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The Persistent Effects of Minimum Legal Drinking Age Laws on Drinking Patterns Later in Life

Andrew D. Plunk, PhD, Patricia Cavazos-Rehg, PhD, Laura J. Bierut, MD, and Richard A. Grucza, PhD

Department of Psychiatry, Washington University School of Medicine, St. Louis, 15 MO, USA

Abstract

Background—Exposure to permissive minimum legal drinking age (MLDA) laws not only affects young adults in the short term, but also later in life; for example, individuals who could legally purchase alcohol before age 21 are more likely to suffer from drinking problems as older adults, long after the laws had been changed. However, it is not known how permissive MLDA exposure affects specific drinking behavior. This present study uses changes in MLDA laws during the 1970s and 1980s as a natural experiment to investigate the potential impact of permissive MLDA exposure on average alcohol consumption, frequency of drinking, and on patterns of bingeing and more moderate, non-heavy drinking.

Methods—Policy exposure data were paired with alcohol use data from the 1991–1992 National Longitudinal Alcohol Epidemiologic Survey and the 2001–2002 National Epidemiologic Survey on Alcohol and Related Conditions. Past-year drinkers born between 1949 and 1972 ($n = 24,088$) were included. Average daily intake, overall drinking frequency, and frequency of both binge episodes (5+ drinks) and days without a binge episode (non-heavy drinking) for the previous year at the time of interview were tracked for each respondent.

Results—Exposure to permissive MLDAs was associated with higher odds to report frequent bingeing and lower odds to report any moderate drinking; these associations were largely driven by men and those who did not attend college. Overall drinking frequency and average alcohol consumption were not affected by MLDA exposure.

Conclusions—The ability to legally purchase alcohol before age 21 does not seem to increase overall drinking frequency, but our findings suggest that it is associated with certain types of problematic drinking behaviors that persist into later adulthood: more frequent binge episodes and less frequent non-heavy drinking. We also propose that policymakers and critics should not focus on college drinking when evaluating the effectiveness of MLDAs.

Keywords

Minimum legal drinking age; binge drinking; drinking patterns; moderate drinking

Introduction

The ability to legally purchase alcohol at a younger age has been associated with a range of negative outcomes. Studies have looked at the effects of minimum legal drinking age

Address for Correspondence: Andrew D. Plunk, PhD, MPH, Department of Psychiatry, Washington University School of Medicine, 660 South Euclid Avenue, Box 8134, St. Louis, Missouri, 63110, Phone: 314-362-2674, Fax: 314-362-4247, plunka@psychiatry.wustl.edu.

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(MLDA) laws, showing, for example, that higher MLDA are associated with later drinking initiation and reduced frequency of heavy drinking among adolescents and young adults, and that lower MLDA are associated with higher rates of traffic fatalities and teen suicides (Birckmayer and Hemenway, 1999; Cook and Moore, 2001; Dee, 1999; Fell, 2008; Hingson et al., 2005; O'Malley and Wagenaar, 1991).

More recent studies have shown long-term, persistent effects of these policies that affect behavior in later adulthood. Exposure to more permissive MLDA (i.e., 18, 19 or 20) as a young adult is associated with greater risk for experiencing several negative outcomes later in life. These include alcohol use disorders, suicide by women, homicide committed against women, and higher risk for fatal traffic accidents among men (Gruca et al., 2012; Kaestner and Yarnoff, 2009; Norberg et al., 2009). However, it is unknown how these outcomes are affected by MLDA exposure. Reduced average alcohol consumption or overall drinking frequency are possibilities, as is a change in drinking patterns. Drinking patterns could also be affected in several ways; both heavy and more moderate drinking behavior could be changed. To better understand these potential effects, this current study explores the association between the ability to legally purchase alcohol before the age of 21 and several measures of drinking behavior later in life.

Excessive alcohol consumption patterns are frequently measured by rates of binge drinking. A “binge” originally referred to a prolonged or all-day drinking occasion but came to be identified with consuming 5 or more drinks in a single occasion, and more recently, what is commonly known as the “5/4 definition,” which uses as its threshold 5 or more drinks for men and 4 or more for women (Cahalan et al., 1969; Wechsler et al., 1995b). Conceptually, a binge is a drinking pattern that raises one’s blood alcohol to .08 or above, which generally occurs after the consumption of 5 drinks for men, or 4 drinks for women, over the course of about two hours (NIAAA, 2004).

Studies have linked early age of onset of binge drinking to binge drinking in adulthood (Wechsler et al., 1995a; Weitzman et al., 2003). It is thus reasonable to hypothesize that MLDA laws, which are known to affect binge drinking among minors, might also exert effects that persist into later adulthood. In other words, young people restricted from purchasing alcohol prior to age 21 may also be less likely to binge drink later in life. It is also possible that in addition to drinking differently, people could be drinking less—that is, that average alcohol intake or frequency of consumption is affected.

To tease apart potential effects on average drinking volume and overall drinking frequency from patterns of drinking, we model MLDA exposure for several measures of drinking behavior: average daily volume of alcohol consumed, overall drinking frequency and two measures of drinking patterns, binge and non-heavy drinking. Binge drinking behavior is measured in binge days, the number of days in which a person drank in excess of the binge threshold. We also explore the effect permissive MLDA exposure might have on less-risky drinking behavior, measured as the frequency of non-heavy drinking; that is, the days in which an individual consumed alcohol, but did not cross the binge threshold. Non-heavy drinking is not completely analogous to the one to two drink per day moderate consumption threshold associated with reduced mortality risk (Costanzo et al., 2010; Di Castelnuovo et al., 2006), and should thus be thought of as “non-heavy,” as opposed to “moderate,” but non-heavy drinking frequency has the advantage of being based on values commonly found in epidemiological surveys: total drinking days and binge drinking days. To our knowledge, non-heavy drinking frequency as we have defined it has not been previously used to assess changes in drinking patterns, but its use is intuitive and warrants further investigation. Hence, in addition to examining the association between MLDA exposure and adult binge

drinking, average daily consumption and drinking frequency, we also examine long-term associations between MLDA exposure and non-heavy drinking.

We base our analyses on a period of MLDA change that occurred between the early 1970s and mid 1980s. Most states maintained an MLDA of 21 from the repeal of prohibition until the 1970s, when roughly half the country reduced their MLDAs to align with the reduction of federal voting age to 18. In many states with a reduced drinking age, the permissive MLDAs were in effect until the passage of the National Minimum Drinking Age Act of 1984, which tied federal highway funds to a drinking age of 21 (Toomey et al., 2009). Reductions in MLDA during this period were often incremental and did not always lead to the lowest possible drinking age; some states adopted MLDAs of 20 or 19 before moving to 18, while others retained their MLDAs of 19 or 20 throughout this period. These differences in policy changes between states and across time allow for a quasi-experimental approach for gauging the effects of permissive MLDA exposure on drinking behavior (Norberg et al., 2009).

Materials and Methods

Subjects

The sample for this study was obtained from two nationally representative US-based surveys: the 1991–92 administration of the National Longitudinal Alcohol Epidemiological Survey (NLAES) and the 2001–02 administration of the National Epidemiological Survey on Alcohol and Related Conditions (NESARC). Both surveys used similar sampling strategies and were conducted by the U.S. Bureau of the Census under supervision of the National Institute of Alcohol Abuse and Alcoholism. The NLAES had 42,862 respondents with a response rate of 91.9%; the NESARC had 43,093 respondents with a response rate of 89%. Both sampled the adult non-institutionalized population; the NLAES was limited to the contiguous US, while the NESARC sampled all states. Both included the District of Columbia (Grant et al., 1994; Grant et al., 2003).

In both, respondents born between 1948 and 1972 were pooled to form the current study sample; respondents with these birth years came of age during the period in which between-state and cross-year differences in MLDA policy existed. Only individuals who self-reported white or African American race or Hispanic ethnicity were included in the analyses; other racial or ethnic categories were either too small or not included because of concerns about heterogeneity due to potential within-group dissimilarity. This yielded a total sample of 39,240 respondents (see Table 1).

Outcome measures and covariates

Main outcome measures included the frequency of any drinking, average alcohol consumption, frequency of binge drinking episodes and frequency of non-heavy drinking. The NLAES defined a binge as five or more drinks in a single day, while the NESARC set the drink thresholds as five for men, and four for women. The inclusion of survey wave (NLAES vs. NESARC) as a covariate accounts for any measurement differences introduced by the change in this definition between the NLAES and NESARC.

Ordinal responses for drinking and binge frequencies were converted to scaled responses using the midpoints from the categorical drinking frequency items from the NLAES/ NESARC into days per year. For instance, a response of the “3–4 days per week” category on a frequency item yielded 3.5 days per week and 182 days per year. Non-heavy drinking days were then obtained by subtracting binge days from total drinking days.

Categories reflecting the frequency of both binge and non-heavy drinking were dummy-coded to yield a separate variable for each that classified respondents as: (a) not having had such an occasion in the past year; (b) having had between one and twelve such occasions in the past year; and (c) having reported more than 12 such occasions in the past year, for an average of over 1 per month. These broad thresholds of frequent vs. infrequent behavior were chosen to maximize power for our analyses.

Average ounces of alcohol consumed per day was calculated by using the following formula included in the NLAES reference manual (NIAAA, 1998), factoring in both heavy and usual consumption for each type of alcohol reported (beer, wine and liquor):

$$\text{AvgEtOH} = \frac{((\text{TotDays} - \text{HvyDays})(\text{UQuant})(\text{USize})(\text{Fact})) + ((\text{HvyDays})(\text{HvyQuant})(\text{HvySize})(\text{Fact}))}{365}$$

Where *AvgEtOH* = average ounces of alcohol per day, *TotDays* = total number of drinking days, *HvyDays* = number of heavy drinking days, *UQuant* = usual number of drinks, *USize* = usual drink size, *Fact* = conversion factor per beverage type, *HvyQuant* = number of drinks on heavy drinking occasions and *HvySize* = size of drinks on heavy drinking occasions (NIAAA, 1998). Other covariates used in our analyses included sex, age, survey wave, race/ethnicity and educational attainment. The attainment variable was coded as not having gone to college vs. any college, irrespective of degree completion, in light of past work positing that college campuses likely serve to insulate students from the effects of drinking age laws due to the ready availability of alcohol and an entrenched culture of drinking (Johnston et al., 2008). The sex and educational attainment covariates were also used as grouping variables for conditional analyses due to differences based on gender and college student status that have also been noted for binge drinking behavior (Gruca et al., 2009; Holdcraft and Iacono, 2002).

MLDA exposure coding

We defined permissive MLDA exposure as the ability to legally purchase alcohol before the age of 21. State of residence at the time of survey administration was used as a proxy for state of residence at age of potential exposure. Previous analyses have shown that this is a reasonable proxy; 63.1% of NLAES respondents were still living in the state in which they were born, 22.4% had moved, but to a state with the same drinking age and 14.5% had moved to a state with a different drinking age, resulting in an estimated 85.5% accuracy rate in MLDA exposure. Analyses of migration patterns using U.S. Census data supported this estimate, additionally demonstrating no correlation between probability of moving and MLDA exposure (Gruca et al., 2012; Norberg et al., 2009). Further, previous work with the NLAES sample showed that both state of birth and state of residence at time of survey were significant predictors of past-year alcohol use disorder, while migration status had no effect (Norberg et al., 2009). Thus, while the use of state of residence at time of survey administration as a proxy for historical residence introduces random error into our estimates, we do not expect it to be systematically biasing. Our migration analyses suggest that this error is uncorrelated with policy exposure, and using state of residence at time of survey did not differ from state of birth for determining policy exposure in the earlier work upon which the current study is based. MLDA policy data was coded as described in our previous studies (Gruca et al., 2012; Norberg et al., 2009). Primary sources for policy data included peer reviewed research (DuMouchel et al., 1987; O'Malley and Wagenaar, 1991; Wagenaar, 1982) the Statewide Availability Data System (Ponicki, 2004) and from database searches of news sources (Associated Press, 1996).

Statistical methods

Our analytic method is an extension of a “differences-in-differences” approach to comparing two groups at two different points in time, and for which one group experienced an environmental change or treatment with the other serving as a control (Ashenfelter and Card, 1985; Snow, 1855). In our case, we extend the two-by-two analysis to multiple groups and times by including state and birth-year fixed-effects categorical variables to all models, since location and year of birth are the requirements for determining exposure. Multinomial logistic regression was used for the main analyses, wherein we modeled the relative odds of the three drinking frequency categories for binge and non-heavy drinking occasions related to permissive MLDA exposure. Logistic, linear and negative binomial regression were used for ancillary analyses, to investigate the potential effect of MLDA exposure on drinking status (e.g., lifetime abstainer vs. past-year drinker), average ounces of alcohol per day and total drinking days, respectively.

The basic structure of the regression models used is based on the following formula:

$$Y_{ist} = \alpha + \beta_1 X_{1ist} + \dots + \beta_n X_{nist} + \beta MLDA_{st} + \epsilon_{ist}$$

Where Y_{ist} refers to the outcome for i individual in s state in t year, allowing us to take advantage of the incremental changes over time in state policies to estimate an effect while controlling for potential invariant state and time confounders.

All analyses were performed in SAS (Version 9.3; SAS Institute, Cary, NC) using survey regression procedures (e.g., PROC SURVEYLOGISTIC) to adjust standard errors to control for within-group correlation by state, which is a primary concern for this analytical method (Angrist and Pischke, 2009; Bertrand et al., 2004). Inflation of standard errors due to lower levels of clustering is expected to be small given that a given state’s sample size is small relative to the full state population (Cochran, 2007; West, 2010). Because of this adjustment for intra-correlation at the state level, sampling design variables were not employed, and unweighted data were used for the analyses. This is appropriate provided that observed policy effects are relatively homogenous with respect to selection probability (Groves, 2004).

Results

Sample description

Demographic information for the combined sample is listed in Table 1, reported separately for all respondents and past-year drinkers, who represented 61% of the sample. Respondents ranged from 18–53 years of age at the time of survey administration, with a median age of 36. Whites, men and college graduates made up a larger proportion of past-year drinkers than the full sample. Frequencies for binge and non-heavy drinking occasions for past-year drinkers are reported in Table 2, categorized by the thresholds used in our analyses. A slight majority ($n = 12,319$; 51.1%) of the sample reported having had no binge occasions in the year prior to their survey, while almost the same percentage reported frequent non-heavy drinking ($n = 12,457$; 51.7%). Those individuals reporting a mix of binge and non-heavy drinking were a slight minority, but a mix of the two was still a commonly reported drinking pattern ($n = 11,769$; 48.9%).

Drinking frequency and abstinence

A series of analyses examining the associations between MLDA exposure and drinking status, drinking frequency, and total alcohol consumption were conducted. No significant associations were observed between MLDA exposure and: (a) lifetime drinking vs. lifetime

abstention ($OR = .98$, $CI [.89, 1.08]$, $p = .66$); (b) past-year drinking vs. lifetime abstention ($OR = 1.02$, $CI [.93, 1.11]$, $p = .70$); nor with (c) past-year drinking vs. past-year abstention among lifetime drinkers ($OR = .98$, $CI [.90, 1.07]$, $p = .68$).

Likewise, there was no association between MLDA exposure and average daily alcohol intake when the log of average alcohol consumption per day was predicted in a linear regression framework ($\beta = -.003$, $SE = .13$, $p = .94$); MLDA exposure was also not associated with total drinking days in our negative binomial regression analysis ($\beta = .02$, $SE = .02$, $p = .39$).

Heavy drinking frequency

Results of the prediction of heavy drinking frequency from MLDA are summarized in Table 3. Two-sample z tests were conducted to assess between-groups differences; significant differences with associated p values are also reported in Table 2. For the full sample of past-year drinkers, exposure to permissive MLDA laws was associated with 15% higher odds to binge more than once per month, compared to the odds of having had no such occasion ($OR = 1.15$, $CI [1.04, 1.28]$, $p = .01$). For analyses conditioned on sex, men were at 19% higher odds to binge more than once per month ($OR = 1.19$, $CI [1.03, 1.37]$, $p = .02$). There were no significant associations for women; a significant difference between groups based on sex was noted for the 1–12 binges per year threshold, but neither odds ratio met nominal significance criteria. Conditional analyses based on educational attainment suggested that those who did not attend college were at 31% higher odds to binge more than once per month ($OR = 1.31$, $CI [1.10, 1.56]$, $p < .001$). This result fell outside the confidence interval for the any college group ($OR = 1.31$ vs. $CI [.88, 1.28]$) and the between group z test was near-significant ($p = .054$), suggesting a likely difference between groups based on education.

Non-heavy drinking frequency

Results from the multinomial logistic regression analyses for non-heavy drinking occasion frequency are reported in Table 4. Exposure to permissive MLDA laws was significantly associated with 19% lower odds of infrequent non-heavy drinking ($OR = .81$, $CI [.71, .94]$, $p < .001$) and a marginally significant 14% reduction in odds for more frequent non-heavy drinking ($OR = .86$, $CI [.74, 1.00]$, $p = .05$). Conditional analyses exhibited similar results as for binge drinking, but with significant associations for any non-heavy drinking (i.e., for both the 1–12 and more than 1 per month categories). Exposure for men was associated with 25% reduced odds for infrequent non-heavy drinking ($OR = .75$, $CI [.63, .89]$, $p < .001$) and 18% lower odds for more frequent non-heavy drinking ($OR = .82$, $CI [.68, .99]$, $p = .04$). Analyses conditioned on sex for women did not yield significant associations; however, odds ratios nearing the edge of the confidence interval for the other group coupled with a near-significant z test ($p = .082$) suggests a trend toward significant between-group differences for the 1–12 per year threshold when conditionally analyzed by sex. Individuals who did not attend college exhibited a similar pattern; MLDA exposure was associated with 28% lower odds of infrequent non-heavy drinking ($OR = .72$, $CI [.58, .89]$, $p < .001$) and 24% reduced odds to more frequently drink non-heavily ($OR = .76$, $CI [.64, .91]$, $p < .001$). As with the binge drinking outcome, there were no significant associations for those who attended college, while the marginal between-group differences persisted. Overall, the differences between groups seem to have been more pronounced in the analyses conditioned on educational attainment for both binge drinking and non-heavy drinking.

Discussion

Summary of findings

We have previously shown that individuals in the United States who were legally permitted to purchase alcohol prior to age 21 remained at elevated risk for alcohol use disorder as adults (Norberg et al., 2009). In this work, we probe this finding further by examining the association between permissive MLDA exposure and specific aspects of adult drinking behavior, namely whether the ability to purchase alcohol before 21 promotes persistent unhealthy drinking patterns later in life, or rather if the impact is on the quantity or frequency of alcohol consumed. Taking advantage of changes in the minimum legal drinking age in the 1970s and 1980s, we examined whether differences in MLDA exposure were associated with a number of drinking-related outcomes. While MLDA differences did not predict lifetime abstinence, past-year abstinence, past-year drinking frequency, or average daily alcohol consumption during the past-year, we found significant associations between MLDA and patterns of drinking behavior. Specifically, we observed an association between permissive MLDA exposure and frequent binge drinking, which alone is an important, if not unexpected, finding. More surprisingly, we noted an association between MLDA exposure and frequency of non-heavy drinking occasions. Exposure to these laws, meaning that one had ready access to alcohol at a younger age, seems to be associated with a certain pattern of drinking behavior that persists into later adulthood. Namely, that frequent binge drinking becomes more common, while any non-heavy drinking behavior among drinkers becomes less frequent.

Although our analyses produced consistent results for the whole sample for both binge and non-heavy drinking, findings for our conditional analyses, especially educational attainment, have interesting implications. Specifically, going to college was associated with a decreased potential MLDA exposure effect. This is consistent with prior research. Binge drinking has decreased in the general population, but has remained common on college campuses with the campus environment—characterized by easy access to alcohol coupled with a culture that promotes drinking—likely insulating against policies aimed at restricting underage access to alcohol (Gruca et al., 2009; Johnston et al., 2008). Specifically, underage college students report being able to obtain alcohol very easily and that the primary source of alcohol were legal-age drinkers (Wagenaar et al., 1996; Wechsler et al., 2002); additionally, most legal-aged college students report frequently providing alcohol to underage peers (Brown et al., 2009). We propose that our findings offer support for this campus insulation effect due to ease of alcohol availability, whereby policy exposure for those individuals who attended college would have been substantively different compared to their non-college peers of the same age.

A very important implication of this interpretation is that we should not overly focus on college students when assessing how MLDA affects youth and young adult drinking behavior. While college campuses are arguably conducive to heavy drinking irrespective of policies intended to curb underage alcohol use, in our sample individuals outside the college environment seem to have been greatly affected by changes in MLDA. Differences in MLDA exposure effects are particularly noteworthy in light of those who argue that the 21 MLDA promotes heavy drinking on college campuses and thus advocate that the drinking age should be lowered (e.g., McCardell, 2008). Our findings suggest that the drinking behavior of those who do not go to college would be more affected by a reduction in MLDA. This is an important consideration, given that low educational attainment is associated with early substance abuse (Johnson et al., 1999) and more generally with decreased health and longevity (Crimmins and Saito, 2001; Lynch, 2006; Walsemann et al., 2012). Any proposed benefit from lowering the MLDA would thus likely accompany an

increased risk for problematic drinking behavior for a population already lacking the protections from risk associated with a college education.

Our finding for the analyses conditioned on sex were also consistent with past work showing that young men binge more frequently. This sex-specific effect could also be interpreted in light of past research associating lower MLDA with homicide deaths among women (Gruzza et al., 2012), where the link between increased binge drinking among men and violence against women is highly plausible.

It is important to stress that we would not have seen any association with MLDA exposure and drinking pattern had we focused on average consumption of alcohol per day as an outcome measure. Likewise, we would have also failed to discern an important aspect of the association had we only examined binge frequency. As a univariate construct, average daily consumption is thus likely missing information regarding the actual health impact of drinking behavior. For example, an individual whose only consumption consists of bi-weekly binges could easily have the same average intake as someone who had a single drink every day. On the average, the behavior of the latter would be associated with the decreased mortality seen in moderate drinkers, while the behavior of the former would not. Teasing apart this relationship is important—ready access to alcohol before age 21 is not only associated with higher odds to frequently binge, but also much lower odds to engage in any drinking that is not bingeing. While obviously related—by definition one cannot in the same occasion both drink non-heavily and heavily—the distinction between these two behaviors is an important one because of the differences in related health outcomes.

Limitations and conclusion

One potential limitation concerns the nature of the policy data itself, which only captures the ability to legally purchase alcohol. Laws intended to penalize or curb youth possession or consumption in other ways were not included in our analyses. There were also no allowances made for smaller jurisdictions within a state that might have had different policies that could further limit access (e.g., dry counties). There could also be other factors influencing lifetime drinking patterns. While our analytic technique controls for many potential confounders, it is possible that something else is impacting behavior; however, barring a systematic endogenous confounder for which we have not controlled, these would be limited to environmental factors that occurred at similar times and in the same places as the changing MLDA laws.

Our estimates could also have been significantly affected by cross-state migration. For instance, if individuals who were at higher risk to develop binge drinking behavior were also more likely to have moved to a state with a permissive MLDA, then estimates based on current state of residence could overstate the effect of exposure on later outcomes. If, on the other hand, cross-state migration was uncorrelated with exposure status or propensity to binge drink, then estimates based on current state of residence may underestimate the full effect of permissive MLDA exposure on later outcomes. Earlier research on the NLAES sample found that cross-state migration was not associated with MLDA exposure or developing alcohol use disorder. This suggests that selective migration likely did not bias our estimates toward overstating the exposure effect, and any potential migration bias that occurred would only serve to underestimate the association between MLDA exposure and later drinking behavior.

Despite these potential limitations, our study implies that there is a strong and significant impact on later drinking behavior associated with MLDA exposure as a young adult, especially for men and those who did not attend college. While the increase in likelihood of frequent bingeing is generally consistent with other published findings, the reduction in any

non-heavy drinking seen both for the full-sample and conditional analyses is an important distinction that allows a more nuanced understanding of drinking behavior.

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References

- Angrist, JD.; Pischke, JS. Mostly harmless econometrics: An empiricist's companion. Princeton Univ Press; 2009.
- Ashenfelter O, Card D. Using the longitudinal structure of earnings to estimate the effect of training programs. *Rev Econ Statist.* 1985;648–660.
- Associated Press. The New York Times. New York: 1996. Louisiana court upholds drinking age of 21, in.
- Bertrand M, Duflo E, Mullainathan S. How much should we trust differences-in-differences estimates? *Q J Econ.* 2004; 119:249–275.
- Birckmayer J, Hemenway D. Minimum-age drinking laws and youth suicide, 1970–1990. *Am J Public Health.* 1999; 89:1365–1368. [PubMed: 10474554]
- Brown RL, Matousek TA, Radue MB. Legal-age students' provision of alcohol to underage college students: An exploratory study. *J Am Coll Health.* 2009; 57:611–618. [PubMed: 19433399]
- Cahalan D, Cisin IH, Crossley HM. American drinking practices: A national study of drinking behavior and attitudes. Monographs of the Rutgers Center of Alcohol Studies. 1969
- Cochran, WG. Sampling techniques. Wiley-India: 2007.
- Cook, PJ.; Moore, MJ. Environment and persistence in youthful drinking patterns. In: Gruber, J., editor. *Risky Behavior among Youths: An Economic Analysis.* University of Chicago Press; 2001. p. 375–438.
- Costanzo S, Di Castelnuovo A, Donati MB, Iacoviello L, de Gaetano G. Alcohol consumption and mortality in patients with cardiovascular disease: A meta-analysis. *J Am Coll Cardiol.* 2010; 55:1339–1347. [PubMed: 20338495]
- Crimmins EM, Saito Y. Trends in healthy life expectancy in the United States, 1970–1990: Gender, racial, and educational differences. *Soc Sci Med.* 2001; 52:1629–1641. [PubMed: 11327137]
- Dee TS. State alcohol policies, teen drinking and traffic fatalities. *J Public Econ.* 1999; 72:289–315.
- Di Castelnuovo A, Costanzo S, Bagnardi V, Donati MB, Iacoviello L, de Gaetano G. Alcohol dosing and total mortality in men and women: An updated meta-analysis of 34 prospective studies. *Arch Intern Med.* 2006; 166:2437–2445. [PubMed: 17159008]
- DuMouchel W, Williams AF, Zador P. Raising the alcohol purchase age: Its effects on fatal motor vehicle crashes in twenty-six states. *J Legal Stud.* 1987; 16:249–249.
- Fell, JC. Examination of the Criticisms of the Minimum Legal Drinking Age 21 Laws in the United States from a Traffic-Safety Perspective. Washington, DC: National Highway Traffic Safety Administration; 2008.
- Grant BF, Harford TC, Dawson DA, Chou P. Prevalence of DSM-IV alcohol abuse and dependence: United States, 1992. *Alcohol Health Res World.* 1994
- Grant, BF.; Moore, TC.; Shepard, J.; Kaplan, K. Source and accuracy statement: Wave 1 National Epidemiologic Survey on Alcohol and Related Conditions (NESARC). Bethesda, MD: National Institute on Alcohol Abuse and Alcoholism; 2003.
- Groves, RM. Survey Errors and Survey Costs. Hoboken, NJ: John Wiley & Sons; 2004.
- Gruza RA, Hipp PR, Norberg KE, Rundell L, Evanoff A, Cavazos-Rehg P, Bierut LJ. The legacy of minimum legal drinking age law changes: Long-term effects on suicide and homicide deaths among women. *Alcohol Clin Exp Res.* 2012; 36:377–384. [PubMed: 22085045]
- Gruza RA, Norberg KE, Bierut LJ. Binge drinking among youth and young adults in the United States, 1979–2006. *J Am Acad Child Adolesc Psychiatry.* 2009; 48:692–702. [PubMed: 19465879]

- Hingson R, Heeren T, Winter M, Wechsler H. Magnitude of alcohol-related mortality and morbidity among U.S. college students ages 18–24: Changes from 1998 to 2001. *Annu Rev Public Health*. 2005; 26:259–279. [PubMed: 15760289]
- Holdcraft LC, Iacono WG. Cohort effects on gender differences in alcohol dependence. *Addiction*. 2002; 97:1025–1036. [PubMed: 12144605]
- Johnson JG, Cohen P, Dohrenwend BP, Link BG, Brook JS. A longitudinal investigation of social causation and social selection processes involved in the association between socioeconomic status and psychiatric disorders. *J Abnorm Psychol*. 1999; 108:490–499. [PubMed: 10466273]
- Johnston, LD.; Bachman, JG.; Schulenberg, JE. Volume II: College students and adults ages 19–45. Bethesda, MD: NIDA; 2008. Monitoring the Future: national survey results on drug use, 1975–2004.
- Kaestner R, Yarnoff B. Long term effects of minimum legal drinking age laws on adult alcohol use and driving fatalities. National Bureau of Economic Research Working Paper Series No 15439. 2009
- Lynch SM. Explaining life course and cohort variation in the relationship between education and health: The role of income. *J Health Soc Behav*. 2006; 47:324–338. [PubMed: 17240923]
- McCardell J. The status quo has bombed. *U.S. News & World Report*. 2008:10–10. [PubMed: 18831098]
- NIAAA. Drinking in the united states: Main findings from the 1992 National Longitudinal Alcohol Epidemiologic Survey (NLAES). Bethesda, MD: NIAAA; 1998.
- NIAAA. NIAAA Council approves definition of binge drinking. *NIAAA Newsletter*. 2004; 3:3–3.
- Norberg KE, Bierut LJ, Grucza RA. Long term effects of minimum drinking age laws on past-year alcohol and drug use disorders. *Alcohol Clin Exp Res*. 2009; 33:2180–2190. [PubMed: 19775322]
- O'Malley PM, Wagenaar AC. Effects of minimum drinking age laws on alcohol use, related behaviors and traffic crash involvement among American youth: 1976–1987. *J Stud Alcohol*. 1991; 52:478–491. [PubMed: 1943105]
- Ponicki WR. Statewide Availability Data System II: 1933–2003. National Institute on Alcohol Abuse and Alcoholism Research Center Grant P 60. 2004
- Snow, J. On the mode of communication of cholera. John Churchill: 1855.
- Toomey TL, Nelson TF, Lenk KM. The age-21 minimum legal drinking age: A case study linking past and current debates. *Addiction*. 2009; 104:1958–1965. [PubMed: 19922564]
- Wagenaar AC. Legal minimum drinking age changes in the United States, 1970–1981. *Alcohol Health Res World*. 1982; 6:21–26.
- Wagenaar AC, Toomey TL, Murray DM, Short BJ, Wolfson M, Jones-Webb R. Sources of alcohol for underage drinkers. *J Stud Alcohol*. 1996; 57:325–333. [PubMed: 8709591]
- Walsemann KM, Bell BA, Hummer RA. Effects of timing and level of degree attained on depressive symptoms and self-rated health at midlife. *Am J Public Health*. 2012; 102:1–7.
- Wechsler H, Dowdall GW, Davenport A, Castillo S. Correlates of college student binge drinking. *Am J Public Health*. 1995a; 85:921–921. [PubMed: 7604914]
- Wechsler H, Dowdall GW, Davenport A, Rimm EB. A gender-specific measure of binge drinking among college students. *Am J Public Health*. 1995b; 85:982–982. [PubMed: 7604925]
- Wechsler H, Lee JE, Nelson TF, Kuo M. Underage college students' drinking behavior, access to alcohol, and the influence of deterrence policies: Findings from the Harvard School of Public Health College Alcohol Study. *J Am Coll Health*. 2002; 50:223–236. [PubMed: 11990980]
- Weitzman ER, Nelson TF, Wechsler H. Taking up binge drinking in college: The influences of person, social group, and environment. *J Adolesc Health*. 2003; 32:26–35. [PubMed: 12507798]
- West, BT. Accounting for Multi-stage Sample Designs in Complex Sample Variance Estimation. supplemental material to Heeringa, et al.'s *Applied Survey Data Analysis*. 2010. available at: <http://www.isr.umich.edu/src/smp/asda/>

Table 1

	n	%		n	%
<i>Full Sample</i>	39240	100	<i>Past-Year Drinkers</i>	24088	100
<i>Sex</i>			<i>Sex</i>		
Women	22159	56.47	Women	11956	49.63
Men	17081	43.53	Men	12132	50.37
<i>Race/Ethnicity</i>			<i>Race/Ethnicity</i>		
White	26010	66.28	White	17121	71.08
African American	7152	18.23	African American	3488	14.48
Hispanic	6078	15.49	Hispanic	3479	14.44
Median Age	36		Median Age	36	
Age Range	18–53		Age Range	18–53	
<i>Educational Attainment</i>	n	%	<i>Educational Attainment</i>	n	%
No College	16313	41.57	No College	8703	36.13
Any College	23099	58.43	Any College	15386	63.87
<i>Drinking Status</i>			<i>Frequency of Binge Occasions</i>		
Past-year drinkers	24088	61.39	No binge drinking	12319	51.14
Former drinkers	6997	17.83	1 to 12 per year	7194	29.86
Lifetime Abstainers	8162	20.80	More than 1 per month	4575	18.99
			<i>Frequency of Non-Heavy Occasions</i>		
			No non-heavy drinking	3586	14.89
			1 to 12 per year	8045	33.40
			More than 1 per month	12457	51.71

Table 2

Non-Heavy Thresholds by Binge Thresholds Among Past-Year Drinkers

<i>Non-Heavy Drinking Occasions</i>	Binge Occasions			Total Non-Heavy
	No Binge Occasions	1 to 12 in Past Year	More than 1 Per Month	
No Non-Heavy Occasions	--	883 (3.7%)	2703 (11.2%)	3586 (14.9%)
1 to 12 in Past Year	6366 (26.4%)	1550 (6.4%)	129 (.5%)	8045 (33.4%)
More than 1 Per Month	5953 (24.7%)	4761 (19.8%)	1743 (7.2%)	12457 (51.7%)
Total Binge	12319 (51.1%)	7194 (29.9%)	4575 (19.0%)	24088 (100%)

Note. Values represent number of respondents in each combination of the 3 thresholds used in our analyses; percentages of the whole sample of past-year drinkers ($n = 24,088$) for each cell are listed in parentheses.

Table 3
Binge Drinking Occasions Among Past-Year Drinkers as a Function of Under 21 MLDA Exposure.

	Odds Ratio	95% CI		p	n
		Lower	Upper		
<i>All Past-Year Drinkers</i>					
No Binge Occasions	ref	--	--	--	24088
1 to 12 per year	1.01	.88	1.16	.91	12319
More than 1 per month	1.15	1.04	1.28	0.01	4575
<i>Conditional Analyses by Sex</i>					
<i>Women</i>					
No Binge Occasions	ref	--	--	--	11956
1 to 12 per year ^a	.91	.77	1.07	.26	7446
More than 1 per month	1.16	.96	1.39	.12	3203
<i>Men</i>					
No Binge Occasions	ref	--	--	--	12132
1 to 12 per year ^a	1.11	.94	1.32	.21	5025
More than 1 per month	1.19	1.03	1.37	.02	3998
<i>Conditional Analyses by Educational Attainment</i>					
<i>No College</i>					
No Binge Occasions	ref	--	--	--	8703
1 to 12 per year	.97	.80	1.18	.77	3961
More than 1 per month ^b	1.31	1.10	1.56	<.001	2542
<i>Any College</i>					
No Binge Occasions	ref	--	--	--	2280
1 to 12 per year	1.03	.89	1.20	.67	15386
More than 1 per month ^b	1.06	.88	1.28	.54	8428
					4659
					2299

Note. A binge was defined as drinking 5 or more drinks in a day in the NLAES and 5+/4+ (men/women) in the NESARC. Sex and educational attainment were covariates unless conditioned for; age, survey wave and race/ethnicity were covariates in all analyses.

Between-groups comparisons:

^a significant at $p < .05$.

^b near-significant at $p = .054$.

Table 4

Non-Heavy Drinking Occasions Among Past-Year Drinkers as a Function of Under 21 MLDA Exposure.

	Odds Ratio	95% CI		p	n
		Lower	Upper		
<i>All Past-Year Drinkers</i>					
No Non-heavy Occasions	ref	--	--	--	24088
1 to 12 per year	.81	.71	.94	<.001	8045
More than 1 per month	.86	.74	1.00	.05	12457
<i>Conditional Analyses by Sex</i>					
<i>Women</i>					
No Non-heavy Occasions	ref	--	--	--	11956
1 to 12 per year ^a	.89	.75	1.05	.17	5106
More than 1 per month	.93	.78	1.10	.38	5543
<i>Men</i>					
No Non-heavy Occasions	ref	--	--	--	12132
1 to 12 per year^a	.75	.63	.89	<.001	2937
More than 1 per month	.82	.68	.99	.04	6914
<i>Conditional Analyses by Educational Attainment</i>					
<i>No College</i>					
No Non-heavy Occasions	ref	--	--	--	8703
1 to 12 per year^b	.72	.58	.89	<.001	2894
More than 1 per month^c	.76	.64	.91	<.001	3882
<i>Any College</i>					
No Non-heavy Occasions	ref	--	--	--	15386
1 to 12 per year ^b	.90	.72	1.14	.39	5151
More than 1 per month ^c	.96	.76	1.20	.71	8574

Note. Sex and educational attainment were covariates unless conditioned for; age, survey wave and race/ethnicity were covariates in all analyses.

Between-groups comparisons:

^a near-significant at $p = .082$,

^b near-significant at $p = .073$,
^c near-significant at $p = .056$.