Tax Policy, Adult Binge Drinking, and Youth Alcohol Consumption in the United States

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Abstract

Background—Prior research attributed youth alcohol consumption to the attitudes and drinking patterns among adults. Yet at a population level, few have examined the relationship between state-level adult binge drinking prevalence and youth drinking behaviors, or whether tax policy plays a role in this relationship.

Methods—We analyzed 6 biennial surveys (1999 to 2009) of individual-level youth alcohol use and related behaviors from state-based Youth Risk Behavior Surveys and corresponding years of state-level adult binge drinking prevalence from the Behavioral Risk Factor Surveillance System. We employed logistic regression with generalized estimating equations method to assess the extent to which state adult binge drinking predicted individual-level youth drinking outcomes and examined the role of alcohol taxes in that relationship.

Results—Population-aggregate analyses based on 194 state-year strata showed a positive correlation between state adult binge drinking and youth binge drinking (Pearson r = 0.40, p < 0.01). For individual-level youth drinking outcomes, a 5 percentage point increase in binge drinking prevalence among adults was associated with a 12% relative increase in the odds of alcohol use (adjusted OR = 1.12, 95% CI: 1.08, 1.16). Taxes were strongly inversely related with adult and youth drinking measures, and the effect of tax on youth drinking was attenuated after controlling for adult binge drinking.

Conclusions—Both tax and adult binge drinking are strong predictors of youth drinking. Tax may affect youth drinking through its effect on adult alcohol consumption. Implementing effective alcohol policies to reduce excessive drinking in the general population is an important strategy to reduce youth drinking.

Keywords

Youth Drinking; Adult Drinking; Binge Drinking; Tax; Alcohol Policy

Underage alcohol consumption is an important public health problem in the United States that underlies the 3 leading causes of death among adolescents (Centers for Disease Control

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and Prevention [CDC], 2011). In addition, alcohol consumption and binge drinking during adolescence are strong risk factors for excessive drinking (McCambridge et al., 2011) and alcohol use disorders in adulthood (Grant and Dawson, 1998). While many interventions to reduce youth drinking are age-specific, the drinking behavior of adults may also influence youth drinking. Adults model drinking behavior for youth (Akers et al., 1979), create the environment and expectancies in which choices about alcohol consumption are made by youth (Foley et al., 2004; Smith et al., 1999) and supply alcohol consumed by youth (Needle et al., 1986; Wagenaar et al., 1996). In addition, youth alcohol consumption and drinking-related behaviors occur in a context influenced by adult behaviors as well as social determinants that may directly influence drinking by both youth and adults (Nelson et al., 2005). For example, alcohol taxes are inversely associated with overall consumption (Elder et al., 2010), and raising taxes is among the most effective means of reducing excessive drinking and alcohol-related harms (Babor et al., 2003; Chaloupka et al., 2002).

Characterizing the relationship between adult and youth alcohol consumption has important implications for public health and prevention. A recent international study linked country-level per capita alcohol consumption of adults to drinking among adolescents (Fuhr and Gmel, 2011). In the United States, the relationship between adult and youth drinking has not been fully characterized. A previous population study based on state-level aggregate data found a positive relationship between adult and youth drinking (Nelson et al., 2009). However, neither study accounted for individual-level youth demographics, population-level covariates, or alcohol policies that might have influenced the relation- ship between adult and youth alcohol consumption.

Alcohol policy may account for the relationship between adult and youth alcohol consumption through multiple functions. First, alcohol policy may represent a common cause for both adult and youth drinking. The general deterring effect of alcohol policy likely applies to both adult and youth consumption. Moreover, if adult alcohol consumption affects youth drinking, it is possible that the influence of policy on youth consumption is mediated through adult consumption patterns. Second, alcohol policy may modify the relationship between adult and youth drinking. In states with stronger alcohol control, adult alcohol consumption may have a weaker impact on youth drinking as compared to states with less stringent control policy. However, to the best of our knowledge, there is no attempt in the current literature that explained the association between contextual adult drinking pattern and individual-level youth drinking in the context of population-level policy determinant.

To examine what may underlie the relationship between adult and youth drinking we hypothesize: (i) adult binge drinking is positively associated with youth alcohol consumption; (ii) alcohol tax is inversely associated with adult and youth consumption and adult binge drinking may mediate the relationship between alcohol tax and youth consumption; and (iii) alcohol tax may modify the relationship between adult and youth drinking. The purpose of the present study was to assess the relationship between adult binge drinking and alcohol-related behaviors among same-state youth at the level of the individual, while accounting for other important individual- and state-level covariates, and to investigate the role of tax on the relationship between adult binge drinking and youth alcohol use.

MATERIALS AND METHODS

Sample

Alcohol consumption and related behaviors, and demographic information for youth in grades 9 to 12 were obtained from the biennial state-based Youth Risk Behavior Surveys (YRBS) from 1999 through 2009, which consisted of a total of 6 survey years. Details about

the YRBS and its methodology can be obtained at http://www.cdc.gov/HealthyYouth/yrbs/index.htm. In brief, the state-based YRBS are administered by state health departments and coordinated by the CDC. Most states employ a 2-stage cluster-sample design to generate representative samples of high school student (grades 9 to 12) who attend public schools. Data from states with response rates of at least 60% are cleaned and weighted by the CDC to be representative of that state's population of students in grades 9 to 12 and are made publicly available for research after obtaining permission from CDC and state health departments. Participation in the YRBS is anonymous and voluntary. Parental permission procedures are administered before the survey. Only states with weighted data were included in this study. For the study period from 1999 to 2009, the total number of states with weighted data in YRBS ranged from 20 to 42 states per survey year and included a total of 518,726 respondents from 194 state-year strata of data. The median number of primary sampling units within these 194 state- year strata was 3 (range: 2 to 51).

Youth Drinking Measures

Four alcohol-related measures among youth during the past 30 days were assessed as binary outcome measures in this study: (i) current alcohol use (having at least 1 drink of alcohol on at least 1 day); (ii) binge drinking (having 2–5 drinks of alcohol "in a row" on at least 1 day); (iii) riding with a drinking driver; and (iv) drinking and driving. The wording for the questions characterizing these variables was consistent throughout the study period.

Adult Binge Drinking Measure

Biennial state-level adult binge drinking prevalence data were obtained from the CDC Behavioral Risk Factor Surveillance System (BRFSS) survey from 1999 to 2009, which corresponded to the years for which YRBS data were collected. Details about the BRFSS are available at www.cdc.gov/brfss. Briefly, the BRFSS is a state-based random-digit dialing telephone survey of noninstitutionalized adults aged 18 years or more in all states; survey instruments contain questions on a variety of health risk measures. From 1999 to 2005, binge drinking was defined as 1 or more "occasions" of consuming 5 or more drinks in the past 30 days; in 2006, this definition was modified for all states to be 5 or more drinks for men and 4 or more drinks for women. Binge drinking is commonly considered a dangerous pattern of alcohol consumption which we hypothesize to influence youth drinking behaviors; therefore, for this study, state-specific adult binge drinking prevalence was used as a state-level exposure variable.

Other Individual- and State-Level Measures

Based on the Alcohol Policy Information System of the National Institute on Alcohol Abuse and Alcoholism, we used the combined taxes for beer per drink (i.e., including excise taxes, ad valorem taxes, and state sales tax, where applied) at the state level as a measure of alcohol tax, which has better goodness-of-fit for predicting drinking outcomes in the United States compared with models using the beer excise tax only (Xuan et al., 2012). Furthermore, beer combined tax was used because it is applied in both the license and control states, and beer taxes are highly correlated with the tax on spirits and wine in the U.S. Several individual- and state-level covariates that are associated with or theoretically related to youth drinking were included in the statistical models. Individual-level youth covariates included gender, age (under 16 or 16+), grade level, and race/ethnicity, all of which are associated with youth drinking (Miller et al., 2007). In addition, a number of state-level covariates that have been linked to alcohol consumption were included (Holt et al., 2006; Ponicki et al., 2007), and they were age, sex, racial/ethnic composition, per capita income, educational attainment, religious affiliation, consumer price index, level of urbanization, proportion of the uninsured, proportion of public-funded treatment facilities, and number of police per 1,000 residents. State-level proportions of the population aged 20

years or younger (i.e., those under the legal drinking age), gender, race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, and other race), educational attainment (below college vs. college degree +), employment status (employed vs. unemployed), proportion of the population with health insurance, level of urbanization, and per capita income were aggregated from the American Community Survey (http://www.census.gov/acs/www/). Religious adherence (Catholic) rates were obtained from the 2000 survey by the Association of Statisticians of American Religious Bodies (http://www.rcms2010.org/). Consumer Price Index data were obtained from the U.S. Bureau of Labor Statistics (http://www.bls.gov/cpi/). Proportions of public-funded treatment facilities were obtained from the National Survey of Substance Abuse Treatment Services (http://wwwdasis.samhsa.gov/dasis2/nssats.htm). Police employment data were obtained based on data from the Bureau of Justice Statistics of the U.S. Department of Justice (http://bjs.ojp.usdoj.gov/index.cfm?ty=tp&tid=71). The number of police officers per capita serves as a proxy for enforcement capacity. Outlet density was operationalized as the number of alcohol outlets per 100,000 residents at the state level (i.e., County Business Pattern data from the U.S. Census). Inclusions of both state- and individual-level covariates in the analysis likely enhanced the validity of assessing the relationship between adult binge drinking and youth alcohol consumption. Finally, year was treated as a continuous covariate (i.e., recode 1999 to 2009 into 1 to 11).

Analyses

We engaged in a multistep analysis process. First, we conducted a population-aggregate analysis based on state-year prevalence. Prevalence estimates of drinking-related outcomes among youth were aggregated by state-year strata. We employed Pearson correlations to test where there was significant association between state-level adult binge drinking prevalence and state-level prevalence of youth drinking-related outcomes. We also employed Spearman correlations to ascertain whether the associations based on ranks were consistent.

Because inferences based on aggregate-level associations are susceptible to inconsistent conclusions drawn upon individual-level analysis (Robinson, 1950), we next conducted a series of analyses examining the association between the state prevalence of adult binge drinking and individual-level youth drinking outcomes. We used logistic regression to assess the bivariate relationship between state-level adult binge drinking prevalence and youth individual-level drinking outcomes and then sequentially included individual-level covariates, a number of important state-level covariates, and year in 3 separate models. To assess the relationship between adult binge drinking prevalence and drinking outcomes among youth, we examined the odds ratio of youth consumption for a difference in binge drinking among adults of 5% based on the interquartile range of the adult binge drinking prevalence among these 194 state-years of data (interquartile range 12.6 to 17.6%, mean difference 5.0%). A difference of 5% is of a similar magnitude to the reduction targeted in the Leading Health Indicators in Healthy People 2020 (US Department of Health and Human Services, 2012). Due to the clustering nature of combining multiple years of cross-sectional YRBS data where student respondents were nested within clusters, a generalized estimating equations (GEE) approach was used to compute beta estimates and robust standard errors. Significance level was assessed based on 95% confidence intervals.

Several other methods capable of handling correlated data in a nested structure were considered but not used. Complex survey procedure was not used because the weights provided in state-based YRBS were constructed to be representative at the state level, and there was no known method in YRBS to convert state weights to national weights. Random effects models were also considered; however, the median number of primary sampling units per state- year in YRBS was only 3, which was substantially less than a commonly recommended threshold to satisfy distribution assumptions for random effects models

(Rabe-Hesketh and Skrondal, 2008). In addition, since the primary objective was to determine the average population effect of adult binge drinking on youth drinking rather than distinguishing differences among clusters, we considered the GEE approach more appropriate (Hu et al., 1998). A fixed effects approach at the state level was not used because the exposure variable of interest was a state-level variable, and therefore having state- level fixed effects would make it difficult to estimate the effects of specific state-level characteristics. However, since state-specific characteristics could have accounted for part of the observed relationships between youth and adult drinking, we adjusted for a large number of potentially important state-level covariates in our final regression model.

To explore whether adult binge drinking mediates the effect of tax on youth drinking, we first ascertained that taxes are associated with adult binge drinking, and adult binge drinking is associated with youth drinking. We modeled a 20 cent change for tax as it reflects the range (min 1.3 cents; max 20.6 cents) of the combined beer tax among the 194 state-year strata and would result in at least a 10% increase in price. Second, we examined the adjusted association between tax and youth drinking. Last, we assessed whether the adjusted association between tax and youth drinking was attenuated after including adult binge drinking as a mediator.

To examine whether alcohol tax modifies the relationship between adult binge drinking and youth alcohol use, we dichotomized tax measure into high versus low tax states, created an inter-action term between tax status and adult binge drinking prevalence at state level and examined whether the interaction term significantly predicts youth consumption in the adjusted models.

RESULTS

The total number of states with weighted data in these 6 biennial YRBS data sets were 20 in 1999, 22 in 2001, 31 in 2003, 40 in 2005, 39 in 2007, and 42 in 2009; adult binge drinking prevalence were available for all state-years that corresponded to YRBS data. The total number of state-year strata was 194, with a total sample size N = 518,726 individual youth respondents. Over the 194 state-year strata, the median prevalence of binge drinking among adults was 15.2% (range: 6.6 to 27.0%). For those same states and years, the median prevalence of current alcohol use by youth was 43.0% (range: 17.6 to 61.3%; Table 1). For binge drinking among youth, the median was 26.0% and ranged from 10.9 to 46.7%. With respect to youth riding with a driver who had been drinking, the median was 28.0% and ranged from 13.5 to 48.7%. For drinking and driving among youth, the median was 11.1% and ranged from 4.6 to 32.3%. High school students who were male, age 16 or above, or in grade levels 11th to 12th were more likely to drink, binge drink, ride with a driver who had been drinking, and engage in drinking and driving during the past 30 days. Non-Hispanic black students had the lowest prevalence in drinking-related behaviors compared with the other racial and ethnic groups. All Pearson chi-square tests were statistically significant at an alpha-level of 0.05.

Pearson correlations (Fig. 1) among the 194 state-year strata showed statistically significant positive associations between state-level adult binge drinking prevalence and youth drinking outcomes (r = 0.43, p < 0.0001 for current alcohol use; r = 0.40, p < 0.0001 for binge drinking; r = 0.35, p < 0.0001 for riding with a driver who has been drinking; r = 0.34, p < 0.0001 for drinking and driving). Spearman correlations yield similar results. Due to the concern about combined cross-sectional and longitudinal effects among 194 state-year strata, we restricted strata to the year of 2009 only (N = 42). The resulting Pearson correlations were similar for youth current alcohol use (r = 0.32, p = 0.04) and youth binge

drinking (r = 0.39, p = 0.01), yet largely reduced for riding with a driver who had been drinking (r = 0.11, p = 0.48), and youth drinking and driving (r = 0.12, p = 0.44).

We examined the correlation among state-level covariates for the year of 2009. Among the 14 state-level covariates, the median of the Pearson correlations was 0.30, among the positive pairwise correlations (48 pairs ranging from 0.74 to 0.001), and the median was −0.17, among the negatively correlated pairs (42 pairs, ranging from −0.68 to −0.01).

Table 2 shows results from a series of logistic regression models, where the outcomes were alcohol consumption and related behaviors among individual-level youth. Analyses based on individual-level youth drinking showed statistically significant bivariate relationships between adult binge- drinking prevalence and drinking-related outcomes among individual youth. Subsequently adjusting for individual-level covariates, state-level covariates and year, the magnitudes of the relationships between adult binge drinking prevalence and individual-level youth drinking-related outcomes remained statistically significant with attenuation. In the fully adjusted GEE model, a 5 percentage point increase in adult binge drinking prevalence was associated with a relative increase in 12% in the odds of current alcohol use among youth (adjusted odds ratio [AOR] = 1.12, 95% CI: 1.08, 1.16), and a 12% relative increase in the odds of binge drinking (AOR = 1.12, 95% CI: 1.07, 1.17) among same-state youth. Based on the magnitude of the test statistics and significance level in the final adjusted models in comparisons with other state-level covariates, adult binge drinking prevalence was a strong predictor to youth drinking. In models further adjusting for tax, outlet density, and police force, respectively, with the other individual- and state-level covariates, we observed minimal change or attenuation of the association between adult binge drinking and youth alcohol use. We dichotomized tax measure into high versus low tax states and examined the interaction effect between dichotomous tax status and adult binge on youth alcohol-related behaviors but again found no significant effect modification.

Because many youth do not obtain drivers licenses until age 16 years or older, the relationship between adult binge drinking prevalence and youth drinking and driving restricted to youth aged 2–16 years was also assessed, and the results were similar to those for the full sample (AOR = 1.15, 95% CI: 1.09, 1.22). In a series of sensitivity analyses, restricting analysis to 2009 only, or from 2003 to 2009 (when more than 30 states were present each year), or when treating time as a categorical rather than continuous variable, yielded similar results as our base case model using data from 1999 to 2009.

With respect to the impact of tax on alcohol consumption, Pearson correlation between beer combined taxes and adult binge drinking was r = −0.48 (p < 0.001). In bivariate analysis, a 20 cent increase in the beer combined taxes was associated with an 8.5 absolute percentage point decrease in adult binge prevalence (t = −7.7, p < 0.001). Because alcohol taxes were strongly inversely related to both adult binge drinking (b = −8.5, p < 0.001) and youth drinking (OR = 0.66, 95% CI: 0.60, 0.72), we also assessed whether adult binge drinking might mediate the relationship between alcohol taxes and youth drinking. In a model that adjusted for individual- and state-level covariates, a 20 cent increase in tax remained protective for youth drinking (AOR = 0.91, 95% CI: 0.84, 0.99). However, after adjusting for adult binge drinking, the association between tax and youth drinking was attenuated and no longer statistically significant (AOR = 0.98, 95% CI: 0.90, 1.07). We observed similar findings when assessing the effect of adult binge drinking on the relationship between tax and youth binge drinking.

DISCUSSION

To our knowledge, this is the first population-based study of the relationship between adult binge drinking and individual-level youth drinking in the United States. After controlling for a variety of individual- and state-level covariates, we demonstrated that the prevalence of binge drinking among adults is a strong independent risk factor for drinking among individual youth in the same state. Specifically, a 5% absolute difference in adult binge drinking prevalence was associated with at least a 10% increase in the odds of youth drinking and binge drinking.

Few studies have examined the relationship between adult and youth drinking at the population level in the United States. This study extends analyses from a prior study of the relationships between adult and youth drinking measures in the United States (Nelson et al., 2009). First, this study examined state-level adult binge drinking as a predictor of youth drinking at the individual level, in addition to the association between the population-aggregate prevalence of adult and youth drinking. In turn, it allowed us to minimize bias in interpreting population-aggregate association as association at the individual level (Robinson, 1950) and allowed us to quantify the relationship between youth drinking and adult binge drinking. The use of individual-level YRBS data also allowed us to control for a number of individual-level covariates. Moreover, this study controlled for a large number of state-level covariates which could have influenced the relationship between adult and youth drinking measures. Controlling for these individual and state-level factors resulted in modest attenuation, and the relationship between adult and youth drinking remained robust in the adjusted models.

The findings are consistent with an international study of alcohol consumption among adolescent youth (Fuhr and Gmel, 2011) and studies of the relationships between adult binge drinking and binge drinking among U.S. college students (Nelson et al., 2005) and among adolescents (Nelson et al., 2009; Wiley et al., 1997). In the United States, a previous study of U.S. college students (who are not exclusively underage) found that adult binge drinking prevalence was correlated with same-state binge drinking among college students ($r = 0.43$, $p < 0.01$) and that a low adult binge drinking prevalence was associated with less binge drinking by students in models adjusted for individual-, college- and selected state-level characteristics (Nelson et al., 2005). In addition, we found no attenuation on the association between adult binge drinking and youth drinking when adjusting for tax, outlet density, or police employment, suggesting that these factors do not mediate the relationship between adult binge drinking and youth drinking. The findings that the association between adult binge drinking and youth alcohol-related behaviors remain stable after adjusting for several alcohol policies suggests behavioral influence and social learning (i.e., adults model drinking behavior for youth) may also operate at broad contextual level.

Because tax was strongly inversely related to both adult binge drinking and youth drinking, we considered tax as a potential common cause for both adult binge drinking and youth drinking, and explored adult binge drinking as a potential mediator between tax and youth drinking. We found that adult binge drinking attenuated the relationship between alcohol taxes and youth drinking, suggesting that alcohol taxes may affect youth drinking through their effects on adult drinking. This finding appears to confirm the mechanism of how adult drinking patterns may affect youth drinking behavior (Akers et al., 1979; Smith et al., 1999; Wagenaar et al., 1996) with new evidence from large population-based surveys and delineate possible mediation mechanism linking tax and youth alcohol consumption through adult drinking as a pathway.

This study is subject to several limitations. First, causal inference is limited with the use of observational study design. Nevertheless, reverse causation suggesting that youth drinking influences adult binge drinking (rather than the converse) is unlikely. The use of multiple years of cross-sectional surveys could strengthen the argument for predicting youth drinking behaviors by adult binge drinking patterns. Furthermore, the adjustment of individual covariates and potential state-level confounders reduces limitations on causal interpretation introduced by an ecological study design. Second, the observed association between adult binge drinking and youth drinking behaviors might be attributable to omitted variables, even if the analyses controlled for a large number of both individual- and state-level covariates. For example, the analyses only focused on tax as a primary alcohol policy. Other policy variables, which form an overall alcohol control environment, may have effects on adult or youth alcohol consumption. Therefore, further research on developing aggregated measurement of state- and community-level alcohol control environment and evaluating respective influences of alcohol control, as well as adult drinking-related behaviors on youth alcohol-related behaviors is warranted. Third, not all states are included and therefore our results may not be nationally representative. Fourth, our attempt to investigate the potential mediating effect of adult binge drinking on the relationship between tax and youth consumption is preliminary. Further research that involves more complex mediating mechanism such as longitudinal mediation models to further delineate the role of adult consumption in explaining the influence of policy on youth consumption is needed. Finally, YRBS state-based surveys are collected via schools and data on students who are missing during the survey time cannot be taken into account. Students who are absent on the survey data may differ from the students who take the survey with respect to alcohol consumption (Bovet et al., 2006). It is unclear how the drinking pattern among those with missing data affects the study conclusion.

The findings of a relationship between adult binge drinking and youth drinking behaviors have important public health implications, support the theory that youth and adult drinking occur in a unified context, and suggest that reducing risky drinking among adults should be considered as part of an overall effort to reduce underage drinking. While other factors such as genetics, psychosocial characteristics, and family dynamics may also play a role in the relationship between adult and youth drinking, there is no evidence to suggest that these factors differ enough at the state level to account for the large state-to-state variations in youth drinking. Furthermore, it would be impractical or impossible to modify many of these factors, particularly at the population level. Finally, to the extent that state alcohol policies may influence both youth and adult drinking, it would further argue in favor of the implementation of effective population-based policy interventions to reduce youth drinking outcomes, regardless of whether the effects of such policies might operate directly on youth or through their impact on excessive drinking among adults, or both.

Acknowledgments

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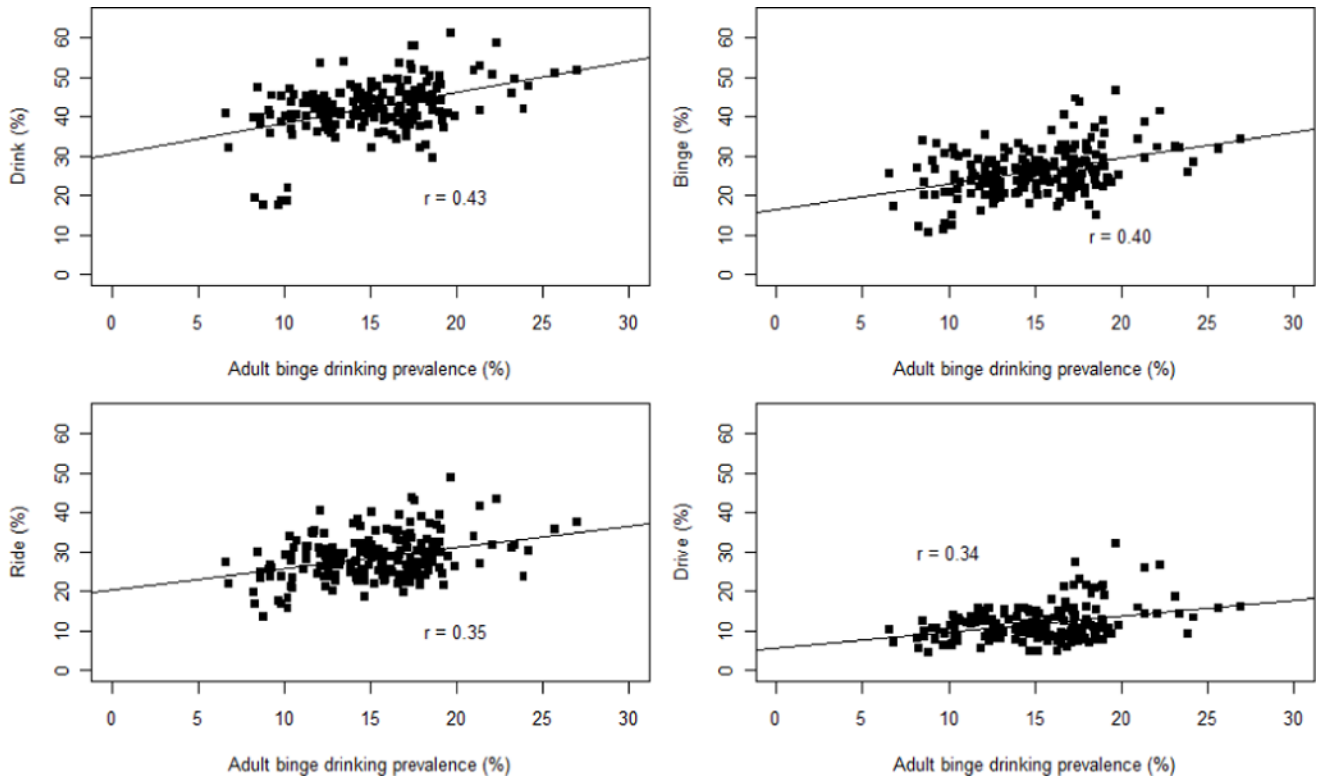
Figure 1.
Correlations (r) between state-level adult binge drinking prevalence and state-level drinking behaviors among youth

Table 1

Prevalence (%) of Youth Drinking Behaviors by Selected Characteristics, State-Based Youth Risk Behavior Surveys of Students in Grades 9 to 12, 1999 to 2009

	Outcomes			
	Drink	**Binge**	**Ride**	**Drive**
Overall prevalence	42.0	25.5	28.0	11.0
Individual characteristics				
Male	42.4	27.6	28.1	13.4
Female	41.6	23.4	27.6	8.6
Under 16 years	34.2	18.4	25.4	6.0
Age 16+ years	47.1	30.2	29.6	14.2
Grade level 9th to 10th	36.7	20.6	26.6	7.4
Grade level 11th to 12th	48.2	31.2	29.5	15.1
White, non-Hispanic	43.9	28.1	27.0	11.7
Black, non-Hispanic	32.3	13.1	26.9	7.0
Hispanic	44.9	26.1	32.0	10.9
Others, non-Hispanic	38.5	23.8	29.7	11.6

Prevalence was pooled across 6 biennial surveys. All chi-square tests were statistically significant at an alpha-level of 0.05. The pooled sample size is n = 518,726.

Drink (had at least 1 drink of alcohol on at least 1 day during the past 30 days); Binge (had 5 or more drinks of alcohol within a couple of hours on at least 1 day during the past 30 days); Ride (at least once in a car or other vehicle driven by someone who had been drinking alcohol during the past 30 days); Drive (drive a car or other vehicle at least once when the person had been drinking alcohol during the past 30 days).

Table 2

Odds ratios and 95% CIs of individual-level youth drinking outcomes associated with an absolute 5 percentage point increase in the state-level binge drinking prevalence among adults

	Youth Alcohol-Related Outcomes			
	Drink	**Binge**	**Ride**	**Drive**
Bivariate GEE model	1.17 (1.13, 1.22)	1.16 (1.14, 1.23)	1.15 (1.11, 1.19)	1.21 (1.16, 1.28)
Adjusted GEE model (individual-level covariates)	1.15 (1.11, 1.19)	1.14 (1.10, 1.18)	1.14 (1.11, 1.18)	1.17 (1.10, 1.23)
Adjusted GEE model (individual- and state-level covariates)	1.11 (1.07, 1.15)	1.10 (1.06, 1.14)	1.11 (1.07, 1.15)	1.13 (1.07, 1.19)
Adjusted GEE model (individual- and state-level covariates and year)	1.11 (1.07, 1.15)	1.10 (1.06, 1.15)	1.11 (1.07, 1.15)	1.13 (1.07, 1.20)
Models adjusting respectively for tax, outlet density, and police force				
Adjusted GEE model (individual- and state-level covariates, year and tax)	1.11 (1.07, 1.15)	1.11 (1.06, 1.16)	1.13 (1.09, 1.18)	1.18 (1.11, 1.26)
Adjusted GEE model (individual- and state-level covariates, year and outlet density)	1.12 (1.08, 1.16)	1.11 (1.07, 1.16)	1.13 (1.09, 1.17)	1.15 (1.09, 1.21)
Adjusted GEE model (individual- and state-level covariates, year and police force)	1.11 (1.08, 1.15)	1.10 (1.06, 1.15)	1.10 (1.06, 1.14)	1.13 (1.06, 1.19)
Models adjusting simultaneously for tax, outlet density, and police force				
Adjusted GEE model (individual- and state-level covariates, year, tax, outlet density, and police force)	1.12 (1.08, 1.16)	1.12 (1.07, 1.17)	1.15 (1.10, 1.20)	1.20 (1.13, 1.27)

Odds ratio was estimated based on GEE approach using compound symmetry structure with clusters defined by the primary sampling units within states. Youth sample consisted of high school students in grades 9–12.

Outcome variables include: Drink (had at least one drink of alcohol on at least one day during the past 30 days); Binge (had 5 or more drinks of alcohol within a couple of hours on at least one day during the past 30 days); Ride (at least once in a car or other vehicle driven by someone who had been drinking alcohol during the past 30 days); Drove (drive a car or other vehicle at least once when the person had been drinking alcohol during the past 30 days).

Individual-level covariates included ender, age (under 16 or 16+), and race/ethnicity as non-Hispanic White, non-Hispanic Black, non-Hispanic Others, and Hispanic.

State-level covariates included state-level age (under 21 or 21+), sex and racial/ethnic (i.e., non-Hispanic White, non-Hispanic Black, non-Hispanic Others, and Hispanic) composition, per capita income, educational attainment, religious affiliation, consumer price index, level of urbanization, proportion of the uninsured, proportion of public-funded treatment facilities. Year was treated as a continuous variable (i.e., years from 1999 to 2009 were recoded from 1 to 11). Tax was measured in cents per drink and modeled as per 20 cent change. Outlet density was measured in terms of number of outlets per 100,000 state residents and modeled as per 100 outlets change. Police employment was measured in terms of number of police officers per 1000 residents.