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Population-level predictions from cannabis risk perceptions to active cannabis use prevalence in the United States, 1991–2014

Maria A. Parker, PhD, MPH[1,2] and **James C. Anthony, PhD**[1]

[1]Department of Epidemiology & Biostatistics, College of Human Medicine, Michigan State University, West Fee Hall, 909 Fee Road, East Lansing, MI 48824, United States

Abstract

Introduction—A mosaic of evidence links risk perceptions with drug use in adolescence, including population summaries to guide public health campaigns, as well as subject-specific estimates on preventing an adolescent's drug use by manipulating that individual's prior risk perceptions. We re-visit these issues with a public health perspective, asking whether population-level cannabis risk perceptions of school-attending adolescents at one grade level might predict cannabis use prevalence two and four grade levels later.

Methods—From 1991–2014, each year's United States 'Monitoring the Future' (MTF) study population included 8th-, 10th-, & 12th-graders. Two and four years later, statistically independent school samples of the same cohorts were drawn and assessed (n~16,000/year). Population-level modeling estimated cannabis use prevalence at time 't' (12th-grade) regressed on that same cohort's cannabis risk perceptions as had been measured at time 't-4' (8th-grade) and time 't-2' (10th-grade).

Results—Higher cannabis risk perception levels for 10th-graders predict lower cannabis use prevalence when 10th-graders have become 12th-graders ($\hat{\beta}=-0.12$), and higher cannabis risk perception levels of 8th-graders predict lower cannabis prevalence when 8th-graders have become 10th-graders ($\hat{\beta}=-0.27$); p-values<0.05. Across four-year spans, the prediction is null (p-value=0.619).

Conclusions—This within-cohort across-grade population- level prediction prompts questions for drug prevention specialists, including "Would a relatively small upward shift in a local area population's appraisal of risk perceptions be followed, two years later, by reduced population

Correspondence: Dr. Maria A. Parker, Vermont Center on Behavior & Health, University of Vermont, 1 South Prospect Street, SATC-UHC, Burlington, VT 05401, United States, Tel.: +1 802 656 0206. maria.parker@uvm.edu.
[2]Present address: Vermont Center on Behavior & Health, University of Vermont, 1 South Prospect Street, SATC-UHC, Burlington, VT 05401, United States.

Contributors
MAP and JCA designed the study. MAP conducted literature searches, provided summaries of previous research studies, and conducted the analyses. All authors contributed to and have approved the final manuscript.

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No conflicts of interest to report.

prevalence of cannabis use?” Future randomized trial designs, health education, or prevention efforts focused on altering early adolescent cannabis risk perceptions might provide the most convincing and definitive evidence.

Keywords

cannabis; epidemiology; adolescents; risk perception; prevalence; marijuana

1. INTRODUCTION

Adolescent drug prevention plans often rest on propositions that increases in drug risk perceptions can prompt delay or abstention from drug use – i.e., “When young people perceive drug use as harmful, they reduce their level of use.” These ideas date back to old drug ‘scare tactics’ that re-surfaced roughly 25 years ago, along with ecological trend lines for student drug risk perceptions and concurrent trend lines for student drug use prevalence (Bachman, Johnston, & O’Malley, 1990; Bachman, Johnston, O’Malley, & Humphrey, 1988; Hall & Weier, 2015; Schuermeyer et al., 2014).

In subsequent research on this relationship, both United States (US) and European research teams offered supportive subject-specific evidence (e.g., Terry-McElrath et al., 2017), including longitudinal studies of the same individuals measured iteratively over time. Namely, individuals perceiving drug use to be a “great risk” behavior seem less likely to be drug users after an interval of followup. On the other hand, individuals seeing minimal risk in drug use are more likely to be users at followup (Ellickson, Tucker, Klein, & Saner, 2004; Stacy, Bentler, & Flay, 1994). However, a large quasi-experimental prevention research trial in the US produced mixed uncertain results not entirely consistent with these original ideas, but not sufficiently persuasive to cause universal abandonment of the ideas. When studied in that large sample prevention science context, young adolescents with the greatest exposure to messages about drug-taking risks actually were more likely to become drug users, as compared with youths at lower exposure levels (Hornik, Jacobsohn, Orwin, Piesse, & Kalton, 2008; Orwin et al., 2006; Palmgreen & Donohew, 2006).

Notwithstanding the subject-specific longitudinal evidence on individuals (Grevenstein, Nagy, & Kroeninger-Jungaberle, 2015), we judge that it is time to look closer at public health evidence about populations and standard quantitative population health metrics such as ‘prevalence proportions’ and ‘incidence rates.’ This population- level/ecological investigation is novel and timely because research on adolescent drug risk perceptions and later drug use in the public health context now faces a new challenge. A prominent psychiatric epidemiologist and National Institute on Drug Abuse (NIDA) leader framed the challenge as follows: “We’ve now had five years of consistent declines in perceived harmfulness [of cannabis use] and the [cannabis] use rates have been reasonably steady – or dropping slightly this year,…” and “This [evidence] is a bit of a puzzle and speaks to a different relationship of these phenomena than we’ve seen in the past” (http://www.usnews.com/news/articles/2015-12-16/key-anti-pot-argument-torched-teen-use-flat-as-risk-perception-plunges, last accessed February 2018; Nelson, 2015).

With this background in mind, we focus on cannabis prevalence estimated for nationally representative samples of school-attending adolescent cohorts in the US, producing cannabis risk perception-cannabis prevalence predictions based on evidence that the age-specific incidence peak of cannabis use now typically precedes college age. Our study answers three overarching questions: At the population- level, are 10^{th}-grade cannabis risk perceptions predictive of 12^{th}-grade cannabis prevalence two years later? How about the risk perception-prevalence prediction from 8^{th}- to 12^{th}-grade? Is there evidence in these population- level estimates that the cannabis risk perception to cannabis prevalence prediction no longer holds (as suggested above), even when there is fairly recent supportive evidence from subject-specific longitudinal investigations (e.g., Grevenstein et al., 2015; Malmberg et al., 2012)? Answers to these research questions require a population perspective and aggregate level research design on cohorts studied over time.

2. MATERIALS AND METHODS

2.1 Study Population, Design, and Sample

Each year, the Monitoring the Future (MTF) team seeks US nationally representative samples of population cohorts of school-attending adolescents, surveying their behaviors, feelings (e.g., about drug use), and other social issues. Since 1991, MTF has fostered over-time study of individual cohorts, via *independently* drawn samples of 8^{th}-, 10^{th}-, and 12^{th}-graders. These cohorts can be arranged in pairs (e.g., 8^{th}- and 10^{th}-grade, 2 years apart) and trios (8^{th}-, 10^{th}- and, 12^{th}-grade, 4 and 2 years apart, respectively). Sample sizes average n=15,800 annually for an overall sample size of n=410,000, 370,000, and 360,000 at 8^{th}-, 10^{th}-, and 12^{th}-grade, respectively. Participation levels varied from 79%–91% (Miech, Johnston, O'Malley, Bachman, & Schulenberg, 2015).

2.2 Measures

MTF participants mark self-administered questionnaire forms during in-school surveys. We encoded standardized survey items as binary variables (a) for 'Great Risk' answers to the cannabis risk perception item ["How much do you think people risk harming themselves (physically or in other ways), if they … smoke marijuana regularly?"], and (b) for '1+ occasions' answers to the cannabis prevalence item ["On how many occasions (if any) have you used marijuana... during the last 30 days?"]. From 1991 through 2014, items were identical, making it possible for us to produce population- level estimates by coupling together estimates extracted from published annual MTF reports based on the longest time series available (Miech et al., 2015).

2.3 Statistical Analysis

We plotted the extracted cannabis prevalence and risk perception values and fit a series of Poisson generalized linear models (identity link; Stata Corp, 2015). These models treated cannabis risk perceptions (CRP) as explanatory variables of interest with cannabis prevalence (CP) as the response (i.e., past month prevalence of cannabis use). In this over-time study, we start at the population- level with aggregate 12^{th}-grade CP_t regressed on the aggregate 10^{th}-grade CRP_{t-2} value (i.e., CP at 'time t' and CRP at 'time t-2'). This analysis used 12^{th}-grade data from 1993–2014 (n=22 pairs of 't' and 't-2' values, as depicted in

Supplementary Figure 1). The next model was a regression of 12th-grade CP_t on 8th-grade CRP_{t-4} across years for 12th-grade classes of 1995–2014 (n=20 grade-pairs). Finally, a model for 1995–2014 regressed 12th-grade CP_t on 10th-grade CRP_{t-2} and 8th-grade CRP_{t-4} (n=20). (Note: when a school's 8th-graders are sampled in a given year, that same school's 10th-graders and 12th-graders are not sampled two and four years later).

For plotting, non-parametric local regression smoothing functions were introduced, including a running mean smoother to average adjacent responses, and a lowess smoother for locally weighted running means. Due to large sample sizes, 95% confidence intervals (CI) are from $p \pm 1.96\sqrt{p(1-p)/n}$, where p is estimated prevalence, 1.96 is from the z-distribution, and n is each year's number of students at grade level (Miech et al., 2015).

For comparative purposes, we regressed 12th-grade CP_t on 12th-grade CRP_t. We also regressed 12th-grade CP_t on 12th-grade CRP_{t-1} (i.e., two successive cohorts). In addition, 12th-grade CP_t was regressed on 10th-grade CP_{t-2}. We also wanted to consider concurrent CP while estimating the relationship between CRP and future CP (e.g., 10th-grade CP_{t-2} for 12th-grade CP_t). Finally, to address subsidiary temporal sequencing issues, models were fit with CRP level as y-outcome and CP as the x-variable of interest.

For each generalized linear model, robust (conservative) standard errors are from Stata Version 14 (Stata Corp, 2015). Estimation of prevalence proportions and trends included post-stratification adjustment for absentees and dropouts (Miech et al., 2015). Detailed descriptions of MTF sample characteristics are available (http://monitoringthefuture.org/pubs.html#monographs, last accessed February 2018; Miech et al., 2015).

3. RESULTS

Table 1 shows our main population- level prediction: the estimated cohort-wise prevalence for recently active cannabis use (CP_t at 12th-grade) is predicted by the CRP_{t-2} estimate from 10th-grade [$\hat{\beta}$=−0.12; 95% CI=−0.25, −0.01; p-value=0.042]. The corresponding model for aggregate CRP_{t-4} (at 8th-grade) did not predict estimated CP_t across the four-year span to 12th-grade ($\hat{\beta}$ = 0.03; 95% CI=−0.09, 0.16; p-value=0.619), and addition of the CRP_{t-4} term to the CRP_{t-2} model did not improve the model fit (likelihood ratio test p-value=0.97; data not shown in a table).

In post-estimation subsidiary analyses, we found that aggregate 8th-grade CRP_{t-4} predicted aggregate 10th-grade at CP_{t-2} two years later, with a larger inverse association ($\hat{\beta}$ = −0.27; 95% CI=−0.53, −0.01; p-value=0.040; data not shown in a table). This two-year lag estimate is not appreciably different from the estimated inverse relationship observed when we regressed 12th-grade CP_t on same-year 12th-grade CRP_t or on prior-year 12th-grade CRP_{t-1} ($\hat{\beta}$=−0.23 and $\hat{\beta}$ = −0.23, respectively; see Table 1). When 12th-grade CP_t was regressed on 10th- grade CP_{t-2}, we found that prior use strongly predicted future use ($\hat{\beta}$ = 0.88; 95% CI=0.75, 1.01; p-value=<0.001; data not shown in a table). Including 10th-grade CP_{t-2} attenuated the relationship between 10th-grade CRP_{t-2} and 12th-grade CP_t ($\hat{\beta}$ = −0.07; 95% CI=−0.11, −0.04; p-value < 0.001).

Figure 1 depicts the 22 observed grade-pair values (CP_t, CRP_{t-2}) for the inverse predictive relationship shown in Table 1's first row (i.e., $\hat{\beta} = -0.12$), as well as model-based predictions for being a recently active cannabis user in 12th-grade. To illustrate, for MTF in 2013, the x–y coordinates exemplify a relatively large CP proportion (y_t: 22.7%) and unremarkable CRP level (x_{t-2}: 55.2%). The year with smallest CP (15.5%) and largest CRP levels (82.1%) was 1993. Both smoothing functions provide evidence of inverse predictive relationships linking earlier CRP_{t-2} at 10th-grade with later CP_t at 12th-grade.

In sensitivity analyses, we made selective exclusions of Figure 1's data points to gauge undue influence of specific values. Removal of four most recent estimates in this 'leave one out' approach [starting with 2014 coordinates, then 2013 coordinates, and so on through 2011], we found no appreciable variation in the predictive relationships linking earlier 10th-grade CRP with later 12th-grade CP (all resulting $\hat{\beta}$ estimates ranged from −0.15 to −0.12).

4. DISCUSSION

In this work, we deliberately take an epidemiological and population- level view that complements prior subject-specific investigations summarized above (e.g., Terry-McElrath et al., 2017). Looking across the succession of cohorts and grade levels, we found a set of supportively inverse estimates for hypothesized two-year time lag predictions leading from higher population-level cohort-specific cannabis risk perception proportions at 10th-grade toward lower prevalence of recently active cannabis use at 12th-grade. To clarify, higher levels of cannabis risk perceptions observed among 10th-graders do predict lower cannabis prevalence in 12th-graders two years later. We also found a robust population- level prediction from higher 8th-grade cannabis risk perception levels toward lower cannabis prevalence at 10th-grade. Notwithstanding these novel findings on two-year lags, our prediction was null for the four-year lag (from 8th-grade cannabis risk perceptions to 12th-grade cannabis prevalence).

In this epidemiological work, we turned to relatively basic but novel analyses of nationally representative data on adolescent cannabis use. These estimates add new pieces to the current mosaic of evidence available to public health officials concerned about adolescent cannabis use. On one hand, it is useful to see evidentiary support for the idea that cannabis risk perception-modulating interventions (in 8th-grade and 10th-grade) might be followed by reduced prevalence of cannabis use (in 10th- and 12th-grade, respectively). Rather than re-approach this challenge with a national mass media approach of uncertain value (Hornik et al., 2008; Orwin et al., 2006; Palmgreen & Donohew, 2006), next steps might include factorial experimentation with units of analysis at school district levels.

Before additional discussion, we note strengths in cohort-wise research designs based on nationally representative data (Miech et al., 2015; Seedall & Anthony, 2015), with sample coverage of mid-to-late teen years. These years represent an important interval for cannabis use initiation before college (Ellickson et al., 2004; Grevenstein et al., 2015; Stacy et al., 1994).

As for limitations, we wonder whether 'great risk' ratings for cannabis perceptions might be heavily determined by a sense of declining probability of adjudication-related social consequences and police apprehension for cannabis offenses, not just among active cannabis users, but also in the teen population generally. There is some recent research suggesting (a) null medical marijuana law (MML) effects on cannabis risk perceptions (Schmidt, Jacobs, & Spetz, 2016) and (b) MML increases in cannabis risk perceptions among 8th-graders, as well as concurrent reductions in cannabis use prevalence among 8th-graders (Keyes et al., 2016). However, these studies focused attention on states with liberalized policies; this investigation's ecological trend lines are specified for the nation as a whole.

Despite this uncertainty, if drug risk perceptions help govern rise and fall of drug epidemics, then these new empirical estimates for cohort-wise predictions might provoke new thinking about primary prevention and other public health efforts shaping population- level cannabis risk perceptions. Limited resources and other constraints now prompt efforts focused on early adolescence and middle-school, but efforts that focus on 9th-grade to 11th-grade might be useful.

5. CONCLUSIONS

In conclusion, this study's estimates on cannabis risk perceptions show a robust inverse prediction toward lower cannabis prevalence estimates with a two-year lag. Truly definitive evidence on population- level cannabis risk perception levels as causes of the rise and fall of cannabis prevalence will require future randomized trials with population- level interventions designed to shift group-level cannabis risk perceptions, and followup intervals of 1–2 years should be sufficient in secondary school prevention trials. By making this study's population-level prediction, we hope to encourage new research of this type as well as prevention program development focused on needs of 16–17-year-olds before the final year of secondary schooling. We note that many 16–17-year-olds say they intend to try cannabis (Stewart & Moreno, 2013), but these teens might never be able to use legally, given cannabis policies set with legal minimum age set at 18–21 years.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- We estimate if population- level cannabis risk perceptions predict odds of cannabis use
- Cannabis risk perceptions at 10^{th}-grade predict cannabis odds at 12^{th}-grade
- Cannabis risk perceptions at 8^{th}-grade predict cannabis odds at 10^{th}-grade
- Cannabis risk perceptions at 8^{th}-grade do not predict cannabis odds at 12^{th}-grade

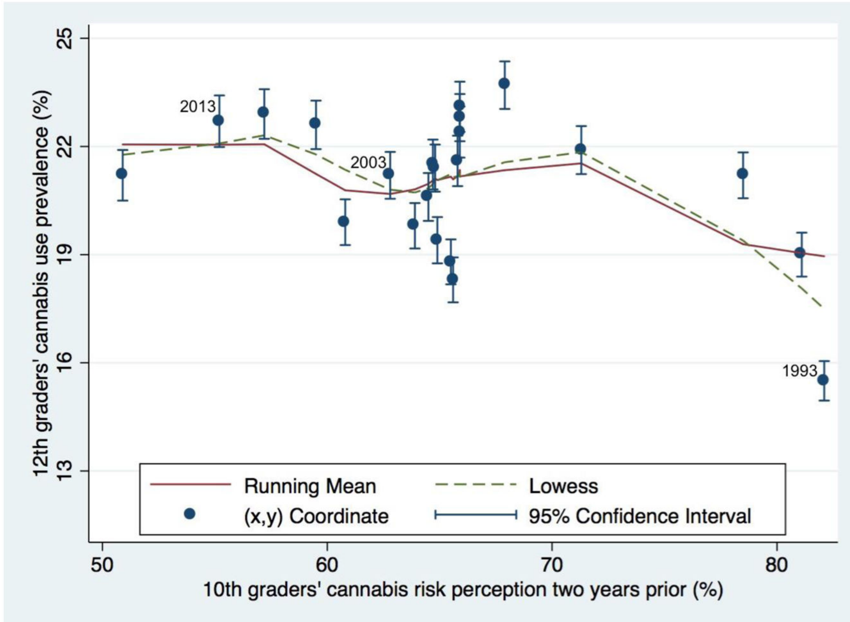

Figure 1.

Estimated prevalence for recently active cannabis use[a] of each year's 12th-graders, based on that cohort's cannabis risk perception value two years prior[b] in 10th-grade. 95% confidence intervals and two non-parametric smoothing functions fitted. Data from the United States Monitoring the Future Reports, 1991–2014.

[a]Prevalence of cannabis use in the past 30 days.

[b]Percent perceiving 'great risk' when cannabis is smoked "regularly."

Table 1

Generalized linear model estimates for the prediction of recent cannabis use among 12th-graders, based on ‘great risk’ cannabis risk perceptions of the same cohorts as independently sampled and assessed in prior years. Data from Monitoring the Future Reports, 1991–2014.[a]

				95% Conf. Interval	
Cannabis risk perceptions	Estimated Coefficient	Robust Std. Err	p-value	Lower	Upper
10th-graders two years prior[b]	−0.12	0.06	0.042	−0.25	−0.01
8th-graders four years prior[c]	0.03	0.06	0.619	−0.09	0.16
12th-graders in the same year	−0.23	0.06	<0.001	−0.34	−0.12
12th-graders in the year prior[d]	−0.23	0.05	<0.001	−0.34	−0.13

[a] Each of these four models included *one* predictor: cannabis risk perceptions.

[b] At time ‘t-2’, based on 1991–2012; Cannabis use estimates based on 1993–2014 (Miech et al., 2015).

[c] At time ‘t-4’, based on 1993–2010; Cannabis use estimates based on 1995–2014 (Miech et al., 2015).

[d] At time ‘t-1’, based on 1991–2013; Cannabis use estimates based on 1992–2014 (Miech et al., 2015).