



Published in final edited form as:

Addict Behav. 2017 November ; 74: 13–19. doi:10.1016/j.addbeh.2017.05.026.

Risk is Still Relevant: Time-Varying Associations between Perceived Risk and Marijuana Use among US 12th Grade Students from 1991–2016

Yvonne M. Terry-McElrath, MSA^{a,*}, Patrick M. O'Malley, PhD^a, Megan E. Patrick, PhD^a, and Richard A. Miech, PhD^a

^aInstitute for Social Research, University of Michigan, 426 Thompson St., Ann Arbor, MI 48106-1248 USA

Abstract

Background—Perceived risk of harm has long been a key preventive factor for adolescent marijuana use. However, in recent years, perceived risk has decreased markedly and marijuana use has increased only slightly, leading to new questions about their association. This study investigates the magnitude and stability of the US adolescent marijuana risk/use association from 1991–2016, overall and by gender and race/ethnicity.

Methods—Self-reported data on past 12-month marijuana use, perceived risk of regular marijuana use, gender, and race/ethnicity were obtained from 275,768 US 12th grade students participating in the nationally representative Monitoring the Future study. Time-varying effect modeling (TVEM) was used to examine the marijuana risk/use association over time.

Results—Both before and after controlling for gender and race/ethnicity, perceived risk was a strong protective factor against adolescent marijuana use. The magnitude of the great risk/use association strengthened for Hispanic students; remained generally stable over time for 12th graders overall, males, females, and White students; and weakened for Black students. The magnitude of the moderate risk/use association strengthened for 12th graders overall, males, females, White and Hispanic students, but did not continue to strengthen for Black students from 2005 onwards. In general, marijuana use prevalence decreased over time within all levels of perceived risk.

Conclusions—Perceived risk remains a strong protective factor for adolescent marijuana use, and the protective association for moderate risk (vs. no/slight risk) is actually increasing over time.

*Corresponding Author. Yvonne M. Terry-McElrath, MSA, Institute for Social Research, University of Michigan, 426 Thompson St., Ann Arbor, MI, 48106-1248. Telephone 734-647-9142; Fax 734-936-0043; yterry@umich.edu.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Contributors

All authors contributed to the design and execution of this study. P.M. O'Malley, M.E. Patrick, and R.A. Miech all participated in the collection of 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

All authors declare that they have no conflicts of interest to disclose.

Results suggest that accurate and credible information on the risks associated with marijuana use should remain a key component of prevention efforts.

Keywords

marijuana; perceived risk; adolescent; time-varying effect modeling

1. Introduction

Significant academic and health risks associated with marijuana use have been recognized, including lower academic achievement and functioning (Brook, Stimmel, Zhang, & Brook, 2008), respiratory disease, injury and death, cognitive impairment, schizophrenia, and other psychoses (National Academies of Sciences, Engineering, and Medicine, 2017; Volkow, Baler, Compton, & Weiss, 2014). From 2004–2011, the rate of emergency department visits for adolescents aged 12–17 involving marijuana rose from 154 per 100,000 to 240.2 (Substance Abuse and Mental Health Services Administration [SAMHSA], 2014a). In 2014, more adolescents aged 12–17 received treatment for marijuana use than all other substances combined, including alcohol (Han, Hedden, Lipari, Copello, & Kroutil, 2015). Given the documented health risks associated with marijuana use—particularly for adolescents—changes in the level of perceived risk associated with marijuana use may call for public health attention, as perceived risk historically has been associated with use behavior.

The degree to which individuals perceive they risk harming themselves by using marijuana is hypothesized to influence decisions to use or abstain. The risk/use association is grounded in the Health Belief Model, which posits that attitudes and beliefs significantly impact the likelihood of health-related behavior (Rosenstock, 1974; Janz & Becker, 1984). As early as 1981, nationally representative data from high school seniors indicated perceived risk of harm from regular marijuana use was strongly associated with actual use (Johnston, Bachman, & O'Malley, 1981). Perceived risk was shown to be a strong explanatory factor in observed national decreases in marijuana use from 1976–1986 (Bachman, Johnston, O'Malley, & Humphrey, 1988). Further, significant declines in perceived risk during the 1990s appeared to explain corresponding increases in marijuana use for US middle and high school students (Bachman, Johnston, & O'Malley, 1998). Perceived risk is now recognized as an important factor for preventing adolescent marijuana use (SAMHSA 2014b; Stephens et al., 2009).

Recent changes in descriptive trends of perceived risk and use indicate they no longer track as mirror-images of each other as they did in the past. The National Survey on Drug Use and Health (NSDUH) and the Monitoring the Future (MTF) study reported that adolescents age 12–17 who perceived great risk of harm from marijuana use remained significantly less likely to use marijuana than those perceiving less or no risk, but the prevalence of perceiving great risk had decreased sharply while use prevalence increased only minimally (SAMHSA, 2013a; Miech, Johnston, O'Malley, Bachman, & Schulenberg, 2016). NSDUH data showed perceived great risk from monthly marijuana use decreased from 55% to 45% from 2007–2011, while monthly marijuana use prevalence increased only 1% (SAMHSA, 2013a). MTF data showed that among 12th grade students, the percentage perceiving great risk in regular

marijuana use decreased from 58% to 32% from 2006–2016, while past 12-month use increased only 3 percentage points (Miech et al., 2016). Similar results have been found for state-level surveys (Hughes, Lipari, & Williams, 2015), including studies in states that have legalized adult recreational marijuana use (Alcohol and Drug Abuse Institute [ADAI], 2015; Colorado Department of Public Health and Environment [CDPHE], n.d.). Overall, these findings raise the possibility that perceived risk may have become a weaker protective factor for adolescent marijuana use, because trends for the two factors have become increasingly disconnected in recent years.

One possible explanation of the disconnect between risk and use trends may involve weakening of the of statistical association between perceiving risk in using marijuana and decisions to use. It may be that both marijuana users and non-users are coming to agree with the perspective that marijuana use does not involve risk for most individuals (e.g., Sullum, 2016). If true, this would lead to an attenuation over time of the statistical association between perceived risk and use that, if occurring among the adolescent population overall or at least the majority of key demographic subgroups, would be observed as a disconnect between risk and use descriptive trends. If the strength of the risk/use association has weakened, allocation of limited prevention resources to addressing deficiencies in knowledge regarding marijuana use risk would lower in priority.

An alternative possibility is that apparent disconnect based on descriptive trends does not equate with weakening of the statistical association between risk and use. Fleming and colleagues used data from Washington state to examine stability over time in the strength of cross-sectional marijuana risk/use associations among 10th grade students from 2000–2014 (Fleming, Guttmanova, Cambron, Rhew & Oesterle, 2016). Logistic regression models using year-specific interaction terms indicated the association between perceiving no/slight risk (vs. moderate/great risk) and use had actually strengthened somewhat over time, controlling for gender and race/ethnicity (Fleming et al., 2016). If the risk/use association is not weakening over time, there should be continued and possibly increased allocation of prevention resources to addressing deficiencies in knowledge regarding marijuana use risks given the overall decreasing prevalence of perceived risk.

There are well-established gender and racial/ethnic differences in marijuana perceptions and use. Compared with boys, girls have had higher perceived risk (Danescu, Kingery, & Coggeshall, 1999; Pacek, Mauro, & Martins, 2015; SAMHSA, 2013a) and lower use prevalence (Miech et al., 2016; SAMHSA 2014c). The association magnitude between marijuana perceptions and use has been stronger for White adolescents than Hispanic or African American adolescents (Wu et al., 2015). The degree to which marijuana risk/use association strength may be weakening or remaining strong over time may vary across gender or racial/ethnic groups. Knowledge of population subgroup differences in either the stability or change in marijuana risk/use association strength could help inform targeted prevention efforts.

1.1. The Current Study

The current study aims to contribute to the marijuana use epidemiology literature by using national data to statistically model adolescent marijuana risk/use association strength over

time at the national level for the adolescent population overall and gender and racial/ethnic subgroups. Such analyses optimally would be conducted using methods specifically designed to examine change over time in association strength. Analyses optimally also would aim to provide a detailed examination of the strength of risk/use association at different levels of perceived risk, as little research has focused on the strength of association between different levels of perceived risk and use. Most research has used only a simple dichotomous categorization of perceiving great risk versus all other risk perception levels; exceptions to this include two studies that have examined perceiving moderate/great harm versus no/slight harm (Brooks-Russell et al., 2015; Fleming et al., 2016).

The current study used time-varying effect modeling (TVEM) to examine time-varying cross-sectional associations from 1991–2016 between various levels of perceived risk and use of marijuana among US 12th grade students. Two research aims were directed by two competing research hypotheses:

H₁: The strength of statistical associations between perceiving (a) great risk or (b) moderate risk (vs. no/slight risk) and past 12-month marijuana use has weakened over time.

H₂: The strength of statistical associations between perceiving (a) great risk or (b) moderate risk (vs. no/slight risk) and past 12-month marijuana use has remained strongly significant.

Research aims included statically modeling risk/use association strength for the overall student population (Aim 1), as well as separately for gender and racial/ethnic subgroups (Aim 2).

2. Methods

2.1. Participants

Analyses used data from the Monitoring the Future (MTF) study; detailed methodology is available elsewhere (Bachman, Johnston, O'Malley, Schulenberg, & Miech, 2015; Miech et al., 2016). MTF annually surveys nationally representative cross-sectional samples of approximately 15,000 12th grade students in approximately 130 schools in the coterminous US. Informed consent is obtained; a University of Michigan Institutional Review Board has approved the MTF study. Surveys were administered in classrooms by study personnel; students self-completed questionnaires during a normal class period. From 1991–2016, student response rates averaged 83%. Absenteeism was the primary reason for missing data; less than 1% of students refused participation. Perceived risk of marijuana use was asked on 5 of the 6 randomly distributed 12th grade questionnaire forms. Between 1991 and 2016, a total of 319,036 students responded to the relevant forms. Of these, 275,768 (86.4%) provided valid data for all measures included in this analysis. Cases retained for analysis were more likely than those removed due to missing data to perceive great risk (57.5% vs. 46.3%; $p < .001$), to report using marijuana (34.2% vs. 29.5%; $p < .001$), and to be female (52.0% vs. 45.7%; $p < .001$) and White (66.9% vs. 49.8%; $p < .001$).

2.2. Measures

Respondents were asked on how many occasions (if any) they had used marijuana (or hashish) during the past 12 months. Responses (on a 7-point scale ranging from 1=0 occasions to 7=40+ occasions) were dichotomized into any use versus no use. Perceived risk was asked as follows: “How much do you think people risk harming themselves (physically or in other ways) if they smoke marijuana regularly?” (response options of no risk, slight risk, moderate risk, and great risk). Initial analyses (not shown) indicated increasing trends over time for both no and slight risk, stable trends for moderate risk, and decreasing trends for great risk. Thus, responses were trichotomized to indicate no/slight risk, moderate risk, or great risk. Respondents self-reported gender and race/ethnicity (coded as African American/Black, Hispanic, White, and Other).

2.3. Analysis

Analyses were conducted using SAS 14.1. Descriptive statistics and yearly prevalence estimates were obtained using the SURVEYMEANS procedure, accounting for the complex sample design and weighted to adjust for differential selection probability. TVEM was used for estimation of time-varying associations. TVEM is a regression-based method of modeling relationships between covariates and an outcome over continuous time; no assumptions regarding the association’s parametric form are made (Lanza, Vasilenko, Liu, Li, & Piper, 2014; Tan, Shiyko, Li, Li, & Dierker, 2012). TVEM assumes only that the relationship changes over time in a smooth manner (Li et al., 2015). The SAS macro %TVEM (version 3.1.0) (Li et al., 2015; TVEM SAS Macro, 2015) was used to fit TVEM models estimating the log odds of any past 12-month marijuana use for specified independent variables as a continuous, flexible, smoothed function of time from 1991–2016 using the following model (here including perceived risk of regular marijuana use, gender and race/ethnicity):

$$\ln\left(\frac{P(\text{MJ_USE}_i=1)}{1 - P(\text{MJ_USE}_i=1)}\right) = \beta_0(t) + \beta_1(t)\text{PerceivedGreatRisk}_i + \beta_2(t)\text{PerceivedModerateRisk}_i + \beta_3(t)\text{Male}_i + \beta_4(t)\text{Black}_i + \beta_5(t)\text{Hispanic}_i + \beta_6(t)\text{otherRaceEth}_i$$

where β_0 is the intercept, and β_1 – β_6 are slope functions describing time-varying associations between risk (referent=no/slight risk), gender (referent=female), and race/ethnicity (referent=White) and the outcome. Figures present coefficient functions and point-wise confidence intervals (CIs). For specific time points when CIs do not contain 1.0, the coefficient is significant at $p < .05$. The method=P-spline argument was used to automatically select the optimal number of knots (corresponding to smoothness) for each coefficient function using sandwich standard errors that do not require further adjustment (Li et al., 2015).

For Research Aim one (RA1), observed time trends in perceived risk and use were graphed, followed by fitting a TVEM model regressing use on perceived risk both before and after controlling for gender and race/ethnicity. Observed trends in use stratified by level of perceived risk were then graphed. For RA2, gender- and race/ethnicity-specific TVEM

models were run, followed by interaction models testing the significance of observed gender or race/ethnicity differences via interaction terms. Observed trends in use stratified by level of perceived risk were examined separately by gender and race/ethnicity.

3. Results

Across 1991–2016, 34.2% of respondents reported past 12-month marijuana use (hereafter referred to simply as use). Risk of harm from regular marijuana use was perceived as great, moderate, or no/slight by 57.5%, 21.6%, and 20.9%, respectively. The sample was 48.0% male, 66.9% White, 11.8% Hispanic, 11.5% Black, and 9.8% Other racial/ethnic group.

3.1. Stability of risk /use association over time among 12th graders overall (RA1)

Figure 1 presents trends in perceived risk and use. The percentage of 12th graders perceiving great risk decreased from 79.5% to 32.8% from 1991–2016; the percentage perceiving no/slight risk correspondingly increased from 6.5% to 42.6% (the strongest rates of change occurred from 2006 onwards). In contrast, since the late 1990s, the percentage reporting moderate risk remained generally stable at approximately 23%. Use trends mirrored trends for great risk through the late 1990s, but did not follow as closely thereafter, especially during recent years of steep declines in great risk and comparatively small increases in use.

Figure 2, left panel, presents the smoothed function of bivariate time-varying odds ratios (ORs) of use by great and moderate risk (referent=no/slight risk). All ORs were much less than 1.0, indicating significantly lower odds of use for those perceiving either moderate or great risk than those perceiving no/slight risk. The great risk/use association remained significantly different from 1.0 and generally stable in magnitude across time (average OR 0.08), weakening slightly in very recent years (2016 OR 0.10 [95% CI 0.09, 0.11]). (ORs indicate weaker association as distance from 1.0 decreases.) The moderate risk/use association also remained significant across time but strengthened in magnitude from 1991 (OR 0.58 [95% CI 0.51, 0.65]) to 2013 (OR 0.33 [95% CI 0.31, 0.34]), and then weakened slightly (2016 OR 0.35 [95% CI 0.32, 0.38]). CI widths for great and moderate risk remained stable across time, but were narrower on average for great risk (0.008) than moderate risk (0.041), indicating less variance between individuals in the strength of great risk/use association than the moderate risk/use association.

Figure 2, right panel, presents multivariable time-varying adjusted odds ratios (AORs) of use by perceived risk level controlling for time-varying gender and race/ethnicity effects among the overall student population. The magnitude and stability of estimated risk/use associations were virtually identical to those obtained prior to controlling for gender and race/ethnicity.

Figure 3 presents use trends stratified by perceived risk. Use remained strongly associated with risk level over time. Use prevalence averaged 31 percentage points higher for students perceiving moderate risk versus great risk (47% vs. 16%), and an additional 23 percentage points higher for students perceiving no/slight risk versus moderate risk (70% vs. 47%). Since the late 1990s, use prevalence decreased over time within all levels of perceived risk. In 1997, use prevalence was 78.7%, 57.6%, and 21.5% for students perceiving no/slight risk,

moderate risk, and great risk, respectively. By 2016, comparable use prevalence levels were 57.0%, 33.7%, and 13.4%.

3.2. Stability of risk/use associations over time by gender and race/ethnicity (RA2)

Separate models were estimated for males and females (controlling for race/ethnicity) (see Figure 4). Magnitude and stability of AORs for great risk were very similar by gender. For both males and females, perceiving great risk (vs. no/slight risk) was associated with generally stable and dramatically lower odds of marijuana use. For both males and females, perceiving moderate risk (vs. no/slight risk) was associated with significantly lower odds of use, and the magnitude strengthened over time. However, the association appeared to be weaker (that is, closer to 1.0) for females than males until recent years. Gender/risk interactions (Supplement Figure 1) confirmed weaker associations for females from 1991–2014 (the male*moderate risk interaction term was significant from 1991–2014, with AORs and 95% CIs below 1.0). Gender-specific use trends by level of perceived risk showed decreasing use over time since the late 1990s within all levels of perceived risk for both males and females (Supplement Figure 2).

Figure 5 presents model results for White, Black, and Hispanic students separately, controlling for gender. Perceiving great or moderate risk (vs. no/slight risk) was associated with significantly lower odds of use across time for each racial/ethnic group (other than perceiving moderate risk in 1991 among Black and Hispanic students and in 1992 among Hispanic students). The great risk/use association weakened from 2007 onwards for Black students but remained generally stable for White and Hispanic students. Among White and Hispanic students, the moderate risk/use association grew stronger (monotonic trend for White students; non-linear trend for Hispanic students). Among Black students, the moderate risk/use association magnitude increased in strength until approximately 2004, and then stabilized. Association magnitudes appeared to be stronger for White than Black students for both great and moderate risk (vs. no/slight risk) and use across time. Association magnitudes also appeared stronger for White than Hispanic students for great risk (vs. no/slight risk) and use across time, and for moderate risk (vs. no/slight risk) and use until recent years. Results for Black/risk and Hispanic/risk interaction terms (Supplement Figures 3 and 4) confirmed the great risk/use association was significantly stronger for White than Black or Hispanic students at all time points, and the moderate risk/use association was significantly stronger for White than Hispanic students until 2014 (significance indicated by interaction term AORs and 95% CIs above 1.0; note the y-axis required expansion to display the associations' magnitude). Use trends by level of perceived risk showed decreasing use prevalence over time since the late 1990s within all levels of perceived risk for White and Hispanic students, but somewhat more stable trends for Black students (Supplement Figure 5).

4. Discussion

This study used nationally representative data from US 12th grade students to examine marijuana risk/use association strength and stability over 26 years. Perceived great and moderate risk had robust, strongly significant protective associations against adolescent

marijuana use for the overall population. The magnitude of the great risk/use association strengthened for Hispanic students; remained essentially stable over time for 12th graders overall, males, females, and White students; and weakened for Black students. The magnitude of the moderate risk/use association strengthened for 12th graders overall, males, females, White and Hispanic students, but did not continue to strengthen for Black students from 2005 onwards. In general, marijuana use prevalence decreased over time within all levels of perceived risk.¹

The results of the current study soundly refuted the hypothesis that the statistical marijuana risk/use association has weakened over time. Instead, the results supported the second hypothesis: as the level of risk an individual perceives to be associated with marijuana use increases, the likelihood of their using marijuana significantly decreases. This association was observed over time among 12th grade students overall and for most gender and racial/ethnic subgroups. Since the overall adolescent marijuana use/risk association has remained strongly significant across time, why has there not been a stronger increase in marijuana use prevalence, given that the prevalence of perceived risk has decreased sharply? Further, how can there be decreasing use prevalence over time within all levels of perceived risk, but a slight increase in overall use prevalence?

The current study showed the likelihood of past 12-month marijuana use varied strongly between perceived risk levels at all time points. Average use prevalence was only 16% among those perceiving great risk in regular marijuana use, but the prevalence of perceiving great risk decreased 47 percentage points across time. Average use prevalence was 70% among those perceiving no/slight risk, and the prevalence of perceiving no/slight risk increased 36 percentage points. Since 2015, more 12th graders have perceived no/slight risk in regular marijuana use than great risk, and overall use prevalence has accordingly moved higher – but not as high as expected. The current study found that use prevalence decreased over time across *all* levels of perceived risk. Similar downward trends observed in all perceived risk levels indicate one or more factors outside of the current analysis have suppressed use regardless of level of risk perception. Identification of what such factors might be is beyond the scope of the current analysis, but—given the similar “suppression” effects across risk levels—it is possible that the factor(s) are associated with initial uptake of marijuana use. Additional research is needed to examine potential outside forces such as the dramatic reduction in adolescent cigarette and alcohol use in the past decade (Miech et al., 2016), which could theoretically reduce marijuana use to the extent that abstinence from these substance lowers risk for marijuana use (Kandel, 2002).

While external factors have likely suppressed marijuana prevalence across levels of perceived risk, a growing number of adolescents are reporting no/slight risk. Adolescents who perceive lower risk report higher use prevalence. The current study found that at lower perceived risk levels, marijuana use prevalence was higher for adolescents overall, males and females, and all racial/ethnic subgroups. Perceived risk is still strongly relevant. In fact, the strength of the great risk/use association has remained generally steady and the strength of

¹While not reported here, all analyses were repeated for past 30-day marijuana use. Results (available upon request) showed that results were robust and supported the same substantive conclusions whether using past 30-day or past 12-month marijuana use.

the moderate risk/use association has actually increased for adolescents overall, both males and females, and for both White and Hispanic adolescents. The increasing importance of perceiving moderate risk (vs. no/slight risk) has implications for prevention efforts to develop and disseminate accurate, credible, age-appropriate information on the risks associated with marijuana use via communication methods that reach intended audiences (Palmgreen & Donohew, 2006; SAMHSA, 2013a).

While the marijuana risk/use association remained significant for all adolescents, among Black adolescents, the magnitude for great risk weakened in recent years, and the magnitude for moderate risk did not continue strengthening over time as it did among White and Hispanic adolescents. The weakened marijuana risk/use association among Black adolescents may at least partially explain the observed rapid increase in marijuana use among this subgroup (Miech et al., 2016; Johnson et al., 2015). Marijuana use disorder prevalence has been observed to be higher among Black individuals than either Hispanic or White individuals aged 12 and older (Pacek, Malcolm & Martins, 2012), and recent increases in past-year marijuana use disorders have been particularly strong among Black adults (Hasin et al., 2015). The weakened risk/use association among Black adolescents somehow may be associated with the observed increase in marijuana use disorder previously reported. Perceived risk can be operationalized in different ways, including risk of physical harm and legal consequences such as arrest (Danesco et al., 1999). Research into the extent to which various aspects of risk may operate differentially with use across racial/ethnic subgroups may help explain this finding.

4.1. Limitations

These findings should be considered within their limitations. Data were cross-sectional (precluding causal interpretation) and based on self-reports. Self-report substance use data have been found to be reasonably reliable and valid under appropriate conditions, which the MTF study has striven to provide (Brener, Billy, & Grady, 2003; Miech et al., 2016; O'Malley, Bachman, & Johnston, 1983). The study also was limited to high school seniors; results may or may not replicate among older or younger people. Findings may not generalize to settings outside of the US or to individuals who drop out of high school. Lower educational attainment is associated with higher marijuana use (SAMHSA, 2013b). Further, analytical cases removed due to missing data were more likely to be non-White; racial/ethnic differences in associations may be under- or overestimated. Additional research that could expand on time-varying associations between perceived risk and other aspects of marijuana use (such as use frequency, age of onset, and interactions with personality measures such as sensation-seeking) would be useful. Limitations notwithstanding, the current study contributes significantly to marijuana use epidemiology by using large, nationally representative samples of 12th grade students from 1991–2016 to examine the strength and stability of the marijuana risk/use association.

5. Conclusions

Perceived risk remains a very strong protective factor for adolescent marijuana use; the protective nature of moderate risk (vs. no/slight risk) has even increased over time for

adolescents overall. Results suggest that accurate and credible information on the risks associated with marijuana use should remain a key component of prevention efforts.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

This study was funded by support from the National Institute on Drug Abuse (R01DA001411 to L.D. Johnston and R01DA037902 to M.E. Patrick). 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

- Alcohol and Drug Abuse Institute. Healthy Youth Survey fact sheet: Marijuana use for Washington state. University of Washington: Alcohol and Drug Abuse Institute; 2015. Retrieved from http://adaai.uw.edu/marijuana/factsheets/WA_healtyyouthsurvey_marijuana.pdf
- Bachman JG, Johnston LD, O'Malley PM. Explaining recent increases in students' marijuana use: impacts of perceived risks and disapproval, 1976 through 1996. *American Journal of Public Health*. 1998; 88:887–892. [PubMed: 9618614]
- Bachman JG, Johnston LD, O'Malley PM, Humphrey RH. Explaining the recent decline in marijuana use: Differentiating the effects of perceived risks, disapproval, and general lifestyle factors. *Journal of Health and Social Behavior*. 1988; 29:92–112. [PubMed: 3367032]
- Bachman, JG., Johnston, LD., O'Malley, PM., Schulenberg, JE., Miech, RA. The Monitoring the Future project after four decades: Design and procedures. *Monitoring the Future Occasional Paper 82*. Ann Arbor, MI: The University of Michigan, Institute for Social Research; 2015. Retrieved from <http://monitoringthefuture.org/pubs/occpapers/mtf-occ82.pdf>
- Brener ND, Billy JOG, Grady WR. Assessment of factors affecting the validity of self-reported health-risk behavior among adolescents: Evidence from the scientific literature. *Journal of Adolescent Health*. 2003; 33:436–57. [PubMed: 14642706]
- Brook JS, Stimmel MA, Zhang C, Brook DW. The association between early marijuana use and subsequent academic achievement and health problems: A longitudinal study. *American Journal of the Addictions*. 2008; 17:155–160.
- Brooks-Rusell, A., Ma, M., McFann, K., Pray, S., Levinson, A. Community Epidemiology and Program Evaluation Group. Brief report: Adolescent alcohol, tobacco and marijuana use, 2013. 2015. Retrieved from <http://www.ucdenver.edu/academics/colleges/PublicHealth/community/CEPEG/UnifYouth/Documents/HKCS%202013%20ATOD%20Brief.pdf>
- Colorado Department of Public Health and Environment. (n.d.). Marijuana use among youth in Colorado: Healthy Kids Colorado Survey 2015. Retrieved from https://www.colorado.gov/pacific/sites/default/files/PF_Youth_MJ-Infographic-Digital.pdf
- Danescu ER, Kingery PM, Coggeshall MB. Perceived risk of harm from marijuana use among youth in the USA. *School Psychology International*. 1999; 20:39–56.
- Fleming CB, Guttmannova K, Cambron C, Rhew IC, Oesterle S. Examination of the divergence in trends for adolescent marijuana use and marijuana-specific risk factors in Washington state. *Journal of Adolescent Health*. 2016; 59:269–275. [PubMed: 27318426]
- Han, B., Hedden, SL., Lipari, R., Copello, EAP., Kroutil, LA. Receipt of services for behavioral health problems: Results from the 2014 National Survey on Drug Use and Health. *NSDUH Data Review*. Rockville, MD: US Department of Health and Human Services, Substance Abuse and Mental Health Services Administration; 2015. Retrieved from <https://www.samhsa.gov/data/sites/default/files/NSDUH-DR-FRR3-2014/NSDUH-DR-FRR3-2014/NSDUH-DR-FRR3-2014.pdf>

- Hasin DS, Saha TD, Kerridge BT, et al. Prevalence of marijuana use disorders in the United States between 2001–2002 and 2012–2013. *JAMA Psychiatry*. 2015; 72:1235–1242. [PubMed: 26502112]
- Hughes, A., Lipari, RN., Williams, M. State estimates of adolescent marijuana use and perceptions of risk of harm from marijuana use: 2013 and 2014. The CHBSQ Report. Rockville, MD: US Department of Health and Human Services, Substance Abuse and Mental Health Services Administration; 2015. Retrieved from https://www.samhsa.gov/data/sites/default/files/report_2121/ShortReport-2121.html
- Janz NK, Becker MH. The Health Belief Model: A decade later. *Health Education Quarterly*. 1984; 11:1–47. [PubMed: 6392204]
- Johnson RM, Fairman B, Gilreath T, Xuan Z, Rothman EF, Parnham T, Furr-Holden DM. Past 15-year trends in adolescent marijuana use: Differences by race/ethnicity and sex. *Drug and Alcohol Dependence*. 2015; 155:8–15. [PubMed: 26361714]
- Johnston, LD., Bachman, JG., O'Malley, PM. Highlights from student drug use in America, 1975–1980. Washington, D.C: National Institute on Drug Abuse; 1981.
- Kandel, DB. Stages and pathways of drug involvement: Examining the gateway hypothesis. United Kingdom: Cambridge University Press; 2002.
- Lanza ST, Vasilenko SA, Liu X, Li R, Piper ME. Advancing the understanding of craving during smoking cessation attempts: A demonstration of the time-varying effect model. *Nicotine and Tobacco Research*. 2014; 16:S127–S134. [PubMed: 23975881]
- Li, R., Dziak, JJ., Tan, X., Huang, L., Wagner, AT., Yang, J. TVEM (Time-varying effect modeling) SAS macro users' guide (version 3.1.0). University Park, PA: The Methodology Center, Penn State; 2015. Retrieved from https://methodology.psu.edu/sites/default/files/software/tvem/TVEM_3.1.0.pdf
- Miech, RA., Johnston, LD., O'Malley, PM., Bachman, JG., Schulenberg, JE. Monitoring the Future national survey results on drug use, 1975–2015: Volume I, Secondary school students. Ann Arbor: Institute for Social Research, The University of Michigan; 2016. Retrieved from http://monitoringthefuture.org/pubs/monographs/mtf-vol1_2015.pdf
- National Academies of Sciences, Engineering, and Medicine. The health effects of cannabis and cannabinoids: The current state of evidence and recommendations for research. Washington, DC: The National Academies Press; 2017.
- O'Malley PM, Bachman JG, Johnston LD. Reliability and consistency of self-reports of drug use. *International Journal of the Addictions*. 1983; 18:805–824. [PubMed: 6605313]
- Paeck LR, Malcolm RJ, Martins SS. Race/ethnicity differences between alcohol, marijuana, and co-occurring alcohol and marijuana use disorders and their association with public health and social problems using a national sample. *American Journal on Addictions*. 2012; 21:435–444. [PubMed: 22882394]
- Pacek LR, Mauro PM, Martins SS. Perceived risk of regular cannabis use in the United States from 2002 to 2012: Differences by sex, age, and race/ethnicity. *Drug and Alcohol Dependence*. 2015; 149:232–244. [PubMed: 25735467]
- Palmgreen, P., Donohew, L. Effective mass media strategies for drug abuse prevention campaigns. In: Sloboda, Z., Bukoski, WJ., editors. *Handbook of drug abuse prevention* (pp. 27–43; Part II, *Handbooks of Sociology and Social Research*. New York, NY: Springer US; 2006.
- Rosenstock IM. Historical origins of the Health Belief Model. *Health Education Monographs*. 1974; 2:328–335.
- Stephens PC, Sloboda Z, Stephens RC, Teasdale B, Grey SF, Hawthorne RD, Williams J. Universal school-based substance abuse prevention programs: Modeling targeted mediators and outcomes for adolescent cigarette, alcohol and marijuana use. *Drug and Alcohol Dependence*. 2009; 102:19–29. [PubMed: 19362433]
- Substance Abuse and Mental Health Services Administration. The NSDUH report: Trends in adolescent substance use and perception of risk from substance use. Rockville, MD: US Department of Health and Human Services, Substance Abuse and Mental Health Services Administration; 2013a. Retrieved from <https://www.samhsa.gov/data/sites/default/files/NSDUH099a/NSDUH099a/sr099a-risk-perception-trends.pdf>

- Substance Abuse and Mental Health Services Administration. The NSDUH report: Substance use among 12th grade aged youth by dropout status. Rockville, MD: Substance Abuse and Mental Health Services Administration, Center for Behavioral Health Statistics and Quality; 2013b.
- Substance Abuse and Mental Health Services Administration. National estimates of drug-related emergency department visits, 2004–2011 – all misuse and abuse. Data table 6/10/2014 [Data file]. 2014a. Retrieved from <https://www.samhsa.gov/data/emergency-department-data-dawn/reports>
- Substance Abuse and Mental Health Services Administration. Risk and protective factors associated with youth marijuana use: Using prevention research to guide prevention practice. Rockville, MD: Substance Abuse and Mental Health Services Administration; 2014b. Retrieved from <https://www.samhsa.gov/capt/sites/default/files/resources/risk-protective-factors-marijuana-use.pdf>
- Substance Abuse and Mental Health Services Administration. Results from the 2013 National Survey on Drug Use and Health: Summary of National Findings (NSDUH Series H-48, HHS Publication No. (SMA) 14-4863). Rockville, MD: Substance Abuse and Mental Health Services Administration; 2014c. Retrieved from <https://www.samhsa.gov/data/sites/default/files/NSDUHresultsPDFWHTML2013/Web/NSDUHresults2013.pdf>
- Sullum, J. Teenagers confound prohibitionists by smoking pot less. 2016 Jun 6. Reason.com. Retrieved from <http://reason.com/archives/2016/06/06/teenagers-confound-prohibitionists-by-us>
- Tan X, Shiyko MP, Li R, Li Y, Dierker L. A time-varying effect model for intensive longitudinal data. *Psychological Methods*. 2012; 17:61–77. [PubMed: 22103434]
- TVEM SAS Macro (Version 3.1.0) [Software]. University Park: The Methodology Center, Penn State; 2015. Available from <https://methodology.psu.edu/downloads/tvem>
- Volkow ND, Baler RD, Compton WM, Weiss SRB. Adverse health effects of marijuana use. *New England Journal of Medicine*. 2014; 370:2219–2227. [PubMed: 24897085]
- Wu L-T, Swartz MS, Brady KT, Hoyle RH. NIDA AAPI Work group. Perceived cannabis use norms and cannabis use among adolescents in the United States. *Journal of Psychiatric Research*. 2015; 64:79–87. [PubMed: 25795093]

Highlights

- Analyzed adolescent marijuana risk/use association magnitude/stability - 26 years.
- Overall marijuana use/risk association remained strongly significant across time.
- Marijuana use prevalence decreased over time within all levels of perceived risk.

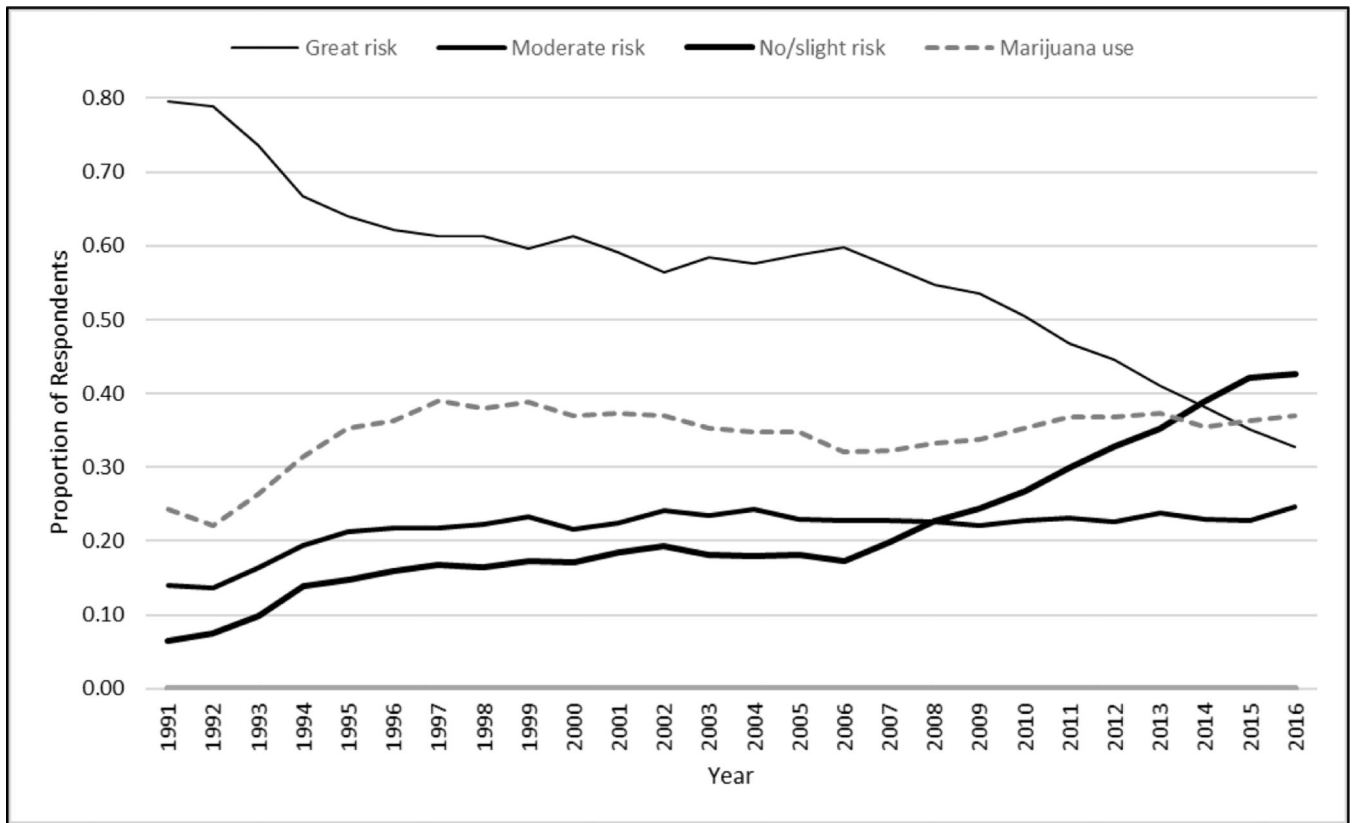


Figure 1. Trends in perceived risk of regular marijuana use and any past 12-month marijuana use among US 12th grade students, 1991–2016

Notes: N = 275,768.

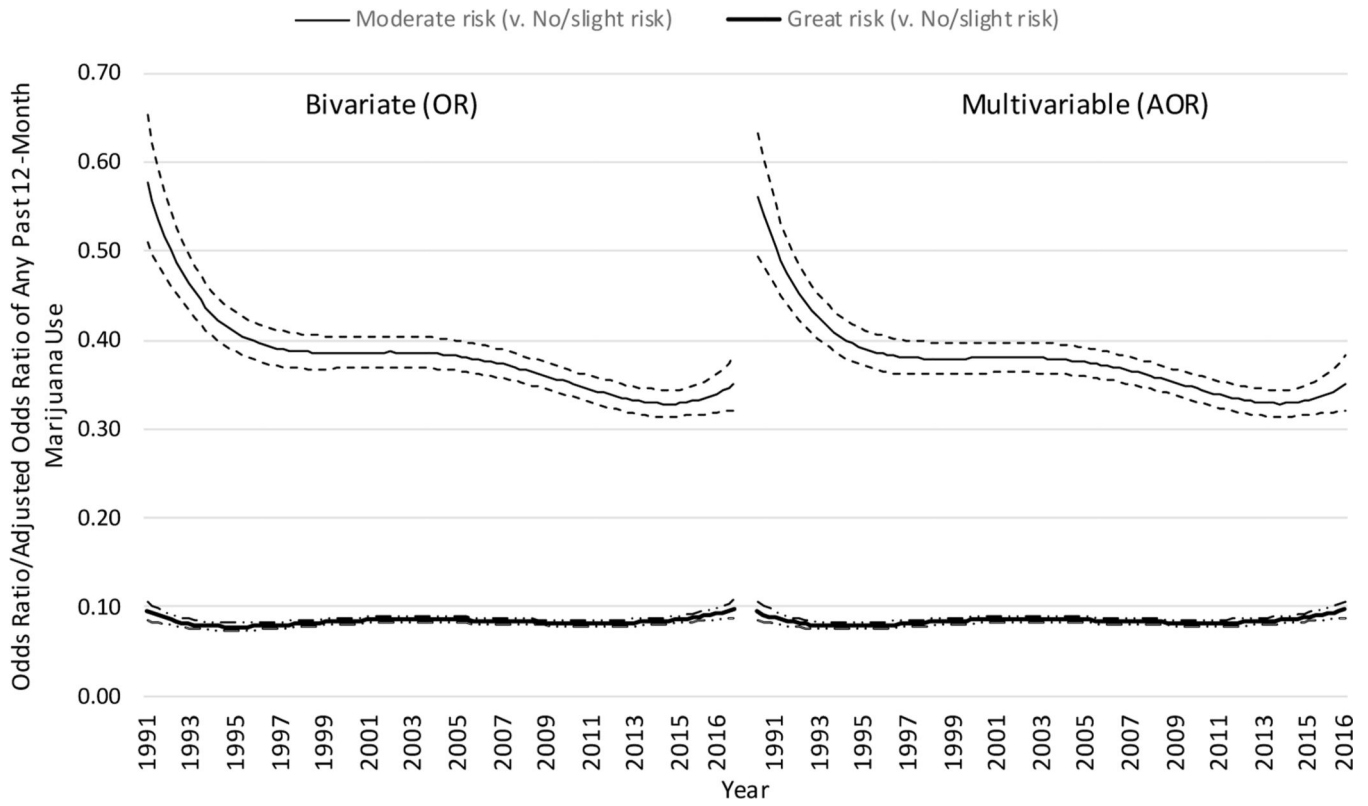


Figure 2. Time-varying associations between perceived risk and past 12-month marijuana use among US 12th grade students, 1991–2016

Notes: N = 275,768. Multivariable model controlled for gender and race/ethnicity. Dotted lines indicate 95% confidence intervals. For specific time points when confidence intervals do not contain 1.0, the coefficient is significant at $p < .05$.

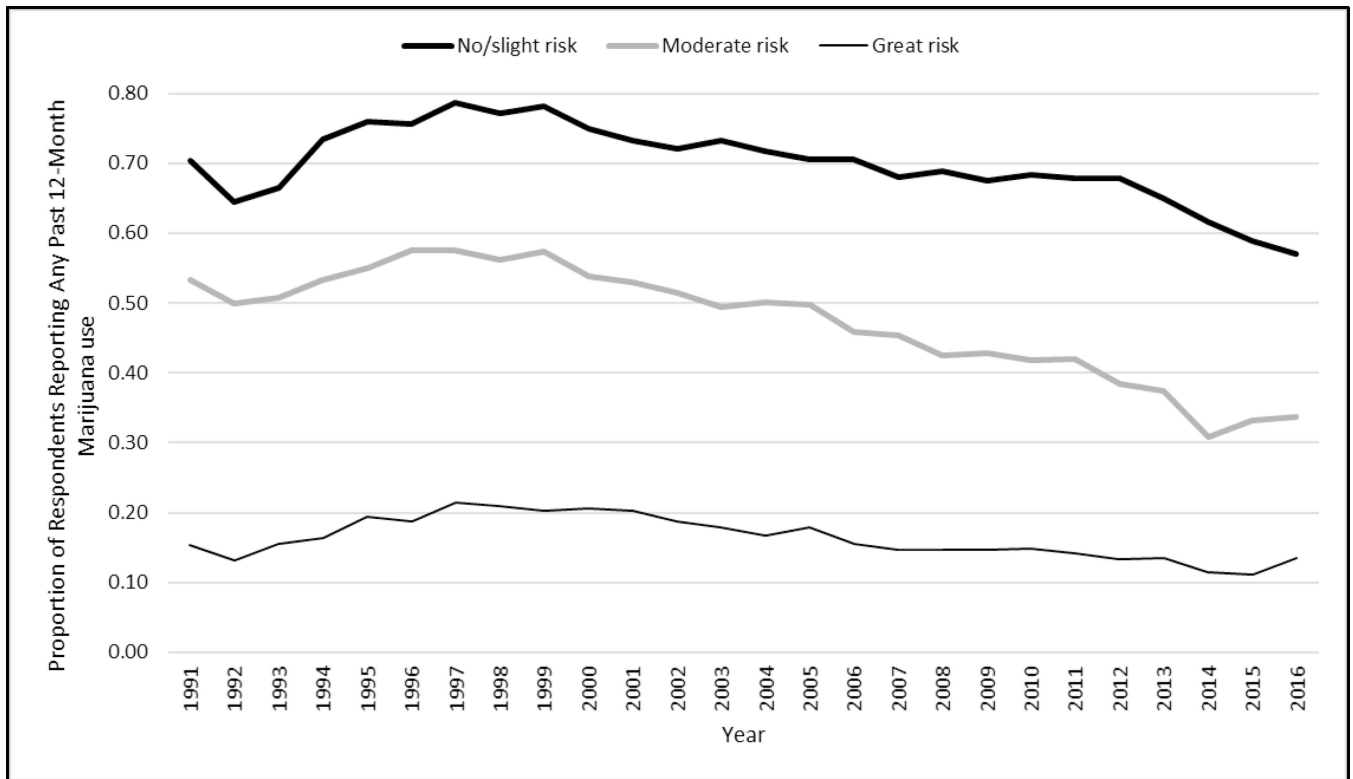


Figure 3. Trends in any past 12-month marijuana use by level of perceived risk of regular marijuana use among US 12th grade students, 1991–2016

Notes: N = 275,768.

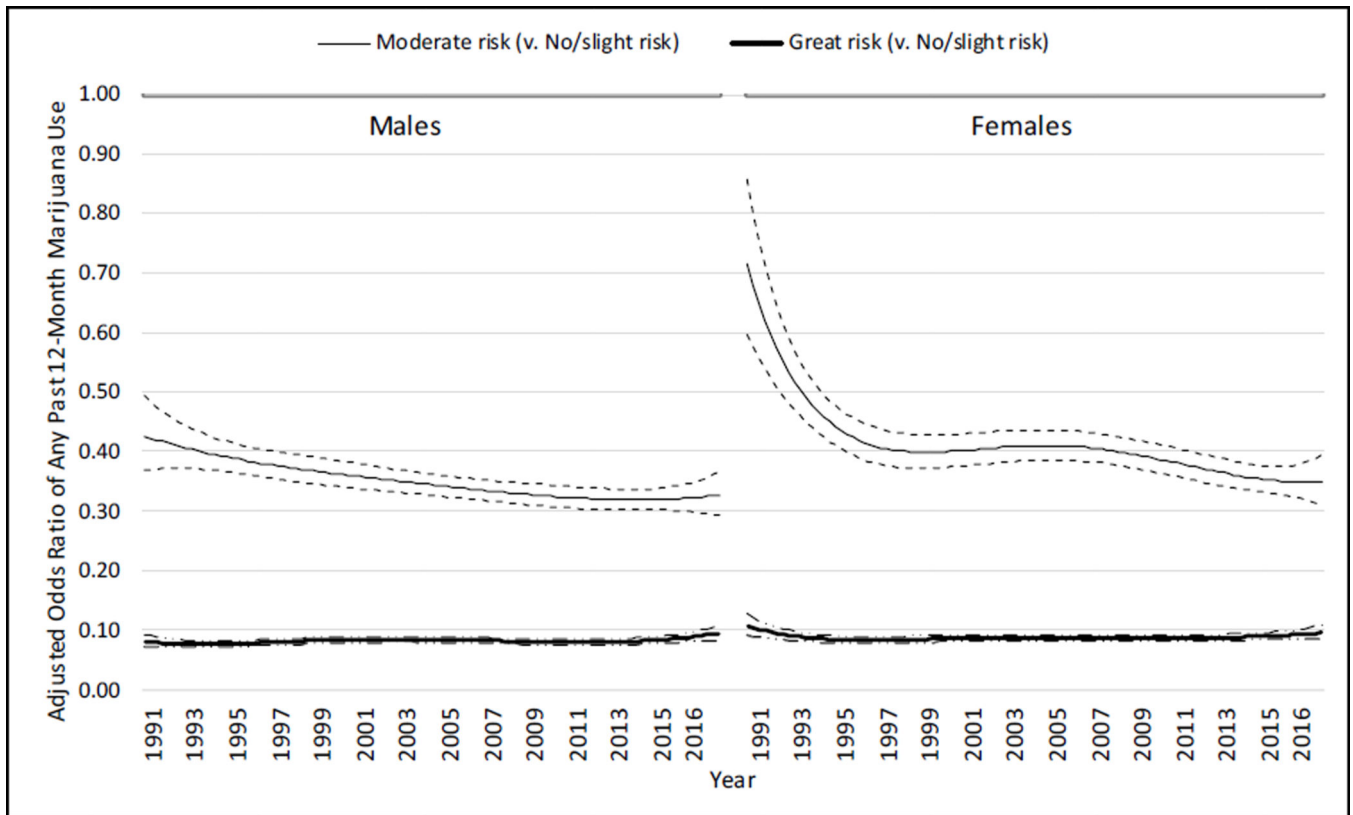


Figure 4. Time-varying associations between risk and past 12-month marijuana use separately by gender among US 12th grade students, 1991–2016

Notes: N = 131,954 males; 143,814 females. Models run separately for males and females, and controlled for race/ethnicity. Dotted lines indicate 95% confidence intervals. For specific time points when confidence intervals do not contain 1.0, the coefficient is significant at $p < .05$.

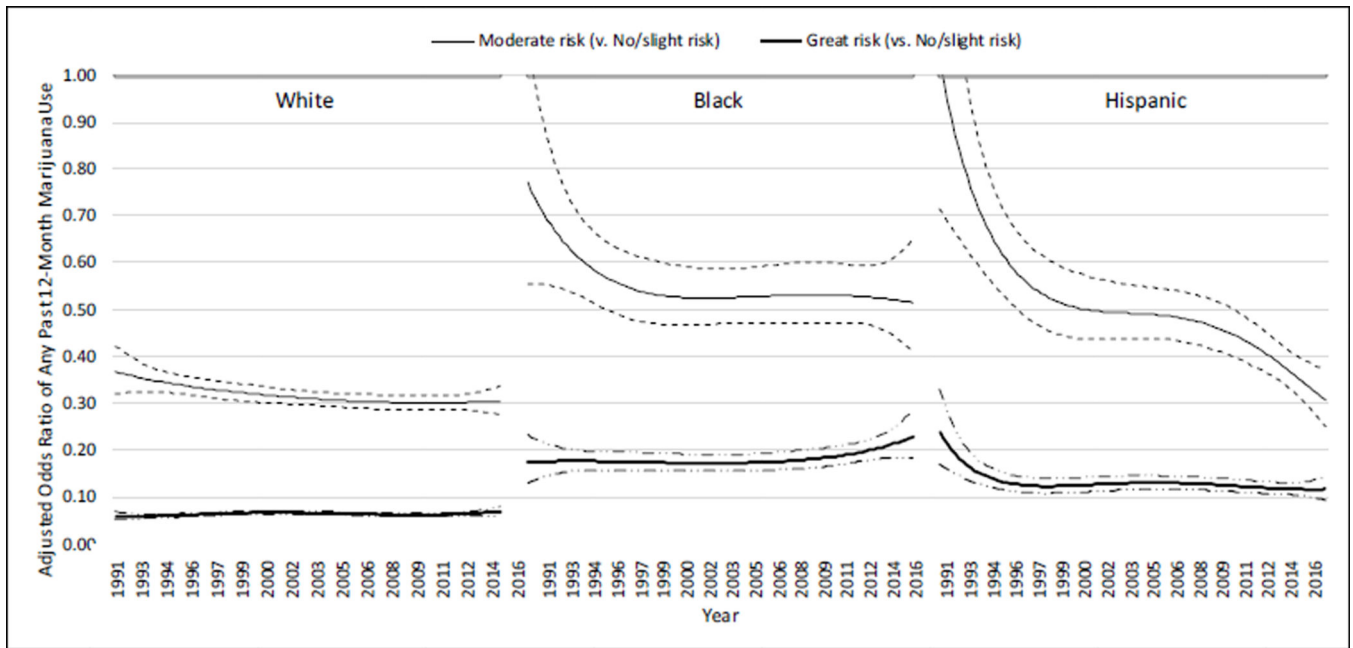


Figure 5. Time-varying associations between risk and past 12-month marijuana use separately for White, Black, and Hispanic US 12th grade students, 1991–2016

Notes: N = 180,054 White students; 33,827 Black students; 33,303 Hispanic students.

Models run separately for each racial/ethnic group and controlled for gender. Dotted lines indicate 95% confidence intervals. For specific time points when confidence intervals do not contain 1.0, the coefficient is significant at $p < .05$.