007), and though men show lower non-conditional dependence (Chou et al., 2015), our results reveal women had long faced higher rates of conditional dependence, until recent years.

What may be driving these trends is not entirely clear. The truth lies between two alternative extreme interpretations. One approach takes trends at face value, inferring a genuine drop in the dependence risk of marijuana use. Perhaps increasing social approval of marijuana use has helped DND users to integrate their marijuana use habits with their other commitments, causing fewer to report giving up important activities and fewer problems with family, friends, and co-workers; perhaps as marijuana has become more widely available, DND users are spending less time seeking marijuana; perhaps the spread of less harmful modes of consumption (e.g., vaporizers) or use with the intent to tread health-related issues has led to fewer emotional, mental, or physical problems. Conversely, perhaps the only change has been in users' propensity to detect problems, attribute them to their cannabis use, and report them – but the underlying risks remain the same. A potential third option concerns a confounder: as marijuana use has spread and normalized, this has driven changes in the composition of the user base (Burns et al., 2013) – perhaps also in characteristics that are not captured in survey data, e.g., users' general capacity for self-control or deference to social norms.

The spread of new ways to consume marijuana, namely vaporization, “dabbing”, and edibles, also likely plays a role, particularly where medical and recreational marijuana laws have driven sales of these products. Flower sales have dropped to only 66% of Washington State's legal marijuana sales by dollar value by mid-2016 (Smart et al., 2017).

As U.S. marijuana policies liberalize, it is especially important that researchers, policymakers, and voters understand the harms of marijuana use – and further, to appreciate these harms may be changing, driven by policy decisions, product characteristics, and social context. The issue merits further research studying how different state marijuana policies or the use of different marijuana products may affect risks of dependence and other health harms. Policy stakes are high, including not only whether marijuana legalization continues to spread to more jurisdictions, but also how harmful aspects of marijuana are perceived and managed within legalized environments.

Author Disclosures

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Contributors

Steven Davenport was the only author of this document, and approves this final article.

Conflict of interest

None

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Figure Legend

Figure 1. Rates of DSM-IV Dependence Among DND Users and Subgroups

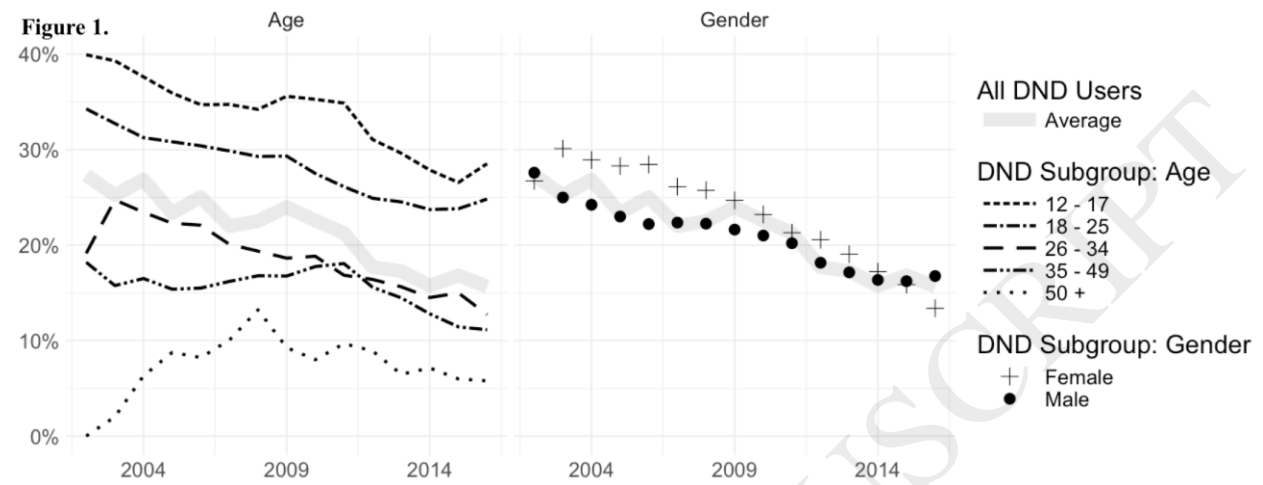


Table 1.

| Condition / Symptom | 2002-4 | 2014-6 | P-value | Difference | Change (%) |
|---|--------|--------|---------------|------------|------------|
| DSM-IV MJ Dependence | 26.5 | 16.1 | <0.001* ** | -10.4 | -39.2 |
| Reduced or Gave Up Important Activities | 17.9 | 9.9 | <0.001* ** | -8 | -44.7 |
| Emotional, Mental, or Physical Problems and Continued Use | 15.1 | 8.1 | <0.001* ** | -7 | -46.4 |
| Attempted to Reduce Use but Failed | 15.1 | 10 | <0.001* ** | -5.1 | -33.8 |
| Lots of Time Getting, Using, or Getting Over Marijuana | 73.9 | 63.1 | 0.004** * | -10.8 | -14.6 |
| Set Limits on Use but Failed to Keep Them | 13.2 | 10.4 | 0.015** | -2.8 | -21.2 |
| Needed More for Same Effect | 44.8 | 40.3 | 0.519 | -4.5 | -10 |

*** p < .01 **: p < .05 * p < .1 . p >= .1