Received Date : 19-Oct-2015

Revised Date : 08-Jan-2016

Accepted Date : 05-Feb-2016

Article type : Original Research Article

Selected state policies and associations with alcohol use behaviors and risky driving behaviors among youth: Findings from the Monitoring the Future study

Patricia A. Cavazos-Rehg, Ph.D.[1*], Ashley J. Housten, O.T.D.[2*], Melissa J. Krauss, M.P.H.[1], Shaina J. Sowles, M.P.H.[1], Edward L. Spitznagel, Ph.D.[3], Frank J. Chaloupka, Ph.D.[4], Ricard Grucza, Ph.D.[1], Lloyd D. Johnston, Ph.D.[5], Patrick M. O'Malley, Ph.D.[5], Laura J. Bierut, M.D.[1]

* Co-first authors

[1] Department of Psychiatry, Washington University School of Medicine, St. Louis, MO, USA

[2] Department of Surgery, Washington University School of Medicine, St. Louis, MO, USA

[3] Division of Biostatistics, Washington University School of Medicine, St. Louis, MO, USA

[4] Department of Economics, University of Illinois at Chicago, Chicago, IL, USA

[5] Institute for Social Research, University of Michigan, Ann Arbor, MI, USA

Address for Correspondence: Patricia A. Cavazos-Rehg, Ph.D.,
Department of Psychiatry, Washington University School of Medicine, 660 South Euclid Avenue, Box 8134, St. Louis, Missouri 63110. Phone: 314-362-2152 Fax: 314-362-4247
rehgp@psychiatry.wustl.edu
Sources of support: National Institutes of Health Grants R01DA039455 (PCR) and R01DA032843 (PCR). Dr. Housten was supported by the National Institutes of Health, National Research Service Award 1T32CA190194, from the National Cancer Institute.

ABSTRACT

Background: Effective policies that can reduce alcohol use behaviors and impaired driving among young people at a population-level are needed. Graduated driver licensing (GDL) laws increase the driving privileges of young novice drivers as they age and gain more driving experience. In this study we seek to determine the effects of GDLs on risky driving behaviors of youth and to assess if GDLs have an unintended effect on underage drinking behaviors.
Methods: We utilized 2000-2013 data on 12th grade students from the Monitoring the Future (MTF) study, an ongoing, annual national survey (since 1975) that studies the substance use behaviors of adolescents, as well as data on GDL laws obtained via the Insurance Institute for Highway Safety (IIHS). We conducted a series of regular logistic regression models that included fixed effects for year and state, and adjusted for demographic characteristics, school characteristics, and other state alcohol policies.
Results: Total weighted sample size was 129,289 12th graders. Past month alcohol use and binge drinking (i.e., ≥5 drinks on one occasion) in the past two weeks were 45% and 26%, respectively. Seventeen percent of respondents reported riding with a driver who drank alcohol. Nearly 12% reported driving in the past two weeks after drinking alcohol, and 7% reported driving after binge drinking. Over half of students lived in a state with a "good" GDL law. The logistic regression models suggest a link between restrictive GDL policies and a reduction of alcohol use behaviors and risky driving behaviors among youth.
Conclusions: Our findings indicate that the effects of GDLs extend beyond driving-related risks and into other drinking-related behaviors that pose immediate or delayed health risks for young people. We speculate that GDLs may dictate social norms and expectations for youth risk behaviors, and should be maximized throughout the U.S.

Keywords: drinking and driving; policy; automobile driving; adolescent

INTRODUCTION

Despite the numerous health and safety consequences that are associated with excessive drinking, hazardous alcohol use still continues to be a popular activity among young people (Chen & Faden, 2013). In 2011, 33% of 8th graders, 56% of 10th graders, and 70% of 12th graders reported ever consuming alcohol, while binge drinking (i.e., ≥5 drinks on at least one occasion in the past two weeks) was reported by 6% of 8th graders, 15% of 10th graders and 22% of 12th graders in the United States (Johnston et al., 2014). One of the most detrimental consequences that stems from frequent or excessive alcohol use at young age is being involved in a motor vehicle crash (MVC). Blood alcohol level (BAC) is a measure of alcohol in a person's blood and it is a crime in all 50 states and DC to drive with a BAC of 0.08 or higher (Insurance Institute for Highway Safety [IIHS], 2015a). For drivers under the age of 21, any detectable blood alcohol (approximately 0.02 BAC) is illegal (IIHS, 2015a). Minimum unsupervised driving age varies by state, but the age range is 14 years, 3 months to 17 years (IIHS, 2015b). MVCs are the leading cause of death among U.S. teens and in 2012, 184,000 young drivers were injured in MVCs and 23% of young drivers (15 -20 years old) involved in fatal MVCs had consumed alcohol (Centers for Disease Control and Prevention [CDC], 2012; National Highway Traffic Safety Administration [NHTSA], 2014).

Initiatives at the population level have been enacted to curb the high prevalence of MVCs among young people. By restricting the number of passengers, nighttime driving and enforcing stipulations on the duration of restrictions for young, newly licensed drivers, graduated driver licensing (GDL) laws have effectively reduced crashes and fatalities for young drivers (Hedlund & Compton, 2005; Shope & Bingham, 2008). For example, Baker et al. (2007) reported that GDLs have been associated with a 38% reduction in fatal vehicle crashes and 40% reduction in injury causing vehicle crashes among drivers aged 16 years. One possible pathway by which GDLs reduce MVCs among young people is by effectively reducing their drinking and driving behaviors through social expectations and values (Cavazos-Rehg et al., 2012). In any case, GDLs do facilitate the safer driving behaviors of young people and are widely believed to play a central role in the 46% decrease among young drivers involved in fatal crashes (7,937 vs. 4,283, respectively) that occurred between 2003 and 2012 (NHTSA, 2014). It is likewise possible that

GDLs reduce MVCs and drunk-driving behaviors via an unintended effect on the underage drinking behaviors themselves though no known studies have yet examined this possible link.

In the current study, we examine the effects of GDLs on acceptance of and engagement in risky driving behaviors of youth using over a decade of national data from the Monitoring the Future study. In addition to replicating previous work that examines associations with these state policies and drunk driving behaviors, we assess if GDLs have an unintended effect on underage drinking behaviors which is likely given their success with reducing drunk driving behaviors among youth. For thoroughness, we also account for use-and-lose policies and beer taxes in our analyses that can impact underage drinking behaviors (Cavazos-Rehg et al., 2012; Elder et al., 2010; Fell et al., 2009; Ponicki et al., 2006; Ponicki et al., 2007; Ruhm, 1996; Xuan et al., 2013). In testing policy associations with high-school peer passenger, driving, and drinking behaviors and accounting for a wide range of factors including individual, family, school, and community-level influences, our study presents novel and comprehensive findings that can have important implications for reducing alcohol use behaviors and impaired driving among young people.

MATERIALS AND METHODS

Data source and respondents

We utilized 2000-2013 data on 12th grade students from the Monitoring the Future (MTF) study, an ongoing national study (since 1975) of the substance use behaviors of adolescents (Johnston et al., 2014). MTF data collection occurs annually in approximately 400 public and private schools (approximately 130 schools per year for 12th graders) selected to provide an accurate representative cross section of students throughout the coterminous U.S. MTF utilizes a three-stage sampling procedure including (a) geographic area selection, (b) the selection of one or more schools in each area, and (c) the selection of students within each school. Additional details on the MTF sampling procedures are available elsewhere (Chaloupka & Johnston, 2007; Johnston et al., 2014). Students complete one of six different surveys dispersed to participants in an ordered sequence that guarantees six equally random subsamples. For this investigation, we focused on 12th grade students because of the MTF inclusion of additional driving-related questions for 12th grade students which are excluded for 8th and 10th grade student participants. This analysis of secondary data was reviewed and approved by Washington University's Institutional Review Board.

Dependent variables: Alcohol use behaviors

Recent alcohol use was measured by an item that queried the number of occasions the participant had alcoholic beverages to drink (more than a few sips) during the last 30 days. Recent binge drinking was assessed by an item that queried the number of times the participant had five or more drinks in a row in the last two weeks. For each of these items, responses were dichotomized as one or more times during the reference time period versus none. Additionally, frequent alcohol use was also examined as a dependent variable, and was defined as drinking alcohol on 20 or more occasions in the last 30 days.

Dependent variables: Risky driving behaviors

The risky driving behaviors that were queried for 12th grade students were the number of times during the last two weeks that the participant was a passenger in a vehicle where the driver had been drinking or where the driver binge drank (i.e., ≥5 drinks on one occasion) immediately prior to driving. In addition, risky driving behavior items were asked, including the number of times, if any, the participant had in the last two weeks driven after drinking alcohol and after binge drinking (i.e., ≥5 drinks on one occasion). For each of the risky driving behavior items, responses were dichotomized as one or more times in the last two weeks versus none.

Independent variable. GDL policy ratings

To assess the impact of GDL laws on youth behavior, we utilized a GDL rating system developed by the International Institute for Highway Safety (IIHS). The IIHS has assessed the strength of state GDL laws, assigning rankings of good, fair, marginal, or poor (Fell et al., 2008) (Table 1; Cavazos-Rehg et al., 2012). These rankings evaluate age restrictions for first permit and the restrictions in three tiered training stages. Ratings are considered good for stronger restrictions used in GDL implementation. A full list of state GDL laws and rankings is available on the IIHS website (IIHS, 2015b).

Covariates

We controlled for student-level demographic variables including sex, age, race/ethnicity, parents educational attainment (neither parent achieved a high school diploma versus having at least one parent who completed and/or achieved a high school diploma or more), and number of parents that currently live in the home (none/one/both). We also controlled for type of school (public/private), school size (based on the number of students from the targeted grade eligible for the survey), percent of students receiving free or reduced cost lunch, percent of students who are Black or Hispanic, and population density.

Percent of students who are Black or Hispanic and percent receiving free/reduced cost lunch are not available in the public-use MTF data files, but were obtained from the Youth, Education, & Society (YES) Surveys of School Principals (Chaloupka & Johnston, 2007). In addition to collecting the MTF survey data from students, YES data is collected annually from the school administrators and response rate is typically ≥ 80%. Identifiable information on each school is provided to enable merging with MTF participants' survey data as needed.

Finally, we also controlled for several time-varying state alcohol policies. For use-and-lose state laws, we used an existing rating system with scores ranging from 0 (no use-and-lose law) to 8 (license sanction is mandatory for three violations—purchase, possession, and consumption; minimum length of license suspension is 91+ days, and law applies to all individuals under 21 years of age) (Fell et al. 2008). Data for use-and-lose state laws can be found at the National Institute on Alcohol Abuse and Alcoholism (NIAAA) Alcohol Policy Information System (APIS) (https://alcoholpolicy.niaaa.nih.gov/). Beer excise tax per barrel and spirits excise tax per gallon was obtained from Ponicki et al. (2006; 2007) at Pacifica Institute for Research and Evaluation and updated using the NIAAA APIS (https://alcoholpolicy.niaaa.nih.gov/). Beer and spirits excise tax were adjusted for inflation to reflect 2012 dollars.

Statistical Analysis

We first examined the association between state GDL rating and each dichotomous alcohol use and risky driving outcome (i.e., alcohol use, binge drinking, frequent alcohol use, riding with a driver who drank alcohol, riding with a driver who binge drank, driving after drinking, driving after binge drinking) using logistic regression. In each model, we adjusted for other state alcohol policies (use-lose policy rating, beer tax), student demographic characteristics, school characteristics, and survey year (linear). However, such models would not help establish causal associations between GDL policy and alcohol use or risky driving. Therefore, we expanded our methodology to use a "differences-in-differences" approach in order to help establish causal effects. This method allows for the estimation of effects of interventions (in this case, GDL policy) by comparing differences in outcomes before and after the intervention among affected and unaffected groups (in this case, states that adopted stronger policies and those that did not) (Bertrand et al., 2002). Expanding the classical approach of comparing two groups at two time points to a regression extension using multiple time points and intervention

groups (Angrist & Pischke, 2008), we used logistic regression models that included fixed effects for unordered categorical indicators of state and year. Including the fixed effects for state and year allow an estimation of the effect of GDL policy rating while accounting for state characteristics that were invariant over time and temporal trends that were invariant across states (Angrist & Pischke, 2008). Thus, associations between GDL policy and alcohol or risky driving behaviors are expected to be observed only if the within-state changes in GDL policy correlate with within-state changes in the prevalence of alcohol or risky driving behaviors.

For both sets of models, parameter estimates and standard errors were calculated using the Statistical Analysis System (SAS) (Version 9.2, SAS Institute, Cary, NC) procedure "surveylogistic", applying sampling weights to adjust for differential selection probabilities and using state as the clustering unit to account for correlation of residuals within states in estimating standard errors (Angrist & Pischke, 2008; Arellano, 1987; Bertrand et al., 2002). Adjusted odds ratios, 95% confidence intervals, and significance of $p = 0.05$ are reported. Total weighted sample size was 129,289 12^{th} graders, but the sample size was smaller for driving-related outcome variables because some items were not queried of all respondents (weighted N for these outcomes was nearly 19,800).

RESULTS

Table 2 provides the demographic characteristics of respondents, substance use and driving behaviors, and exposure to state alcohol policies. Slightly over half of the participants were female, and the majority was White. Most participants had at least one parent with more than a high school education and lived with two parents. Use of alcohol in the past month and binge drinking in the past month were 45% and 26%, respectively. Seventeen percent of respondents reported riding with a driver who had drank alcohol. However, approximately 9% of respondents reported riding with someone who binge drank. Nearly 12% of all respondents reported recently driving themselves after drinking alcohol; 7% of all respondents reported driving after binge drinking (these groups are not mutually exclusive). Over half of students lived in a state with a "good" GDL law. The median use-and-lose policy score that students were exposed to was approximately 4, and the median beer excise tax per barrel that students were exposed to was approximately $6.54. Additional characteristics of the participants are shown in Table 2. Although data from the 2000-2013 Monitoring the Future surveys were analyzed for this study, GDL policies have become more restrictive over time and by 2009 no state had poor

GDL policies and over half received a good ranking for GDL policies (Cavazos-Rehg et al., 2012).

Multivariable Models

Associations between GDL policy rating and alcohol and risky driving behaviors are shown in Tables 3 and 4. Table 3 presents results from the regular logistic regression models, and Table 4 presents results from the logistic regression models that include fixed effects for year and state, helping to establish causal associations between GDL policy and the outcomes of interest. In regular logistic regression models (Table 3), adjusting for demographic characteristics, school characteristics, and other state alcohol policies, compared to respondents in states with *good* GDL policies, respondents in states with *marginal* GDL policies had increased odds of recent alcohol use and binge drinking, and those in states with *fair* or *poor* GDL policies had increased odds of frequent alcohol use. Furthermore, respondents in states with *fair* GDL policies were more likely to report riding with a driver who binge drank, driving after drinking, and driving after binge drinking. Those in states with *marginal* GDL policies were more likely to report riding with a driver who drank alcohol or binge drank, as well as driving after drinking. Full results for all covariates in the regular logistic regression models are shown in eTables 1 and 2.

In models that included fixed effects for year and state (Table 4), there is further evidence that GDL policies are associated with alcohol use behaviors and risky driving behaviors. After adjusting for year and state fixed effects, as well as demographic characteristics, school characteristics, and other state alcohol policies, compared to *good* GDL policies, *poor* policies were associated with increased odds of binge drinking and frequent alcohol use. In addition, *marginal* GDL policies (compared to *good* GDL policies) were associated with increased odds of riding with a driver who had engaged in binge drinking. Full results for all covariates in the models that include fixed effects for year and state can be found in eTables 3 and 4.

DISCUSSION

The goal of our study was to investigate the impact of GDLs on risky drunk driving behaviors as well as underage drinking behaviors themselves. In multivariable models, we found relatively consistent associations between restrictive GDLs and reduced youth alcohol use behaviors and alcohol-related risky driving behaviors (both driving after drinking and riding with a driver who had drank). Thus, our results found evidence of an association between restrictive

GDL policies and a reduction of alcohol use behaviors and risky driving behaviors among youth, which is consistent with existing research in the field (Baker et al., 2007; Cavazos-Rehg et al., 2012; Fell et al., 2008; Fell et al., 2009; Hedlund & Compton, 2005; Karaca-Mandic & Ridgeway, 2010; IIHS, 2014; Shope & Bingham, 2008). These important findings have implications for states that can still make progress towards implementing restrictive GDLs.

Moreover, our novel findings are the first of their kind to signal a potential broader impact of GDLs to underage drinking patterns. Our findings show that youth in states with less restrictive GDL policies were more likely to report alcohol-related risky driving behaviors. Since MVCs are the leading cause of death among U.S. teens and approximately 1 in 5 young drivers involved in a fatal MVC had consumed alcohol prior to their crash, the high frequency of youth alcohol-related risky driving behaviors necessitates population level policy initiatives to address the perceived normalcy of these risky behaviors (Centers for Disease Control and Prevention [CDC], 2012; National Highway Traffic Safety Administration [NHTSA], 2014). Thus, it is promising that restrictive GDL policies are potentially reducing not only the risky driving behaviors among young people, but also their underage drinking behaviors patterns. Youth alcohol use behaviors are strongly influenced by social norms (Ajzen, 1991; Ajzen & Madden, 1986; Baranowski et al., 2002; Keyes et al., 2012). It is therefore possible that GDLs help to dictate social norms and expectations for youth risk behaviors, in general, that extend beyond driving-related risks and into other behaviors that pose immediate or delayed health risks for young people. To illustrate, one component of GDLs is a nighttime driving curfew and this regulation could potentially help to promote structure and adherence among youth (Lin & Fearn, 2003), while additionally curtailing opportunities for them to engage underage drinking (Simons-Morton & Hartos, 2003). In any case, our results suggest the importance of GDLs deterring underage drinking behaviors, which are a serious public health concern among young people.

In contrast to GDLs, beer tax had no influence on youth alcohol use behaviors and risky driving behaviors. Use-and-lose policies had sporadic but still limited impact. It may be that GDLs are more influential in controlling youth risk behaviors. GDLs have clear guidelines and structured rules for youth to follow (e.g., curfew and passenger limit). This is in contrast to price control measures (like beer taxes) or punitive actions that result when rules are broken (use-and-lose policies) (Farrelly et al., 2013).

While not the primary focus of our study, our results draw attention to several individual and social risk factors that increase risk for alcohol use behaviors and hazardous driving behaviors among young people. We found that age, gender, and race can play a role in most of the risk behaviors we measured. Male gender and older age of youth are demographic factors that have consistently been found to increase risk for underage drinking and impaired driving (O'Malley & Johnston, 1999; O'Malley & Johnston, 2003; Elliot et al., 2006; Scott-Parker et al., 2014). Likewise, our results mirror epidemiological studies that document lower drinking patterns among African Americans versus Whites and Hispanics (Chen & Faden, 2013; Orcutt & Schwabe, 2012). Still, given the prevalence of risky alcohol use among youth (O'Malley & Johnston, 2013), the recent climb in the prevalence of alcohol dependence among women and the fact that African Americans tend to experience more alcohol-related problems over their life-course (Grant et al., 2004; Grucza et al., 2008a; Grucza et al., 2008b; Zapolski et al., 2014), it is likely that all youth would benefit from targeted intervention that reduce their risk for underage drinking and related problems irrespective of their gender or race/ethnicity.

We also found that familial factors (i.e. parental educational attainment and number of parents in household) were significantly and consistently associated with alcohol use and risky driving behaviors. Furthermore, community/school-level characteristics such as school size, location, and percentage of students receiving free or reduced cost lunch, also showed significant association with alcohol use behaviors. These results reflect well-documented scientific paradigms that stress the important role of social-environment determinants of health for predicting youth risk behaviors (Frieden, 2010; Robert Wood Johnson Foundation, 2008). Attention to these factors, and the youth impacted by them, is encouraged as they may signal a need for targeted prevention efforts.

These findings have limitations. All of the responses were self-reported from the Monitoring the Future survey. While self-reported answers may introduce bias, the surveys were confidential. In addition, participants take part in the MTF at school and data from high school dropouts or adolescents schooled at home are not included in this study. We further acknowledge that in-school surveys can underestimate the substance use of certain populations but note that our findings will be highly relevant for the majority of youth in this country (~90%). Likewise, though our study evaluates individual, family, school, community, and state-level influences

(like BAC and GDL restrictions) it is beyond the scope of any study to examine every known determinant of the alcohol use behaviors and risky driving behaviors of youth.

Our findings suggest that strong GDL laws not only reduce youth alcohol-related risky driving behaviors but also reduce overall youth use alcohol behaviors, potentially by influencing social norms and expectations about drinking and driving as well as alcohol use among young people. Socio-demographic characteristics, like family and school environments, also play an important role in impacting alcohol use and associated drinking and driving behaviors. Working to reduce youth alcohol use and risky driving behaviors is a public health priority. Our investigation supports that GDLs are effectively lowering these risk behaviors at a population-level; continued research to substantiate our findings and strengthening policy efforts accordingly in order to address this serious public health issue are warranted.

ACKNOWLEDGEMENTS

One of the authors, Dr. Bierut, is listed as an inventor on Issued U.S. Patent 8, 080, 371, "Markers for Addiction," covering the use of certain SNPs in determining the diagnosis, prognosis, and treatment of addiction.

We are grateful to Timothy Perry at the Institute for Social Research, University of Michigan, for assistance with the Monitoring the Future data.

REFERENCES

Angrist JD, Pischke J-S (2008) Mostly Harmless Econometrics: An Empiricist's Companion. Princeton University Press, New Jesery.

Arellano M (1987) Estimators. Oxf Bull Econ Stat 49:431-434.

Ajzen I. (1991) The theory of planned behavior. Organ Behav Hum Decis Process 50:179-211.

Ajzen I, Madden TJ (1986) Prediction of goal-directed behavior: Attitudes, intentions, and perceived behavioral control. J Exp Soc Psychol 22:453-474.

Baker SP, Chen L-H, Li G (2007) Nationwide review of graduated driver licensing. Washington, DC: AAA Foundation for Traffic Safety. Available from: https://www.aaafoundation.org/sites/default/files/NationwideReviewOfGDL.pdf

Baranowski T, Perry CL, Parcel GS (2002) How individuals, environments, and health behavior interact in Health Behavior and Health Education: Theory, Research, and Practice (Glanz K, Rimer BK, Viswanath K eds), pp165-184. Jossey-Bass, California.

Bertrand M, Duflo E, Mullainathan S (2002) How much should we trust differences-in-differences estimates? (No. w8841) National Bureau of Economic Research.

Cavazos-Rehg PA, Krauss MJ, Spitznagel EL, Chaloupka FJ, Schootman M, Grucza RA, Bierut LJ (2012) Associations between selected state laws and teenagers' drinking and driving behaviors. Alcohol Clin Exp Res 36:1647-1652.

Centers for Disease Control and Prevention (2012) Web-based injury statistics query and reporting system (WISQARS). *National Center for Injury Prevention and Control*. Atlanta, GA, USA.

Chaloupka FJ, Johnston LD (2007) Bridging the gap: research informing practice and policy for healthy youth behavior. Am J Prev Med 33:S147-S161.

Chen CM, Yi H, Faden V (2013) Surveillance Report #96, Trends in underage drinking in the United States, 1991–2011. Bethesda, MD. Retrieved from http://pubs.niaaa.nih.gov/publications/surveillance96/Underage11.pdf

Elder RW, Lawrence B, Ferguson A, Naimi TS, Brewer RD, Chattopadhyay SK, Toomey TL, Fielding JE (2010) The effectiveness of tax policy interventions for reducing excessive alcohol consumption and related harms. Am J Prev Med 38:217-229.

Elliott MR, Shope JT, Raghunathan TE, Waller PF (2006) Gender differences among young drivers in the association between high-risk driving and substance use/environmental influences. J Stud Alcohol 67:252-260.

Farrelly MC, Loomis BR, Han B, Gfroerer J, Kulper N, Lance Couzens G, Dube S, Caraballo RS (2013) A comprehensive examination of the influence of state tobacco control programs and policies on youth smoking. Am J Public Health 103:549-555.

Fell JC, Fisher DA, Voas RB, Blackman K, Tippetts AS (2008) The relationship of underage drinking laws to reductions in drinking drivers in fatal crashes in the United States. Accid Anal Prev 40:1430-1440.

Fell JC, Fisher DA, Voas RB, Blackman K, Tippetts AS (2009) The impact of underage drinking laws on alcohol-related fatal crashes of young drivers. Alcohol Clin Exp Res 33:1208-1219.

Frieden TR (2010) A framework for public health action: The health impact pyramid. Am J Public Health 100:590-595.

Grant BF, Dawson DA, Stinson FS, Chou SP, Dufour MC, Pickering RP (2004) The 12-month prevalence and trends in DSM-IV alcohol abuse and dependence: United States, 1991–1992 and 2001–2002. Drug Alcohol Depend 74:223-234.

Grucza RA, Bucholz KK, Rice JP, Bierut LJ (2008a) Secular Trends in the Lifetime Prevalence of Alcohol Dependence in the United States: A Re-evaluation. Alcohol Clin Exp Res 32:763-770.

Grucza RA, Bucholz KK, Rice JP, Bierut LJ (2008b) Correspondence between secular changes in alcohol dependence and age of drinking onset among women in the United States. Alcohol Clin Exp Res 32:1493-1501.

Hedlund J, Compton R (2005) Graduated driver licensing research in 2004 and 2005. J Safety Res 36:109-119.

Insurance Institute for Highway Safety (2014) GDL Crash Reduction Calculator. Available at: http://www.iihs.org/iihs/topics/laws/gdl_calculator?topicName=teenagers. Accessed October 14, 2015.

Insurance Institute for Highway Safety (2015a) Alcohol-Impaired Driving: Q & A. Available at: http://www.iihs.org/iihs/topics/t/alcohol-impaired-driving/qanda. Accessed October 5, 2015.

Insurance Institute for Highway Safety (2015b) Graduated Driver Licencing Introduction, Teenagers: State Laws. Available at: http://www.iihs.org/iihs/topics/laws/graduatedlicenseintro?topicName=teenagers. Accessed October 9, 2015.

Johnston L, O'Malley PM, Bachman JG, Schulenberg JE (2014) Monitoring the Future National Survey Results on Drug Use, 1975–2013. *Institue for Social Research, the University of Michigan: Rockville, Michigan, USA.*

Karaca-Mandic P, Ridgeway G (2010) Behavioral impact of graduated driver licensing on teenage driving risk and exposure. J Health Econ 29:48-61.

Keyes KM, Schulenberg JE, O'Malley PM, Johnston LD, Bachman JG, Li G, Hasin D (2012) Birth cohort effects on adolescent alcohol use: The influence of social norms from 1976 to 2007. Arch Gen Psychiatry 69:1304-1313.

Lin M-L, Fearn KT (2003) The provisional license: nighttime and passenger restrictions—a literature review. J Safety Res 34:51-61.

National Highway Traffic Safety Administration (2014) Young drivers: Traffic safety facts: 2012 data, in Washington, DC. *US Department of Transportation*.

O'Malley, PM & Johnston, LD (1999) Drinking and driving among US high school seniors, 1984-1997. Am J Public Health 89:678-684

O'Malley, PM, Johnston, LD (2003) Unsafe driving by high school seniors: National trends from 1976 to 2001 in tickets and accidents after use of alcohol, marijuana, and other illegal drugs. Journal of Studies on Alcohol 64:305-312.

O'Malley, PM, Johnston, LD (2013) Driving after drug or alcohol use by US high school seniors, 2001-2011. Am J Public Health 103(11):2027–2034.

Orcutt JD, Schwabe AM (2012) Gender, race/ethnicity, and deviant drinking: A longitudinal application of social structure and social learning theory. Sociol Spectr 32:20-36.

Ponicki WR, Gruenewald PJ (2006) The joint impacts of minimum legal drinking age and beer taxes on US youth traffic fatalities, 1975-1998. Alcohol Clin Exp Res 30:205a-205a.

Ponicki WR, Gruenewald PJ, LaScala EA (2007) Joint impacts of minimum legal drinking age and beer taxes on US youth traffic fatalities, 1975 to 2001. Alcohol Clin Exp Res 31:804-813.

Robert Wood Johnson Foundation (2008) Overcoming obstacles to health: Report from the Robert Wood Johnson Foundation to the Commission to Build a Healthier America. *Robert Wood Johnson Foundation*.

Ruhm CJ (1996) Alcohol policies and highway vehicle fatalities. J Health Econ 15:435-454.

Scott-Parker B, Watson B, King MJ, Hyde MK (2014) "I drove after drinking alcohol" and other risky driving behaviours reported by young novice drivers. Accid Anal Prev 70:65-73.

Shope JT, Bingham CR (2008) Teen Driving: Motor-Vehicle Crashes and Factors That Contribute. Am J Prev Med 35:S261-S271.

Simons-Morton BG, Hartos JL (2003) Improving the effectiveness of countermeasures to prevent motor vehicle crashes among young drivers. Am J Health Educ 34:S57-S61.

Xuan Z, Nelson TF, Heeren T,Blanchette J, Nelson DE, Gruenewald P, Naimi TS (2013) Tax policy, adult binge drinking, and youth alcohol consumption in the United States. Alcohol Clin Exp Res 37:1713-1719.

422 Zapolski TCB, Pedersen SL, McCarthy DM, Smith GT (2014) Less drinking, yet more
423 problems: Understanding African American drinking and related problems. Psychol Bull
424 140:188-223.
425

Table 1: Graduated drivers licensing law definition and scoring system

Graduated driving licensing laws: This law consists of supervised driving, driver education, restrictions on the number of passengers, restrictions on nighttime driving, and stipulations on the duration of restrictions for young, newly licensed drivers	
Learner's entry age	1 point for learner's entry age ≥ 16
Learner's holding period	2 points for ≥ 6 mo; 1 point for 3 to 5 mo; none for < 3 mo
Practice driving certification	1 point for ≥ 30 hr; none for less than 30 hr
Driver education	Where completion of driver education changed a requirement, point values were determined for the driver education track.
Passenger restriction	2 points for ≤ 1 underage passenger; 1 for 2 passengers; none for 3; where supervising driver may be < 21, point values were determined including the supervising driver as a passenger
Night driving restriction	2 points for 9 or 10 pm; 1 point for after 10 pm
Duration of restrictions	1 point if difference between minimum unrestricted license age and minimum intermediate license age is 12 or more months; night driving and passenger restrictions were valued independently

Table 2. Characteristics of 12th grade participants, 2000-2013 (Total weighted N=125,776 unless otherwise noted)[a]

Variable	Weighted n (weighted %)
----------*State alcohol policies*----------	
Graduated driver's license	
Good	69,798 (55.5)
Fair	38,702 (30.8)
Marginal	10,856 (8.9)
Poor	6,420 (5.1)
Use lose score median (IQR)	3.93 (1.02, 5.62)
Beer tax (dollars per barrel) median (IQR)	6.54 (4.27, 8.45)
----------*Alcohol and driving behaviors*----------	
Any alcohol	56,718 (45.1)
Binge drinking [a]	32,632/124,433 (26.2)
Frequent alcohol use	3,417 (2.7)
Passenger in a vehicle with driver who:	
Drank alcohol [a]	3,208/18,439 (17.4)
Binge drank [a]	1,675/18,415 (9.1)
Drove vehicle after:	
Drinking alcohol [a]	2,160/18,437 (11.7)
Binge drinking [a]	1,338/18,407 (7.3)

----------*Student characteristics*----------	
Sex	
Male	60,770 (48.3)
Female	65,005 (51.7)
Age	
≤17 years	54,494 (43.3)
≥ 18 years	71,282 (56.7)
Race	
Non-Hispanic White	85,689 (68.1)
Non-Hispanic Black	12,817 (10.2)
Hispanic	16,322 (13.0)
Other	10,948 (8.7)
Parent's education	
Both parents ≤ high school	33,847 (26.9)
At least one parent >high school	91,929 (73.1)
Number of parents in the home	
None	6,638 (5.3)
One	31,267 (24.9)
Two	87,871 (69.8)
----------*School characteristics*----------	

Type of school	
Public	114,210 (90.8)
Private	11,565 (9.2)
School size (# of students in targeted grade)	
Small (1-99)	22,453 (17.9)
Medium (100-199)	76,216 (60.6)
Large (≥200)	27,107 (21.5)
% students on subsidized lunches, median (IQR)	27.7 (10.9, 49.3)
% of students Black, median (IQR)	3.9 (1.0, 14.8)
% of students Hispanic, median (IQR)	3.9 (1.0, 14.0)
Standard Metropolitan Statistical Area (SMSA)	
Non-SMSA	31,136 (24.8)
Other SMSA (not self-representing)	60,787 (48.3)
Large SMSA (self-representing)	33,853 (26.9)

[a] Denominator differs for some drinking-related variables because some items were not queried of all respondents.

Table 3. Multivariable logistic regression models predicting alcohol use and risky driving behaviors, 12th graders, 2000-2013 [a]

	Alcohol use behaviors			Risky driving behaviors			
				Passenger in a vehicle with driver who…		Drove vehicle after…	
Variable	Any alcohol (Weighted N= 129,289)	Binge drinking (Weighted N=127,946)	Frequent alcohol use (Weighted N=129,289)	Drank alcohol (Weighted N=19,781)	Binge drank (Weighted N=19,756)	Drinking alcohol (Weighted N=19,789)	Binge drinking (Weighted N=19,754)
	aOR (95% CI)	aOR (95% CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)
Graduated driver's license policy rating							
Good	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Fair	1.04 (0.92, 1.17)	1.05 (0.93, 1.20)	1.26 (1.04, 1.53)*	1.13 (0.92, 1.39)	1.35 (1.09, 1.66)**	1.40 (1.10, 1.78)**	1.36 (1.04, 1.79)*
Marginal	1.28 (1.05, 1.55)*	1.28 (1.04, 1.58)*	1.15 (0.86, 1.56)	1.34 (1.12, 1.60)**	1.73 (1.29, 2.30)***	1.42 (1.05, 1.92)*	1.10 (0.80, 1.50)
Poor	1.05 (0.91, 1.20)	1.15 (0.97, 1.35)	1.33 (1.02, 1.73)*	1.03 (0.80, 1.33)	1.21 (0.86, 1.72)	1.16 (0.86, 1.57)	1.06 (0.71, 1.58)

[a] All models adjust for gender, age, race, parent's education level, number of parents in the home, population density, type of school (private vs public), school size, percent of Black and Hispanic students, percent of students receiving free/reduced cost lunch, state beer tax, spirits tax, use-lose policy score, and year (linear).

***p<0.001

**p<0.01

* p<0.05

Table 4. "Differences-in-differences" logistic regression models predicting alcohol use and risky driving behaviors, 12th graders, 2000-2013

	Alcohol use behaviors			Risky driving behaviors			
				Passenger in a vehicle with driver who…		Drove vehicle after…	
Variable	Any alcohol (Weighted N= 129,289)	Binge drinking (Weighted N=127,946)	Frequent alcohol use (Weighted N=129,289)	Drank alcohol (Weighted N=19,781)	Binge drank (Weighted N=19,756)	Drinking alcohol (Weighted N=19,789)	Binge drinking (Weighted N=19,754)
	aOR (95% CI)	aOR (95% CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)	aOR (95%CI)
Graduated driver's license policy rating							
Good	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Fair	0.99 (0.84, 1.16)	1.06 (0.93, 1.22)	1.10 (0.85, 1.42)	0.96 (0.76, 1.21)	1.13 (0.93, 1.37)	1.02 (0.81, 1.29)	1.06 (0.81, 1.39)
Marginal	1.12 (0.84, 1.49)	1.16 (0.88, 1.51)	1.36 (0.76, 2.44)	1.30 (0.97, 1.74)	2.03 (1.48, 2.79)***	1.11 (0.70, 1.76)	0.94 (0.57, 1.55)
Poor	1.21 (0.98, 1.49)	1.37 (1.16, 1.62)***	1.60 (1.17, 2.20)**	0.82 (0.62, 1.09)	1.01 (0.69, 1.46)	0.81 (0.59, 1.10)	0.81 (0.50, 1.30)

[a] All models adjust for state and year fixed effects, as well as gender, age, race, parent's education level, number of parents in the home, population density, type of school (private vs public), school size, percent of Black and Hispanic students, percent of students receiving free/reduced cost lunch, state beer tax, spirits tax, use-lose policy score, and year (linear).

***p<0.001

**p<0.01

* p<.05