# Drink like a Man? Modified Poisson Analysis of Adolescent Binge Drinking in the US, 1976–2022

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## Abstract

This study estimates temporal trajectories and sociodemographic disparities in underage adolescent binge drinking in the United States over the past four decades. By compiling 47 waves of national representative data from the Monitoring the Future (MTF) study between 1976 to 2022, we analyzed two types of adolescent binge drinking behaviors, past-two-week excessive drinking and drunkenness in the past 30 days, using the innovative modified Poisson (mixture) approach to grouped and right-censored counts (GRC). The overall decrease in incidence rates was attributable to substantial reductions in the risks of excessive drinking (45.77% in 1980 and 12.62% in 2022) and drunkenness (35.12% in 1998 and 14.81% in 2022). However, at-risk adolescents only showed mild reductions in incidence rates over time. While males consistently drank more often and were at a higher risk of binge drinking and drunkenness than females, the sex disparities tended to converge over time. The modified Poisson approach is a useful tool to estimate incidence, risk, and at-risk incidence in epidemiological studies with GRC counts. The alarming high incidence rates of at-risk adolescents, especially males, warrant further investigation.



**Key words:** Adolescent Binge Drinking, Grouped and Right Censored Counts, Modified Poisson Estimator, Mixture Models

## INTRODUCTION

After decades-long efforts in preventing and reducing underage drinking on federal and state levels, binge drinking remains a serious public health and safety concern that still haunts American adolescents. Commonly defined as consuming at least four (for women) or five drinks (for men) within one occasion (Wechsler et al., 1994), youth who indulge in heavy and binge drinking behaviors are more likely to exhibit low academic achievement (Bachman et al., 2008; Miller et al., 2007), long-term physical and emotional impairments (Schulenberg & Maggs, 2002), potential cognitive deficits (Brown et al., 2000), a greater likelihood of suicide ideation and attempts (Miller et al., 2007; Schilling et al., 2009), risky health and social behaviours (Miller et al., 2007; O'Malley & Johnston, 1999), and other substance abuse (Miller et al., 2007; Patrick et al., 2018) during adolescence and early adulthood. Underage binge drinking is also associated with collateral costs such as alcohol-related traffic crashes and fatalities of passengers and pedestrians (Giesbrecht et al., 2010; Hosseinichimeh et al., 2022). As by far the most popular psychoactive substance across all ages in the United States, alcohol has been widely consumed by adolescents despite the country's minimum legal drinking age of 21 years old (Council, 2004; General, 2006; Patrick & Schulenberg, 2014). Existing institutional measures to combat with underage drinking include the implementation of the Minimum Legal Drinking Age (MLDA) law in the 1980s and the more recent *Surgeon General's Call to Action to Prevent and Reduce Underage Drinking* in 2007. These legislative and administrative efforts, together with intervention and prevention programs, may have strengthened public awareness of adolescent binge drinking and its various health, social, and economic costs, and thus curbed binge drinking among American adolescents (Hingson & White, 2014). As reported by 12$^{th}$ graders, their prevalence of high intensity drinking (defined as having 10+ drinks in a row in the last two weeks) dropped from 10.6% in 2005 to 4.3% in 2022 (Johnston

et al., 2023).

Adolescent binge drinking often involves complex interplays between socio-demographical, individual, family, and social factors. Family context plays a critical role in shaping adolescents' access to alcohol and predicting their early onset of drinking behaviors (Mattick et al., 2018; Tucker et al., 2003). Binge drinking tends to occur more often among adolescents with disrupted family relations (Tucker et al., 2003). The absence of parental monitoring and supervision such as growing up in single- or no-parent families is a key risk factor for adolescent alcohol use (Dever et al., 2012). Regarding regional variations, adolescents from the Northcentral region report significantly higher rates of binge drinking (O'Malley & Johnston, 1999). White adolescents show the highest prevalence of alcohol consumption and heavy drinking among all racial groups (Caetano et al., 2014). As a traditionally male-dominated practice, drinking has always been woven into the social and cultural fabric that affirms masculinity and manliness (Lemle & Mishkind, 1989), which is manifested in the popular saying that "drink like a man". While males constantly consume more alcohol than females since adolescence, the sex disparity in adolescent binge drinking grows with age (Griffin et al., 2000; Swendsen et al., 2012) but diminishes over time (Wallace Jr et al., 2003; White, 2020).

Key methodological and conceptual issues remain when analyzing adolescent binge drinking. Given the sensitive nature of substance use and recall bias, existing surveys such as the MTF study, the Youth Risk Behavior Surveillance System, the National Longitudinal Study of Adolescent to Adult Health, and Canadian Health Survey on Children and Youth often use grouped and right-censored counts (GRC) to measure frequencies of adolescent risky behaviors. Due to the lack of statistical tools for analyzing GRC counts, researchers previously treated those counts as categories so as to apply multinomial or ordered logistic regression, which failed to estimate incidence and

resulted in a serious loss of information contained in GRC counts (Guo & Fu, 2024; Patrick et al., 2018). Meanwhile, adolescent drinking behaviors are often unevenly distributed across socio-demographic groups (Chassin et al., 2002; Schulenberg & Maggs, 2002; Sher et al., 1991). It is therefore conceptually important to distinguish between those who are at risk of binge drinking and those who are not, and also distinguish between the overall incidence and incidence of those at risk of binge drinking (Guo & Fu, 2024; Luczak et al., 2002). In other words, we interpret the overall incidence as a weighted average of zero incidence for those not at risk (who always report no binge drinking) and the incidence reported by those at risk of binge drinking. Previous research has been unable to estimate the overall incidence from GRC counts and has also failed to distinguish between overall incidence and at-risk incidence in the analysis of GRC counts. Our study aims to address these issues.

Based on an innovative modified Poisson (mixture) approach (Fu et al., 2020; Fu et al., 2021; Gu et al., 2023; Guo & Fu, 2024), we address these methodological and conceptual issues and estimate incidence of adolescent binge drinking in the US over the last four decades. More specifically, we analyze 47 waves of the MTF study, investigate sociodemographic disparities in adolescent binge drinking and drunkenness, and estimate their sex-specific trajectories from 1976 to 2022.

## METHODS

### Data

We retrieved and compiled 47 waves of datasets from the Monitoring the Future (MTF) survey collected from 1976 to 2022. The MTF study as a nationally representative survey investigates various topics including juvenile deviance and delinquency, substance use, and civic engagement.

This study started its pilot study of 12th graders in 1975, launched a more systematic investigation in 1976, and included 8th and 10th graders in 1991. To ensure its national representativeness, the MTF study employed a three-stage random sampling strategy, which selected particular geographical areas at stage 1, specified a certain number of schools within each chosen area at stage 2, and finally chose classes within each specified school. Survey questionnaires were distributed in school and hence the sampling frame of MTF project excluded dropouts and absentees on the survey day. Since older adolescents tend to report more prevalent and frequent alcohol consumption, we restrict our analysis to 12th graders. This restriction also allows for a more extended period of study. Students who did not report their past two weeks of binge drinking or past 30-day drunkenness were excluded from the corresponding analytical sample. Following the general guidelines for multiple imputation (Rubin, 2004; Schafer & Olsen, 1998), we conducted five rounds of imputation using fully conditional specification (FCS) logistic regression. We also performed a robustness analysis based on seven rounds of imputation (Graham et al., 2007) and the results are virtually the same. We assumed the data were missing at random (MAR) for all cases with missing values and performed multiple imputations (MI) using FCS based on sex, race/ethnicity, family structure, mother's employment status, academic performance, and parental educational background, utilizing SAS PROC MI.

**Measures**

We investigated two outcomes measuring adolescent binge drinking: excessive drinking in the past two weeks and drunkenness in the past 30 days. Information on excessive drinking based on the following survey question is available over the period of study: "How many times have you had five or more drinks in a row over the last two weeks?" with its GRC response categories "none,"

"once," "twice," "3 to 5 times," "6 to 9 times," and "10 or more times". Researchers have suggested that this measure of excessive drinking primarily applies to nonclinical populations and have called for the inclusion of a 'drunkenness' component in the measurement of binge drinking behaviors (Courtney & Polich, 2009; Lannoy et al., 2021). Information on drunkenness is available in the MTF survey from 1991 onwards according to the following question, "On how many occasions have you had alcoholic beverages to get drunk during the last 30 days?" with slightly different GRC response categories: "0 occasions", "1–2 occasions", "3–5 occasions", "6–9 occasions", "10–19 occasions", "20–39 occasions", and "40 or more occasions". Including the measure of drunkenness provides a more comprehensive understanding of the temporal trends in binge drinking.

We considered three covariates to account for their sociodemographic characteristics: sex (female vs male), race (Black vs. non-Black), and school performance (GPA B- vs. below). We also included three dummy variables, parental educational attainment (individuals with both parents graduated from high school or above were coded as one, and zero otherwise), family structure (students who grew up in intact families with both parents presented were coded as one, and zero otherwise), and mother's employment status (those with stay-at-home mother were coded as one, and zero otherwise), to investigate the impact of family background on adolescent binge drinking. Finally, we used two control variables to account for regional variations of adolescent binge drinking: the current school location (Northcentral, South, West, and Northeast) and Metropolitan Statistical Area (MSA, those attending school in areas defined as MSA by the US Census Bureau were coded as one, and zero otherwise).

**Analytical Approach**

We implemented the modified Poisson (mixture) approach via generalized linear models to analyze the GRC counts of adolescent binge drinking (Fu et al., 2020; Fu et al., 2021). This modified Poisson approach demonstrates clear methodological advantages over traditional methods when analyzing grouped and right-censored count data (Fu et al., 2018, 2020; Fu et al., 2021; Guo & Fu, 2024). To describe the modified Poisson (mixture) model, we used a random variable $Y$ to denote the occurrence of binge drinking that followed a Poisson distribution $\mathbf{Pois}(\mu)$. Its expected frequency $\mu$ was denoted by a combination of covariates $\mathbf{X} = (X_0, \cdots, X_q)^T$ and their coefficients $\boldsymbol{\beta} = (\beta_0, \cdots, \beta_q)^T$ through the link function $\mu = \exp(\boldsymbol{\beta}^T \mathbf{X})$ (Lambert, 1992). We further denoted any GRC scheme with N adjacent groups as $\mathcal{G} = \{l_i\}_{i=1}^{N+1}$, where $0 = l_1 < l_2 = 1 < \cdots < l_{N+1} = \infty$ were the boundaries of the N groups and $l_{N+1} = \infty$ specifically denoted the right theoretical boundary of the last group. For example, we expressed GRC response categories of the two aforementioned variables of excessive drinking and drunkenness as $\mathcal{G}_1^* = \{0,1,2,3,6,10,\infty\}$ and $\mathcal{G}_2^* = \{0,1,3,6,10,20,40,\infty\}$, respectively. An observation of binge drinking measured by the GRC counts had a multinomial distribution $Y_{\mathcal{G}} \sim \mathbf{M}(\theta_1^{\mathcal{G}}, \cdots, \theta_N^{\mathcal{G}})$:

$$\mathbf{Prob}(Y_{\mathcal{G}} = j) = \theta^{\mathcal{G}}(j, \mu) = \sum_{k=l_j}^{l_{j+1}-1} e^{-\mu} \frac{\mu^k}{k!}.$$

The log-likelihood of the modified Poisson model was:

$$\ell_n^{\mathbf{Pois}}(\boldsymbol{\beta}) = \sum_{i=1}^{n} \log\theta^{\mathcal{G}}(Y_{\mathcal{G}}^i, \exp(\boldsymbol{\beta}^T \mathbf{X}^i))$$

.

For the Poisson-Bernoulli mixture model, the occurrence of binge-drinking events followed a zero-inflated Poisson distribution given by $Y \sim \mathbf{ZIP}(p, \lambda)$, where $\lambda$ represented their expected frequency at a given time (or incidence) and $p$ was the proportion of individuals at risk, which corresponded to one's risk of binge drinking or drunkenness at the individual level (Kleinman & Norton, 2009). We had:

$$\mathbf{Prob}(Y = k) = \begin{cases} (1-p) + pe^{-\lambda}, & k = 0, \\ pe^{-\lambda}\dfrac{\mu^{\lambda}}{k!}, & k \geq 1. \end{cases}$$

Again, an observation of binge drinking measured by GRC counts followed a multinomial distribution $Y_{\mathcal{G}} \sim \mathbf{M}(\pi_1^{\mathcal{G}}, \cdots, \pi_N^{\mathcal{G}})$, where:

$$\pi^{\mathcal{G}}(j, \lambda, p) = \begin{cases} 1 - p + pe^{-\lambda}, & j = 1, \\ p\sum_{k=l_j}^{l_{j+1}-1} e^{-\lambda}\dfrac{\lambda^k}{k!}, & 2 \leq j \leq N. \end{cases}$$

The binomial part of the modified Poisson mixture model had the link function $p = \dfrac{1}{1 + \exp(-\boldsymbol{\gamma}^{\mathbf{T}}\mathbf{U})}$ with a second set of predictors $\mathbf{U} = (U_0, \cdots, U_s)^T$ and their regression coefficients $\boldsymbol{\gamma} = (\gamma_0, \cdots, \gamma_s)^T$.

The log-likelihood of the modified Poisson mixture model was:

$$\ell_n^{\mathbf{ZIP}}(\boldsymbol{\beta}, \boldsymbol{\gamma}) = \sum_{i=1}^{n} \log\pi^{\mathcal{G}}(Y_{\mathcal{G}}^i, \exp(\boldsymbol{\beta}^T \mathbf{X}^i), (1 + \exp(-\boldsymbol{\gamma}^T \mathbf{U}^i))^{-1})$$

.

We applied a hybrid line search algorithm to estimate the modified Poisson (mixture) models using R (Fu et al., 2021). We also centered covariates around their sample means and weighted results using the sampling weights provided by the MTF project.

## RESULTS

Table 1 presents descriptive statistics of 476,751 observations for analyzing excessive drinking and 92,061 observations for analyzing drunkenness. About one-third of adolescents (31.40%) consumed five drinks in a row over the last two weeks, and a slightly lower proportion (29.25%) reported being drunk in the previous month. For more extreme binge drinking behaviors, those reported "10 or more times" and "6 to 9 times" of five drinks on one occasion over the past two weeks accounted for 1.42% and 2.32% of the sample, respectively. Likewise, 3.38% and 3.96% of respondents reported being drunk ten or more times and six to nine times over the past month, respectively. Descriptive statistics of covariates are largely the same in the two samples focusing on different binge drinking behaviors. Slightly over half of the respondents self-identified as female, and about 12% were Black. Around 80% of $12^{th}$ graders from both samples had both parents with high school diplomas, roughly three-quarters lived in intact families, and most were from metropolitan areas. About one in five respondents attended school in the Northeastern region, while respondents from the Southern region accounted for about one-third of both samples. In terms of their school performance, more students reported B- and above in the excessive-drinking sample (80.13%) than those in the drunkenness (72.21%) sample. 21.16% of $12^{th}$ graders in the excessive-drinking sample had stay-at-home mothers, and the corresponding proportion in the drunkenness sample was 15.54%. Descriptive statistics after multiple imputation are similar to those in Table 1 (results available upon request).

[Table 1 about here]

Tables 2(A) and Table 2(B) present regression estimates based on the modified Poisson (mixture) models, adjusting for the effects of survey years. Results from modified Poisson models showed that students who were female or Black reported significantly fewer incidences of binge-drinking behaviors. Likewise, those who had better school performance, lived in intact families, or attended school in the West or South were significantly associated with fewer binge-drinking incidences. Residing in metropolitan statistical areas and having a stay-at-home mother were protective factors against more frequent excessive drinking but showed non-significant effects on drunkenness. Having better educated parents increased the overall incidence of adolescent drunkenness.

[Table 2(A) and 2(B) around here]

The modified Poisson (mixture) models further decomposed the overall incidence into the proportion of adolescents at risk (or individual risk of binge drinking) and their at-risk incidence, which yielded a more nuanced picture of adolescent binge drinking. Results from both Binomial and Poisson parts of the modified Poisson mixture models suggested that being female, having satisfactory school performance, living in intact families, and residing in the Western region were correlated with lower risk and fewer at-risk incidents of binge drinking. The impacts of race and family backgrounds also vary between the two binge-drinking behaviors. Adolescents with stay-at-home mothers had significantly lower risk of excessive drinking and drunkenness. Yet, for those who were already at risk, having a stay-at-home mother was significantly associated with more frequent binge-drinking incidents. Black students were associated with lower risk of both binge-drinking behaviors. However, at-risk black students reported significantly higher incidents of drunkenness than their counterparts did. Having better-educated parents significantly increased the

risk of drunkenness. Among at-risk 12th graders, those having better-educated parents reported significantly fewer incidence of drunkenness. A robust analysis showed that the effects of parental education on excessive drinking were mixed (see Appendix). Living in metropolitan statistical areas was significantly associated with lower risk and at-risk incidence of excessive drinking but showed no significant effect on drunkenness. Since the MTF survey no longer includes mothers' employment history in its most recent (2022) wave, we calculated regression estimates in Table 2 based on 46 waves of survey data (1991–2021).

Drawing on estimates from modified Poisson (mixture) models in Table 2 yet without the single variable of mother's employment, we next estimated trajectories of incidence/risk using all 47 waves of survey data. In Figure 1 and Figure 2, we held all covariates at their sample means and also estimated sex-specific trajectories to highlight sex disparities over time. As shown in Figure 1(A), the overall incidence of adolescent excessive drinking largely exhibited a chronic decline from 1.11 incidents in 1979 to 0.15 incidents in 2021. Sex disparities in excessive drinking remained relatively stable until 1998 and then narrowed down afterwards. Figure 1(B) presents the proportion of adolescents at risk of excessive drinking over time. Despite a plateau around the 1990s, the proportion of at-risk adolescents also exhibited a long-term decline over the period of study, which dropped from 45.77% in 1980 to 10.56% in 2021. It then increased slightly in the most recent wave and reached 12.62% in 2022. The sex disparities gradually reduced over time and almost converged in 2021 (10.98% for males and 10.17% for females). Figure 1(C) shows the trajectory of at-risk incidence of excessive drinking, which remained high and flat until the COVID-19 period with a nadir of 1.40 incidents in 2021. The sex disparities in at-risk incidence remained stable until more recent waves, but swiftly converged with the onset of the COVID-19 pandemic, reaching 1.31 incidents for at-risk females and 1.49 incidents for at-risk males in 2021.

Across all three measures of risk and incidence, male students were more vulnerable to excessive drinking than their female counterparts over the period of study, despite diminished sex disparities in recent waves.

Figures 2(A) to 2(C) present (sex-specific) trajectories of past-30-days drunkenness from 1991 to 2022. Mirroring the temporal pattern observed with excessive drinking, Figure 2(A) indicates a declining trend in the overall incidence of drunkenness following its peak at 1.65 incidents in 1997, notwithstanding occasional fluctuations during the COVID-19 pandemic. Male students constantly reported more incidences of drunkenness than females, with the smallest sex disparity appearing in 2021 (0.36 incidents for females and 0.47 incidents for males). The trajectory of risk of drunkenness, as shown in Figure 2(B), also underwent a major downfall from 35.12% in 1998 to 13.25% in 2021. The sex disparities narrowed down in more recent years, which decreased from 14.84% in 1998 (43.45% for males and 28.61% for females) to a historic low of 5.96% in 2021 (13.87% for males and 7.91% for females). The incidence rates of drunkenness among the at-risk adolescents, illustrated in Figure 2(C), underwent several cycles of fluctuation. It increased from 3.92 incidents in 1993 to 5.38 incidents in 1997 before experiencing varied fluctuations in subsequent waves. Its corresponding sex disparities varied over time, with the largest gap observed in 2011 (6.58 incidents for at-risk males and 4.19 incidence for at-risk females) and the narrowest gap in 2015 (3.79 incidents for at-risk males and 3.71 incidence for at-risk females).

## DISCUSSION

By retrieving and compiling 47 waves of survey data from the MTF project, we examined the temporal trajectories and sociodemographic disparities of two adolescent binge-drinking behaviors:

excessive drinking in the past two weeks and past-30-days drunkenness. Being female or Black, attending schools in the South or West, having better school performance, and living in intact families significantly protected adolescents against binge drinking. Adolescent binge drinking displayed a distinct gendered pattern, with male adolescents consistently facing elevated risk of binge drinking and consuming alcohol more heavily compared to their female counterparts when exposed to risk. Over time, sex disparities in the overall incidence and risk of both binge-drinking behaviors gradually diminished, particularly during the COVID-19 pandemic. However, these differences appeared to widen post-pandemic. Consistent with prior research, our findings underscored that male adolescents constitute a high-risk demographic warranting increased attention from all stakeholders (Wallace Jr et al., 2003; White, 2020).

Employing innovative modified Poisson (mixture) models, we distinguished between risk and at-risk incidence from the overall incidence, allowing for a detailed examination of temporal changes over the last four decades. Our findings revealed that the sustained decline in overall incidence of binge drinking primarily stemmed from a reduction in the proportion of individuals at risk rather than changes in at-risk incidence. Specifically, the chronic decline in overall incidence of past-two-week excessive drinking was driven by a 35% decrease in risk from 1980 to 2021 (45.77% in 1980 to 10.56% in 2021). Similarly, a 21% decline in the risk of drunkenness from 1998 to 2021 (35.12% in 1998 to 13.25% in 2021) substantially contributed to the long-term decrease in the overall incidence of adolescent drunkenness.

While the landscape of adolescent drinking appears to be shifting towards quieter alcohol-free gatherings over time, evidenced by steady declines in overall incidence and risk of binge drinking behaviors among all adolescents, this trend only scratches the surface of the broader narrative. Our research unveils a more nuanced reality: despite declines in overall incidence or risk, at-risk

adolescents prevail in their routines of problematic drinking, nearly matching their peers four decades ago. For instance, following downward adjustments to the Minimum Legal Drinking Age (MLDA) in 29 states during the 1970s, our findings reveal a peak in adolescent overall incidence and risk of excessive drinking in 1979 and 1980, respectively. Subsequently, during the late 1980s and early 1990s, coinciding with the gradual reinstatement of the MLDA to 21 years old in response to a surge in cases of underage driving under the influence (DUI) nationwide (Voas et al., 2003), both measures showed significant declines. However, even within this stringent social and legislative framework that strongly discourages underage drinking, at-risk adolescents of this period did not proportionally curb their intensive drinking behaviors. Although the proportion of at-risk adolescents engaging in excessive drinking decreased from its peak of 45.77% in 1980 to 29.79% in 1993, those at-risk adolescents in 1993 reported only 0.29 fewer incidents of excessive drinking compared to their counterparts from over a decade age (2.42 incidents in 1993 versus 2.71 incidents in 1980).

**Limitations**

Our estimates could be conservative in two ways. First, high-school dropouts often drank more heavily but were excluded from the MTF project's sampling frame (Bachman et al., 2008). Second, we measured excessive drinking among all adolescents by *consuming five-plus drinks in a row*, while some studies used the criteria of *four-plus drinks on one occasion* (Wechsler et al., 1995; White, 2020). Our results, therefore, may still underestimate the extent of adolescent binge drinking compared to studies using lower thresholds for binge drinking.

**Public Health Implications**

First and foremost, despite the persistent declines in risk and overall incident of binge drinking over the past four decades, the stagnation in mitigating problematic alcohol consumption among at-risk adolescents underscores the need to reevaluate current intervention and prevention strategies against underage drinking. Second, adolescent binge drinking exhibits a highly gendered trajectory over time. Boys not only embrace the 'drink like a man' ethos but also adhere steadfastly to the 'drink like a fish' mantra—enduring consistently higher risk and engaging in more intense binge drinking episodes, warranting heightened attention in studies of adolescent binge drinking etiology. While recent years have shown a reduction in sex disparities in overall incidence rate and risk, notable gender differences in binge drinking persist among at-risk adolescents. Finally, recognizing that all models possess limitations but some prove useful (Box, 1976), modified Poisson (mixture) models offer a direct avenue for analyzing incidence among the at-risk population, presenting an ideal toolkit particularly when GRC counts are utilized in epidemiological studies.

## Figures and Tables

Table 1 Descriptive Statistics of 12th Graders, Monitoring the Future Project, 1976–2022

| | **Binge Drinking (N=476,751)** | | **Drunkenness (N=92,061)** | |
|---|---|---|---|---|
| | N | % | N | % |
| Dependent Variable | | | | |
| *Excessive Drinking* | | | | |
| None | 327,071 | 68.60% | | |
| Once | 52,069 | 10.92% | | |
| Twice | 39,349 | 8.25% | | |
| 3 to 5 times | 40,476 | 8.49% | | |
| 6 to 9 times | 11,038 | 2.32% | | |
| 10 or more times | 6,748 | 1.42% | | |
| *Drunkenness* | | | | |
| 0 occasion | | | 64,635 | 70.75% |
| 1-2 occasions | | | 14,286 | 15.51% |
| 3-5 occasions | | | 6,397 | 6.95% |
| 6-9 occasions | | | 3,642 | 3.96% |
| 10-19 occasions | | | 2,073 | 2.25% |
| 20-39 occasions | | | 534 | 0.58% |
| 40 or more occasions | | | 505 | 0.55% |
| *Academic and demographic factors* | | | | |
| Female | 247,071 | 51.82% | 48,501 | 52.68% |
| Black | 55,815 | 11.71% | 11,321 | 12.30% |
| GPA B- and above | 382,031 | 80.13% | 77,221 | 72.21% |
| *Family background* | | | | |
| Parents with high-school diplomas | 379,113 | 79.52% | 74,143 | 82.71% |
| Intact family | 359,335 | 75.38% | 67,689 | 73.53% |
| Stay-at-home mother [a] | 99,518 | 21.16% | 14,014 | 15.54% |
| *School location* | | | | |
| Northeast | 105,489 | 22.13% | 19,069 | 20.71% |
| Northcentral | 135,654 | 28.45% | 25,256 | 27.43% |
| South | 156,199 | 32.76% | 32,006 | 34.77% |
| West | 79,409 | 16.66% | 15,730 | 17.09% |
| Metropolitan Statistical Area (MSA) | 367,716 | 77.13% | 71,765 | 77.95% |

Note: [a] The MTF project no longer includes this variable after the 2021 wave.

Table 2(A) Estimates of Adolescent Excessive Drinking using Modified Poisson (Mixture) Models, Monitoring the Future Project, 1976–2021 [a, b]

| | **Modified Poisson Model** | **Modified Poisson Mixture Models** | |
|---|---|---|---|
| | | Binomial | Poisson |
| | IRR with 95% CI | OR with 95% CI | IRR with 95% CI |
| *Academic and demographic factors* | | | |
| Female | 0.467*** (0.449,0.486) | 0.444*** (0.411,0.479) | 0.747*** (0.715,0.781) |
| Black | 0.447*** (0.441,0.454) | 0.335*** (0.327,0.343) | 0.967*** (0.952,0.983) |
| GPA B- and above | 0.630*** (0.625,0.634) | 0.635*** (0.625,0.644) | 0.820*** (0.813,0.826) |
| *Family background* | | | |
| Parents with high-school diplomas | 1.007 (0.999,1.015) | 0.996 (0.979,1.013) | 1.011** (1.003,1.020) |
| Intact family | 0.844*** (0.838,0.850) | 0.894*** (0.881,0.907) | 0.902*** (0.895,0.910) |
| Stay-at-home mother [a] | 0.949*** (0.942,0.956) | 0.882*** (0.869,0.895) | 1.023*** (1.014,1.032) |
| *School location* (Northeast as reference) | | | |
| Northcentral | 1.021*** (1.013,1.029) | 0.965*** (0.948,0.982) | 1.045*** (1.035,1.054) |
| South | 0.910*** (0.903,0.917) | 0.790*** (0.777,0.804) | 1.051*** (1.041,1.060) |
| West | 0.743*** (0.736,0.750) | 0.698*** (0.685,0.712) | 0.923*** (0.913,0.933) |
| Metropolitan Statistical Area (MSA) | 0.932*** (0.926,0.938) | 0.965*** (0.952,0.978) | 0.952*** (0.945,0.959) |
| Intercept | 0.688*** (0.686,0.690) | 0.447*** (0.444,0.450) | 2.432*** (2.422,2.442) |

Note: [a] * p<.05; ** p<.01; *** p<.001 (two-tailed tests).

[b] Abbreviations: CI, confidence interval; IRR, incidence rate ratio; MSA, Metropolitan Statistical Area; OR, odds ratio.

Table 2(B) Estimates of Adolescent Drunkenness using Modified Poisson (Mixture) Models, Monitoring the Future Project, 1991–2021 [a, b]

| | **Modified Poisson Model** | **Modified Poisson Mixture Models** | |
|---|---|---|---|
| | | Binomial | Poisson |
| | IRR with 95% CI | OR with 95% CI | IRR with 95% CI |
| *Academic and demographic factors* | | | |
| Female | 0.547*** (0.505,0.594) | 0.644*** (0.565,0.734) | 0.765*** (0.696,0.840) |
| Black | 0.521*** (0.492,0.552) | 0.385*** (0.365,0.406) | 1.077** (1.029,1.128) |
| GPA B- and above | 0.625*** (0.611,0.639) | 0.677*** (0.655,0.701) | 0.821*** (0.801,0.841) |
| *Family background* | | | |
| Parents with high-school diplomas | 1.066*** (1.043,1.090) | 1.232*** (1.190,1.276) | 0.928*** (0.910,0.945) |
| Intact family | 0.781*** (0.768,0.794) | 0.862*** (0.837,0.888) | 0.873*** (0.860,0.886) |
| Stay-at-home mother | 1.023 (0.993,1.054) | 0.868*** (0.836,0.902) | 1.124*** (1.094,1.154) |
| *School location* (Northeast as reference) | | | |
| Northcentral | 0.910*** (0.896,0.924) | 0.888*** (0.855,0.922) | 0.985 (0.970,1.001) |
| South | 0.816*** (0.803,0.829) | 0.760*** (0.733,0.789) | 0.976** (0.962,0.991) |
| West | 0.653*** (0.642,0.665) | 0.690*** (0.663,0.718) | 0.850*** (0.835,0.865) |
| Metropolitan Statistical Area (MSA) | 0.994 (0.981,1.006) | 0.988 (0.959,1.018) | 1.009 (0.996,1.021) |
| Intercept | 1.110*** (1.101,1.119) | 0.375*** (0.370,0.380) | 4.626*** (4.588,4.665) |

Note: [a] * p<.05; ** p<.01; *** p<.001 (two-tailed tests).

[b] Abbreviations: CI, confidence interval; IRR, incidence rate ratio; MSA, Metropolitan Statistical Area; OR, odds ratio.

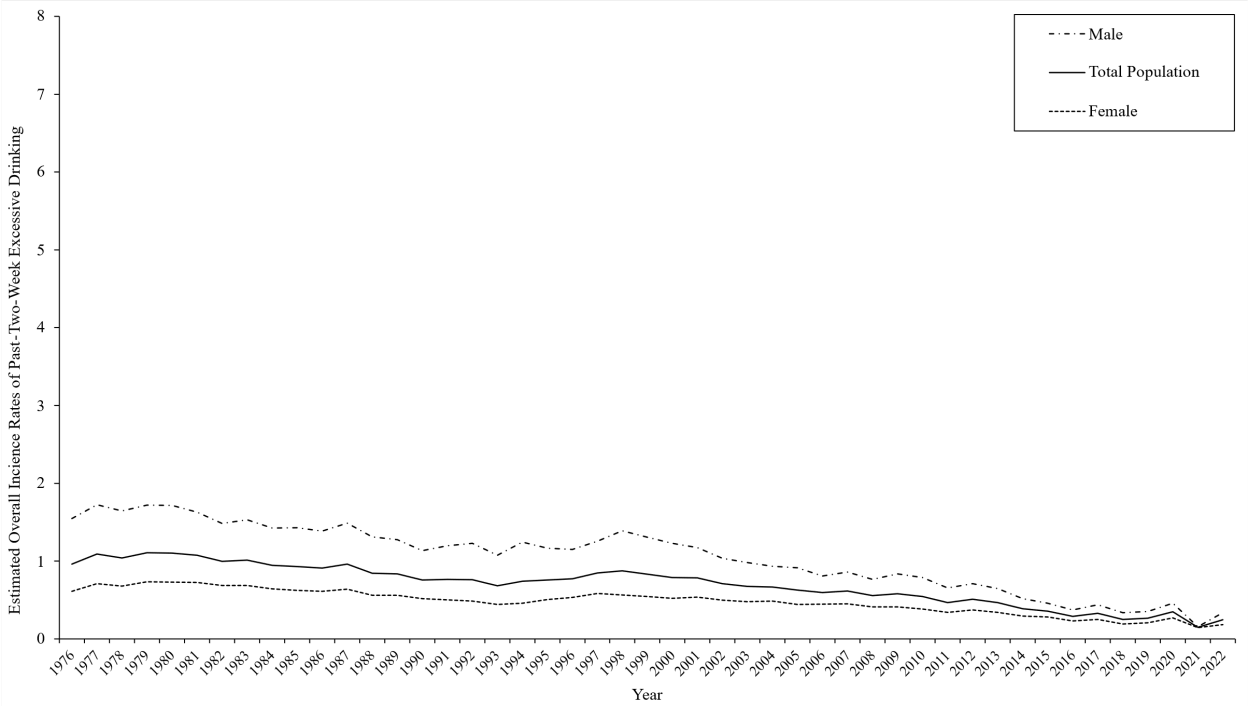


Figure 1(A) Estimated Overall Incidence Rates of Past-Two-Week Excessive Drinking, Monitoring the Future Project, 1976–2022


Figure 1(B) Estimated Proportions of Adolescents at Risk of Past-Two-Week Excessive Drinking, Monitoring the Future Project, 1976–2022

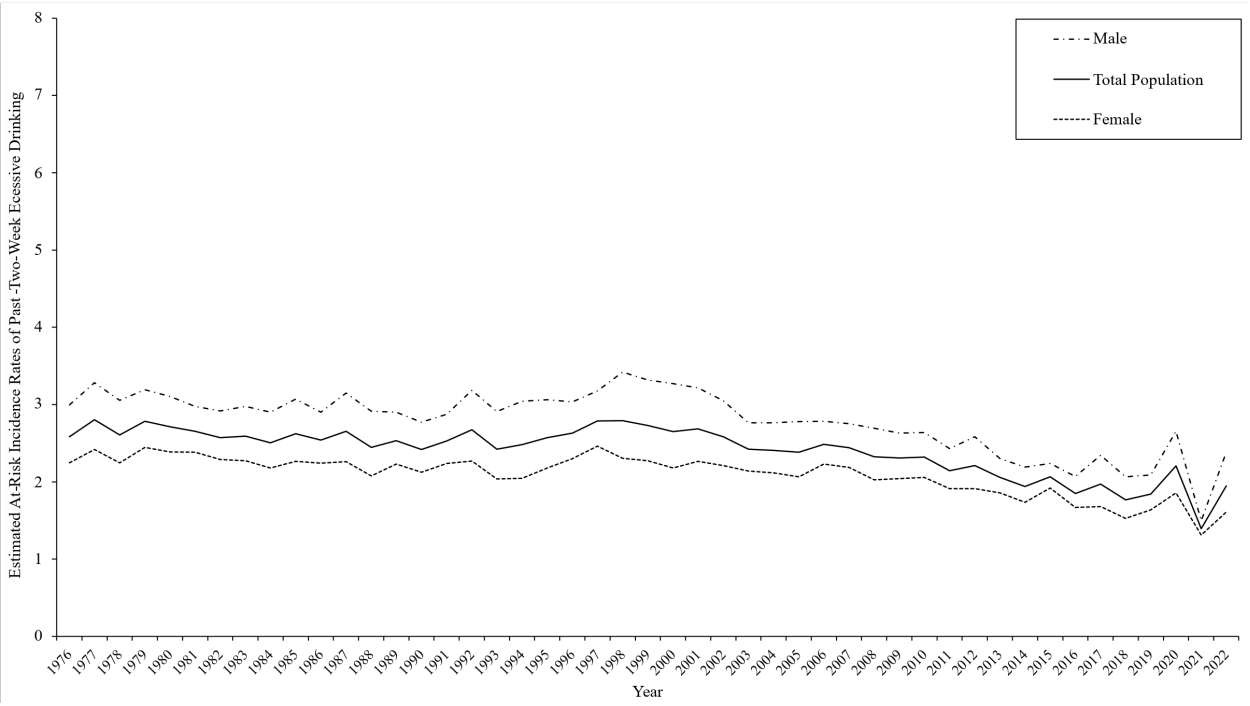


Figure 1(C) Estimated At-Risk Incidence Rates of Past-Two-Week Excessive Drinking, Monitoring the Future Project, 1976–2022

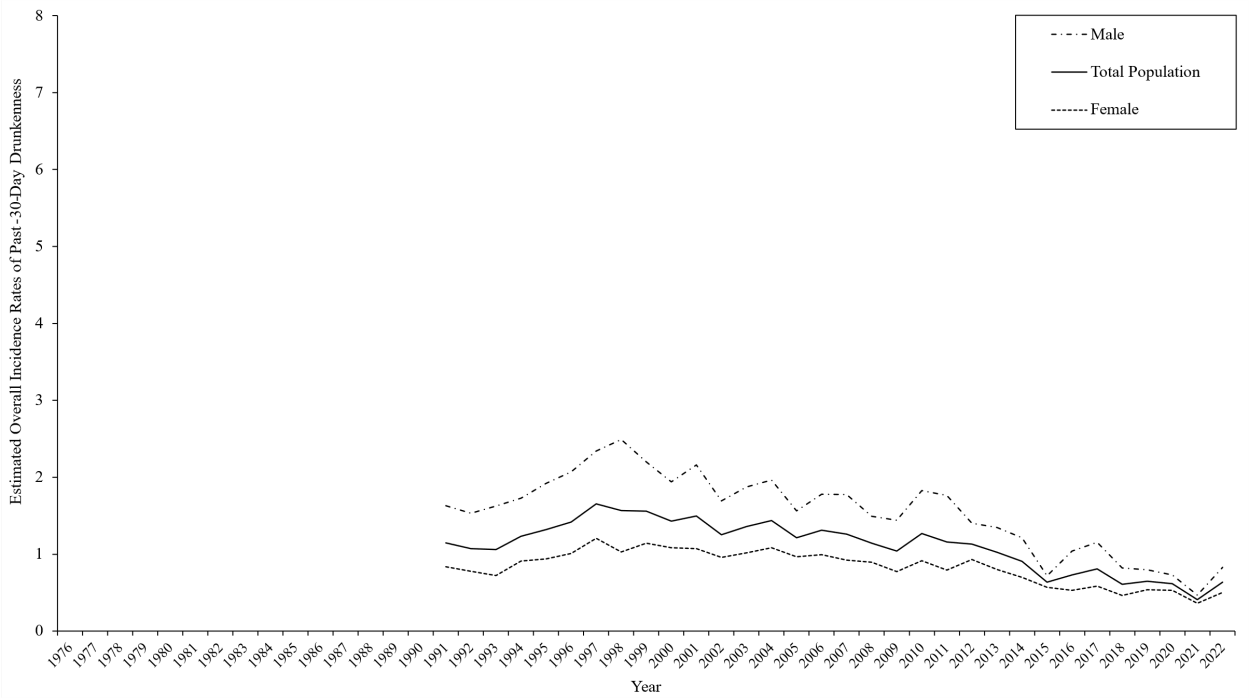


Figure 2(A) Estimated Overall Incidence Rates of Past-30-Day Drunkenness, Monitoring the Future Project, 1991–2022

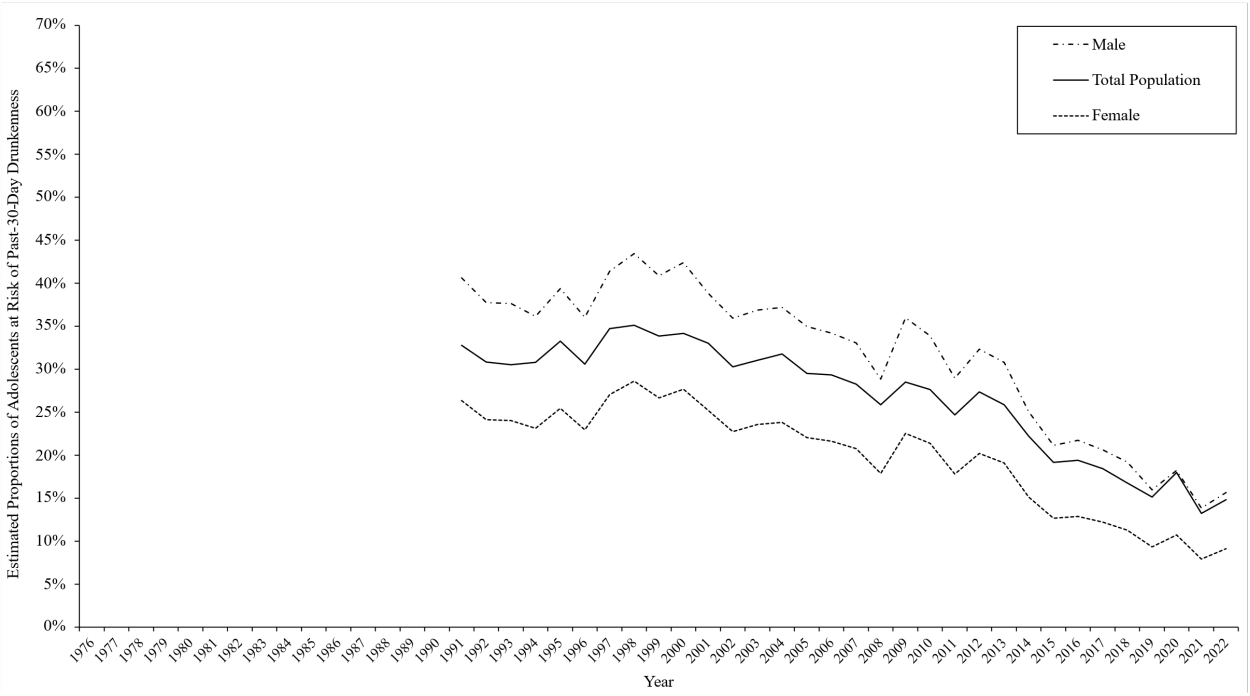


Figure 2(B) Estimated Proportions of Adolescents at Risk of Past-30-Day Drunkenness, Monitoring the Future Project, 1991–2022

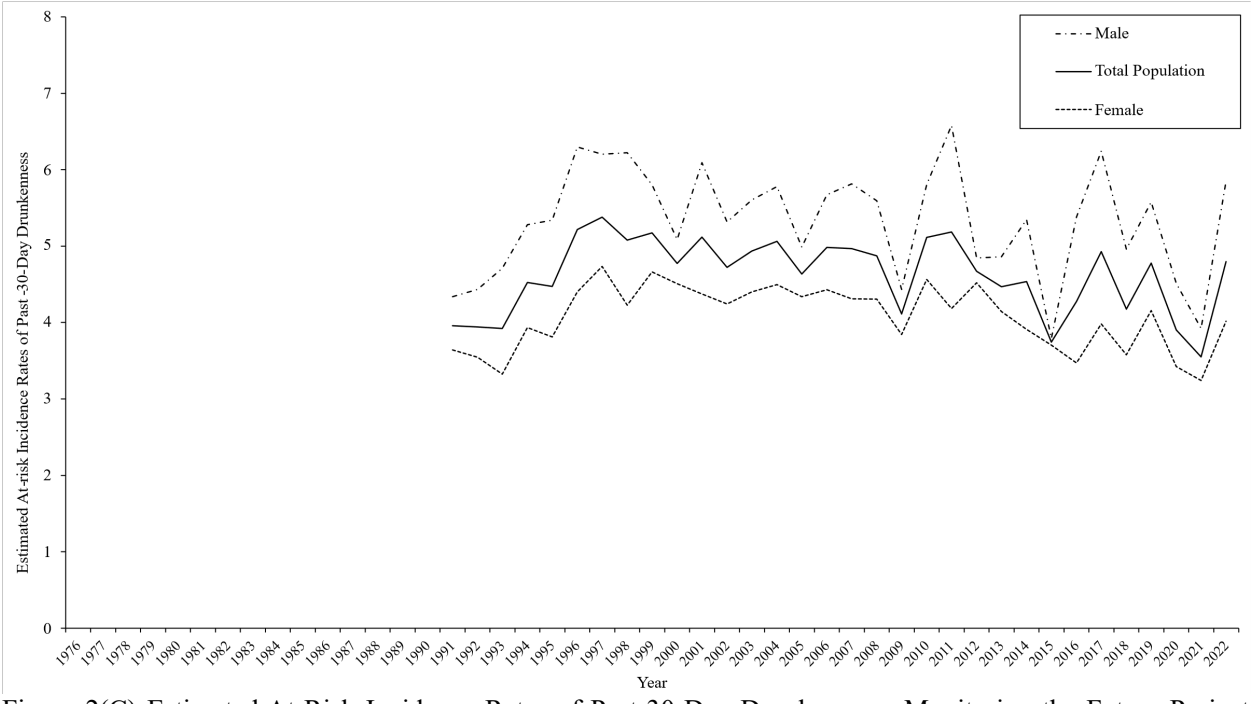


Figure 2(C) Estimated At-Risk Incidence Rates of Past-30-Day Drunkenness, Monitoring the Future Project, 1991–2022

**Appendix A** Estimates of Adolescent Excessive Drinking using Modified Poisson (Mixture) Models, Monitoring the Future Project, 1976–2021 [a, b]

| | **Modified Poisson Model** | **Modified Poisson Mixture Models** | |
|---|---|---|---|
| | | Binomial | Poisson |
| | IRR with 95% CI | OR with 95% CI | IRR with 95% CI |
| *Academic and demographic factors* | | | |
| Female | 0.468*** (0.450,0.486) | 0.446*** (0.412,0.483) | 0.745*** (0.713,0.780) |
| Black | 0.450*** (0.440,0.459) | 0.339*** (0.330,0.350) | 0.960*** (0.943,0.978) |
| GPA B- and above | 0.630*** (0.626,0.635) | 0.629*** (0.620,0.638) | 0.825*** (0.819,0.831) |
| *Family background* | | | |
| Parents with high-school diplomas | 0.989** (0.982,0.996) | 1.088*** (1.072,1.104) | 0.940*** (0.933,0.947) |
| Intact family | 0.845*** (0.838,0.851) | 0.892*** (0.880,0.905) | 0.904*** (0.897,0.911) |
| Stay-at-home mother [a] | 0.947*** (0.940,0.954) | 0.883*** (0.870,0.897) | 1.021*** (1.012,1.030) |
| *School location* (Northeast as reference) | | | |
| Northcentral | 1.021*** (1.013,1.029) | 0.963*** (0.947,0.980) | 1.045*** (1.036,1.054) |
| South | 0.909*** (0.902,0.916) | 0.793*** (0.780,0.807) | 1.047*** (1.038,1.057) |
| West | 0.743*** (0.736,0.749) | 0.700*** (0.687,0.714) | 0.921*** (0.911,0.930) |
| Metropolitan Statistical Area (MSA) | 0.933*** (0.927,0.939) | 0.960*** (0.947,0.973) | 0.956*** (0.949,0.963) |
| Intercept | 0.688*** (0.686,0.691) | 0.447*** (0.444,0.450) | 2.432*** (2.422,2.443) |

Note: [a] * p<.05; ** p<.01; *** p<.001 (two-tailed tests).

[b] Abbreviations: CI, confidence interval; IRR, incidence rate ratio; MSA, Metropolitan Statistical Area; OR, odds ratio.

[c] Appendix A produces results in Table 2(A) with seven rather than five rounds of imputation.

**Appendix B** Estimates of Adolescent Drunkenness using Modified Poisson (Mixture) Models, Monitoring the Future Project, 1991–2021 [a, b]

| | **Modified Poisson Model** | **Modified Poisson Mixture Models** | |
|---|---|---|---|
| | | Binomial | Poisson |
| | IRR with 95% CI | OR with 95% CI | IRR with 95% CI |
| *Academic and demographic factors* | | | |
| Female | 0.534*** (0.476,0.598) | 0.637*** (0.560,0.725) | 0.753*** (0.677,0.838) |
| Black | 0.527*** (0.505,0.551) | 0.390*** (0.372,0.410) | 1.078*** (1.033,1.125) |
| GPA B- and above | 0.626*** (0.615,0.637) | 0.676*** (0.654,0.699) | 0.824*** (0.810,0.838) |
| *Family background* | | | |
| Parents with high-school diplomas | 1.076*** (1.049,1.104) | 1.227*** (1.185,1.272) | 0.938*** (0.919,0.958) |
| Intact family | 0.783*** (0.767,0.799) | 0.866*** (0.841,0.892) | 0.872*** (0.857,0.888) |
| Stay-at-home mother | 1.021* (1.004,1.037) | 0.868*** (0.838,0.900) | 1.121*** (1.103,1.139) |
| *School location* (Northeast as reference) | | | |
| Northcentral | 0.909*** (0.895,0.923) | 0.888*** (0.855,0.922) | 0.984* (0.969,0.999) |
| South | 0.816*** (0.802,0.829) | 0.760*** (0.733,0.788) | 0.976** (0.961,0.991) |
| West | 0.654*** (0.643,0.665) | 0.690*** (0.663,0.718) | 0.849*** (0.835,0.864) |
| Metropolitan Statistical Area (MSA) | 0.993 (0.981,1.006) | 0.988 (0.959,1.018) | 1.008 (0.996,1.021) |
| Intercept | 1.111*** (1.104,1.118) | 0.375*** (0.370,0.380) | 4.629*** (4.599,4.659) |

Note: [a] * p<.05; ** p<.01; *** p<.001 (two-tailed tests).

[b] Abbreviations: CI, confidence interval; IRR, incidence rate ratio; MSA, Metropolitan Statistical Area; OR, odds ratio.

[c] Appendix B produces results in Table 2(B) with seven rather than five rounds of imputation.

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