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Estimating Alcohol-Attributable Injury Deaths: A Comparison of Epidemiological Methods

Timothy S. Naimi, M.D., M.P.H[1] [Director], **Adam Sherk, Ph.D.[1] [Scientist]**, **Marissa B. Esser, Ph.D., M.P.H[2]**, **Jinhui Zhao, Ph.D[1] [Scientist]**

[1]Canadian Institute for Substance Use Research, Victoria, BC, Canada

[2]Alcohol Program, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention. Atlanta, GA, USA

Abstract

Background and Aims: Injuries often involve alcohol, but determining the proportion caused by alcohol is difficult. Several approaches have been used to determine the causal role of alcohol, but these methods have not been compared directly with one another. Such a comparison would be useful for understanding the strengths and comparability of different approaches. This study compared estimates of average annual alcohol-attributable deaths in the United States from injuries during 2015–2019 using a blood alcohol concentration (BAC) method compared with a population attributable fraction (PAF) approach.

Methods: For the BAC method, we used a direct method involving the proportion of decedents with a high blood alcohol concentration (BAC, e.g., ≥0.10%). For the PAF approach, we compared the use of unadjusted survey data with average consumption data adjusted using alcohol sales data to account for underreporting and accounting for binge drinking. Survey data were from the Behavioral Risk Factor Surveillance System and mortality data were from the National Vital Statistics System.

Results: The number of alcohol-attributable injury deaths using the direct method (48,516 deaths annually) was similar to that using PAF methods (47,879 deaths annually), but only when alcohol use measures were adjusted using alcohol sales data. Furthermore, estimates were similar for cause-specific categories of deaths, including non-motor vehicle unintentional injuries and motor vehicle crashes. Among PAF methods, excessive drinking accounted for 38% of injury deaths using unadjusted survey data, but 65% of injury deaths using adjusted data.

Conclusions: Estimates of alcohol-attributable injury deaths from a direct method and from a population attributable fraction method that adjusts for alcohol use based on alcohol sales data appear to be comparable.

Corresponding author: Timothy Naimi; tnaimi@uvic.ca; 2300 McKenzie Ave., Room 273; Victoria, BC V8P 5C2, Canada.
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Keywords

alcohol; binge drinking; injury; alcohol-attributable deaths; alcohol-attributable fractions; population alcohol-attributable fraction

INTRODUCTION

Alcohol is a leading behavioral cause of death and disability.(1) Injuries, including those that are unintentional (e.g., falls, poisoning) and intentional (e.g., homicide, suicide), account for a substantial proportion of alcohol-attributable mortality, and are among the leading causes of alcohol-attributable death among adults aged 20–64 years.(2) Alcohol-attributable injury deaths typically result from impairment due to high per-occasion consumption (e.g., binge drinking), which results in elevated blood alcohol concentration (BAC) levels.(3, 4)

Despite the substantial contribution of alcohol in injury deaths,(4) determining the proportion that are due to alcohol use can be methodologically challenging. One approach relies on “direct” estimates of alcohol attribution based on the proportion of decedents with BACs above a particular threshold. However, selecting appropriate BAC thresholds that represent levels where the deaths can be causally attributed to alcohol use is difficult because alcohol-impairment levels vary across individuals, risks may vary by injury type, and impairment-level BACs do not necessarily imply attribution. Also, comparator BACs for non-fatal injuries are typically not available to determine BAC-attributable relative risk functions for deaths on a condition-specific basis. Alcohol testing among decedents is not routine or uniform across jurisdictions, and it is potentially subject to biases in the selection of decedents for BAC testing.(5)

An alternative approach involves generating “indirect” estimates of alcohol-attributable injury deaths using population attributable fraction (PAF) methodology.(6) This method relies on accurate estimates of the distribution of drinking levels in the population, and risk estimates of alcohol-related conditions. The distribution of consumption is dependent on survey data, which substantially underestimate population-level average consumption relative to alcohol sales and shipment data.(7) Also, most studies of alcohol and injuries are based on risks associated with average drinking levels,(8, 9) even though measures of per-occasion consumption (e.g., binge drinking) or direct BAC measurement are more physiologically related to injury risk since they are related to acute impairment.(4)

The purpose of this study was to compare the direct BAC-based method and the indirect PAF method for assessing alcohol-attributable injury deaths among people aged 15 years or older in the United States. The study examined the effects of adjusting survey data on alcohol consumption to account for underreporting and how binge drinking information can be used for PAF calculations.

METHOD

Overview

The AAF for the direct method (method 1) is based on the proportion of decedents who exceed a particular BAC threshold (generally based on findings from a recent meta-analysis) (4), whereas the three indirect approaches (methods 2-4) are based on PAF methodology. For all methods, the causes of death and corresponding International Classification of Diseases (ICD)-10 codes are those used in the Centers for Disease Control and Prevention's Alcohol-Related Disease Impact (ARDI) application.(10) These injury deaths were categorized into unintentional injuries, intentional injuries, and motor vehicle traffic crash subgroups. The indirect PAF method relies on prevalence estimates of three levels of average consumption (low, medium, and high) using Behavioral Risk Factor Surveillance System (BRFSS) survey data (Table 1). Relative risks for injury at each level of consumption for binge drinkers and non-binge drinkers, respectively, were obtained from another meta-analysis,(11) consistent with the World Health Organization (WHO) approach.(12) Since relative risks are based on both average consumption level and binge drinking status, and both measures are under-estimated in surveys,(13) we explored the impact of adjusting average consumption and binge drinking on our estimates. We did not pre-register our analytic plan.

Data Sources

All methods relied on sex-specific mortality data from the National Vital Statistics System.(14) We used the average annual number of deaths from injuries during 2015–2019 for each alcohol-related acute condition in CDC's ARDI application (Table 2 lists specific conditions).(10)

Consistent with CDC's ARDI application, the years of the pooled average annual mortality data aligned with the years of the alcohol consumption data. Pooled BRFSS data from 2015–2019 were used to determine average daily alcohol consumption and binge drinking status. The BRFSS is an ongoing state-based, nationwide telephone survey of noninstitutionalized U.S. adults (18 years and older), including landline and cellphone sampling of adults who report living in any private residence or college housing.(15) Average alcohol consumption was determined by multiplying the frequency of past 30-day alcohol consumption by the average amount consumed per drinking day, and dividing by 30. Persons in the low consumption group consumed an average of >0–≤1 drinks daily (females) or >0–≤2 drinks daily (males); those in the medium consumption group consumed an average of >1–≤2 drinks daily (females) or >2–≤4 drinks daily (males); and those in the high consumption group consumed an average of >2 drinks daily (females) or >4 drinks daily (males).(16) Binge drinking was defined as the consumption of ≥5 drinks for males, or ≥4 drinks for females, during ≥1 occasion in the past 30 days. A respondent's binge drinking status was based on a non-zero response about the number of binge drinking occasions in the past 30 days.

Method 1: Direct method using BAC-based AAFs

The AAF was interpreted as the proportion of deaths for a particular cause of injury that was attributable to alcohol use based on an established BAC threshold.(2) The AAFs for each cause of unintentional and intentional non-motor vehicle injury death were obtained from a recent meta-analysis by Alpert et al.(4) To define alcohol attribution, Alpert et al. used a BAC cutoff of 0.10% or greater for most conditions, but used other evidence of intoxication for six conditions. For motor vehicle traffic crashes and other road vehicle deaths, a BAC threshold of 0.08% or higher was used to define alcohol attribution, aligning with methods used by the U.S. National Highway Transportation System Administration and the level used to define legal impairment for driving in most U.S. states. Sex-specific AAFs for motor vehicle crashes and other road vehicle crash deaths were obtained from the Fatality Analysis Reporting System (FARS), which is a census of all motor vehicle crash fatalities that occur on U.S. public roadways.(17)

Methods 2-4: indirect methods using PAFs to estimate AAFs

Using indirect PAF methodology, estimation of AAFs requires the prevalence of alcohol use at various levels of average consumption, and the relative risk for a given outcome at each of those levels. We also applied different relative risk estimates for various levels of average consumption based on binge drinking status.

For this study, the AAF formula can be expressed as follows (for each injury category, and separately by sex):

$$AAF = \frac{P_{L,B}(RR_{L,B}-1)+P_{L,NB}(RR_{L,NB}-1)+P_{M,B}(RR_{M,B}-1)+P_{M,NB}(RR_{M,NB}-1)+P_{H,B}(RR_{H,B}-1)+P_{H,NB}(RR_{H,NB}-1)}{1+P_{L,B}(RR_{L,B}-1)+P_{L,NB}(RR_{L,NB}-1)+P_{M,B}(RR_{M,B}-1)+P_{M,NB}(RR_{M,NB}-1)+P_{H,B}(RR_{H,B}-1)+P_{H,NB}(RR_{H,NB}-1)}$$

In the formula, $P_{\mathrm{L,B}}$ and $RR_{\mathrm{L,B}}$ are the prevalence and relative risk (RR) of those drinkers with low average daily consumption (ADC) who binge drink; $P_{\mathrm{L,NB}}$ and $RR_{\mathrm{L,NB}}$ are the prevalence and RR of those with low ADC who do not binge drink; $P_{\mathrm{M,B}}$ and $RR_{\mathrm{M,B}}$ are the prevalence and RR of those with medium ADC who binge drink; $P_{\mathrm{M,NB}}$ and $RR_{\mathrm{M,NB}}$ are the prevalence and RR of those with medium ADC who do not binge drink; $P_{\mathrm{H,B}}$ and $RR_{\mathrm{H,B}}$ are the prevalence and RR of those with high ADC who binge drink, and; $P_{\mathrm{H,NB}}$ and $RR_{\mathrm{H,NB}}$ are the prevalence and RR of those with high ADC who do not binge drink.

Cause-specific continuous relative risk functions (corresponding to the injury categories of motor vehicle collisions, unintentional injuries and intentional injuries) were from the WHO's 2018 Global Status Report on Alcohol and Health.(11, 12) For each of these three injury types, there were two continuous RR functions: one for those who reported binge drinking and another one for those who did not report binge drinking. By sex, for each of the prevalence categories in the formula above, median consumption values (in g/day) for those drinking low, medium and high amounts were calculated from the respondent-level BRFSS information. For each sex, categorical RR estimates were calculated by evaluating the RR functions at these median consumption values intwelve g/day, resulting in a total of 36 categorical RR estimates, corresponding to the two sexes, three alcohol use groups, three injury categories and two binge statues (nonbinger and binger). Low, medium and high average consumption by sex are defined above.

In method 2, we used unadjusted BRFSS data to group respondents into low, medium, and high average consumption groups by sex, and determined the prevalence of each level of consumption in the population. Since there were separate relative risk functions based on binge drinking status (dichotomous), we also used unadjusted BRFSS data to determine binge drinking status in method 2.

In method 3, we adjusted average consumption estimates (corresponding to the rightward arrow in Figure 1) to address the underreporting of average alcohol use. As in a previously published methodology, we adjusted individual-level respondent data so that average consumption among the weighted population accounted for 73% of per capita alcohol sales based on tax and shipment data to better reflect population-level alcohol consumption;(16) the 73% matches the average "coverage" of per capita consumption in U.S. cohort studies used to determine relative risk estimates.(7) Per capita alcohol consumption estimates from tax and shipment data were from the Alcohol Epidemiological Data System.(18) After this adjustment, we determined revised prevalence estimates, by sex, of the proportion of the population drinking at low, medium, and high levels of average consumption.

In method 4, we adjusted both average consumption and binge drinking probability based on the revised average consumption estimates from method 3. The binge drinking adjustment for each respondent was as follows: adjusted average consumption (adjusted to 73% of per capita alcohol sales, as in method 3) in grams of ethanol per day was inputted into the function representing the appropriate sex-age group binge probability function (see arrows shown on Figure 1). Specifically, using unadjusted BRFSS data, we created modeled binge drinking probability functions for four sex-age strata: males aged 18 to 44 years, males aged ≥45, females aged 18 to 44, and females aged ≥45. Logistic regression was used to model the dichotomous binge drinking status (dependent variable), based on each respondent's average consumption in U.S. standard drinks (14 grams of ethanol per standard drink, independent variable) to estimate binge drinking probability using maximum likelihood.(19) The result is the probability of binge drinking, given any average alcohol use estimate. This probability based on the adjusted average consumption estimate was used in method 4 instead of the dichotomous binge drinking status variable, which was based on unadjusted data. Using the binge drinking probabilities, we then recalculated the prevalence of binge drinking within each of the low, medium, and high average consumption levels, by sex and age group.

RESULTS

Compared to method 2 that used unadjusted average alcohol use data, methods 3 and 4 that adjusted average consumption yielded a lower prevalence of low consumption and a greater prevalence of medium consumption and high consumption, for both males and females (Table 1). In method 3, binge drinking was not adjusted, so the total number of people who binge drank stayed the same as in method 2. However, after adjusting for average consumption in method 3, the prevalence of binge drinking decreased across all consumption levels because of the changing denominator of drinkers in each consumption category. After further adjustment for binge drinking (method 4), the number of binge drinkers increased and the prevalence of binge drinking in each average alcohol consumption group returned to levels similar to those using unadjusted data (method 2). Using males as an example, compared to the unadjusted data (method 2), the data adjusted for both average consumption and binge drinking (method 4) resulted in an increase in the percent of males drinking at the medium average consumption level from 4.4% to 9.6%, and an increase in the average annual number of males who binge drank from approximately 4.0 million to 8.5 million. The percent of males drinking at the high level increased from approximately 2.4% to 9.6%, and the average annual number of males who binge drank increased from approximately 2.6 million to 10.6 million. Across all levels of consumption, the average annual number of males who binge drank increased from approximately 24 million (method 2) to 34 million (method 4).

When estimating the total average annual number of alcohol-attributable injury deaths (Table 2), the direct method 1 and the fully adjusted method 4 yielded similar results (48,516 for method 1 and 47,879 for method 4, a relative difference of 1.3%). The unadjusted method (method 2) yielded the lowest estimate of injury deaths (34,908), and the method adjusting average consumption to a portion of per capita sales (method 3) yielded 37,668 deaths. Therefore, compared to unadjusted method 2, the adjustment for average consumption to a portion of per capita sales (method 3) increased the total alcohol-attributable injury death estimate by 2,760 (a 7.9% relative increase). The further adjustment for binge drinking prevalence (method 4) increased the estimated deaths by 10,211 (a 29.2% increase relative to method 2, or a 27.1% relative increase compared to method 3).

For the direct method 1 and the fully adjusted method 4, results were similar for cause of death categories such as unintentional injuries (20,886 for method 1 and 21,722 for method 4, a 4.0% relative increase), and motor vehicle traffic crashes (12,650 for method 1 and 12,933 for method 4, a 2.2% relative increase). Differences for intentional injury deaths were somewhat larger (14,980 for method 1 and 13,224 for method 4, an 11.7% relative decrease). However, there was more variability for some individual causes of death within these three broader categories; for example, method 1 had higher estimates for motor vehicle non-traffic crashes compared to method 4 (426 vs. 249), but lower estimates for occupational/machine injuries (180 vs. 54) and child maltreatment (170 vs. 82).

Table 3 presents the average annual number of alcohol-attributable injury deaths from unintentional and intentional injuries excluding motor vehicle crash deaths using PAF methods (methods 2–4), stratified by sex and level of alcohol use. By sex, males accounted for approximately 80% of the alcohol-attributable injury deaths for all three methods. Excessive alcohol use accounted for 38.3% of the alcohol-attributable injury deaths using the unadjusted method (method 2) versus 64.8% using the fully adjusted method (method 4). The total number of non-motor vehicle traffic crash injury deaths in method 4 (35,866) was similar to that of method 1 (34,964, shown in Table 2), but method 1 is not reported in Table 3 because it does not involve measures of average consumption levels.

DISCUSSION

This study compared two types of approaches for estimating the number of alcohol-attributable injury deaths; the 'direct' method applied the AAF for cause-specific injury deaths based on BAC thresholds, and the 'indirect' method used PAF methodology with and without adjustments to prevalence estimates of average alcohol consumption. The study found that the PAF method using unadjusted self-reported alcohol consumption resulted in the lowest estimates of alcohol-attributable injury deaths, which is because of the underreporting of alcohol use in the BRFSS.(7) However, after using per capita alcohol sales data to account for the underreporting of alcohol use and binge drinking, the total number of alcohol-attributable injury deaths was similar between the direct BAC-based method (about 48,500 deaths) and the PAF methodology with those adjustments (approximately 48,000 deaths), with only a 1.3% relative difference. The similarity in the estimates for these two methods also held for cause-specific categories of injury deaths, suggesting further validity of the estimates. Similar to findings for alcohol-related chronic disease outcomes, such as liver disease,(20) these findings suggest that estimates of alcohol-related harm based solely on self-reported alcohol use without adjustments for per capita alcohol sales data can lead to substantial underestimates of alcohol's attribution.

For methods 1 and 4, there were greater relative differences for some individual causes of causes of death compared to differences among the larger categories of injury deaths and total injury deaths. Analyses based on the direct AAF estimates (which were measured for each individual condition in method 1) might differ from those based on PAF methods since relative risk estimates used in the PAF methods were based on pooled risk from multiple related conditions.

Compared to the use of unadjusted survey data, the adjustment of both average consumption and binge drinking prevalence based on per capita sales data increased alcohol-attributable death estimates by almost 40%, with most of that increase due to adjustments in binge drinking prevalence. The role of binge drinking has been documented in numerous causes of injuries, such as falls, overdose, and motor vehicle crashes,(8, 21, 22) and our findings underscore the importance of adjusting for binge drinking, in addition to adjusting average consumption, when using PAF methodology for estimating alcohol-attributable injuries.

The consistency of findings between the estimated average annual deaths from motor vehicle crashes using the direct approach (method 1) and the fully adjusted PAF approach (method 4) is also noteworthy. First, unlike most BAC-based studies of non-motor vehicle crashes, there have been previous controlled studies assessing the relative risk of a fatal crash at particular BAC levels compared to no alcohol involvement.(23-25) Therefore, the risk of alcohol use at BACs ≥0.08% (a BAC level that generally equates to binge drinking) for motor vehicle crash deaths has strong empirical evidence, and provides justification for attributing deaths at this BAC level to alcohol use (as in method 1). Second, the AAF estimates come from FARS, which is U.S.-specific, updated annually, and has detailed surveillance of exclusively fatal crashes. For PAF methods 2–4, however, the relative risks are from meta-analyses whose component studies are not limited to the U.S., are of varying recency, and include a mix of fatal and non-fatal injury outcomes. Furthermore, when adjusting binge drinking prevalence estimates to address underreporting or survey non-coverage of groups in the population (e.g., people who are experiencing homelessness or incarceration), the relative risk estimates for injury deaths among people who binge drink are still based on unadjusted data. This is a weakness because estimates of consumption and risk could otherwise be mismatched, unless the degree of underreporting is similar for average consumption and binge drinking. Therefore, even though there is no ‘gold standard’ by which to ascertain the number of alcohol-attributable deaths from injuries, the finding that the direct BAC-based method and method 4 arrive at similar estimates for motor vehicle crash fatalities suggests that both methods may have reasonable construct validity.

PAF methods are needed in countries where direct AAF estimates are unavailable. This may be especially likely for low- and middle-income countries where BAC testing among injury decedents may be relatively uncommon, whereas information on the distribution of consumption in the population is generally available in all countries. However, one of the concerns about using PAF approaches is that relative risk curves for most alcohol-related conditions, including injuries, are based on average alcohol consumption. Although average consumption and per-occasion consumption are typically correlated,(26) binge drinking (a threshold measure of per-occasion consumption) has a more central role in injuries and injury mortality.(27) In our study, based on unadjusted BRFSS data, we found that low levels of average consumption accounted for the majority of injury deaths. This is consistent with previous findings that binge drinking is common among those with ‘moderate’ average alcohol consumption.(28, 29) Even after adjustments for survey underreporting, we found that one-third of injury deaths were among people who drink at low levels. This highlights that a large proportion of alcohol-attributable deaths from injuries are from those who consume modest amounts of alcohol on average, and who are unlikely to have an alcohol use disorder, but may drink to impairment (e.g., binge drink).(30)

There are few studies, and fewer meta-analyses, of the graded relationship between various levels of per-occasion consumption and injury mortality. Currently, the WHO approach adjusts for average consumption (to account for survey-based underreporting) and uses separate risk curves for people who binge drink versus do not binge drink;(12) this is a methodological asset because of the strong relationship between binge drinking and injury, and because the prevalence of binge drinking may vary among different populations within the same strata of average consumption. However, that method does not adjust the likelihood of binge drinking to account for survey underreporting of binge drinking, or differential non-coverage of people who binge drink compared to people who do not. This study offers an approach by which to accomplish this objective, which could yield results from a PAF methodology similar to those of a direct BAC-based AAF method.

This study is subject to additional caveats and limitations. The total number of deaths from each type of injury reported in vital statistics data is based on the underlying (i.e., primary) cause of death, so deaths from contributing (i.e., multiple) causes that might also be related to alcohol are not incorporated in our estimates. Furthermore, cause-specific AAFs based on BAC levels are generated from available surveillance of alcohol involvement in injury deaths. However, alcohol may not be routinely or reliably assessed in toxicology testing across states or countries, and may vary by time, location and cause of death.(5) This selective and variable testing may bias estimates of alcohol involvement, which are the basis of the direct AAFs. Estimates of alcohol consumption in cohort studies are also limited, which affects the accuracy of relative risks for injury outcomes. Data from cohort studies may involve consumption information at only one point in time and may fail to elicit information about alcohol consumption patterns (e.g., binge drinking). Although our primary intent was the comparison of the most likely estimate for each of the methods, the lack of uncertainty estimates precludes us from determining whether the observed differences were statistically significant.

Although the PAF methodology using adjusted binge drinking prevalence estimates yielded alcohol-attributable death estimates similar to those using the direct approach, we cannot definitively infer its validity since there is no 'gold standard' by which to measure the relationship between average consumption and binge drinking, or of alcohol's contribution to injury deaths. For example, although there is evidence to suggest that both binge drinking and average consumption are underestimated in general public health surveys (based on non-coverage or incorrect estimates among those who respond to the survey),(31) it is not certain whether the magnitude of underestimates for average consumption and binge drinking are comparable, as was assumed for this analysis. Nevertheless, a strength of this study is that we built on the WHO PAF approach, which distinguishes the risk from various levels of average consumption on the basis of binge drinking status, and developed an approach to adjust binge drinking prevalence estimates based on average consumption adjusted to a portion of per capita sales. Using lower BAC cutoffs (e.g., 0.05%) for the direct method (method 1) would result in larger AAFs and higher injury mortality estimates, but the specificity for alcohol being the causal factor would decrease; the reverse would have been the case were higher BAC cutoffs used.

Conclusion

Estimates of alcohol-attributable injury deaths from a direct AAF method and from PAF methods that adjust alcohol use to more closely approximate per capita consumption and account for binge drinking were similar. Studies on the frequency of various levels of per-occasion consumption (based on standard drinks consumed) and cause-specific outcomes could provide further information on alcohol's contribution to unintentional and intentional injury deaths. Regardless of the method, this study found that tens of thousands of people die from alcohol-attributable injuries every year in the U.S. Effective population-level alcohol control policies can reduce the prevalence and frequency of high per-occasion consumption (including binge drinking), which increases the risk of fatal injury.(32)

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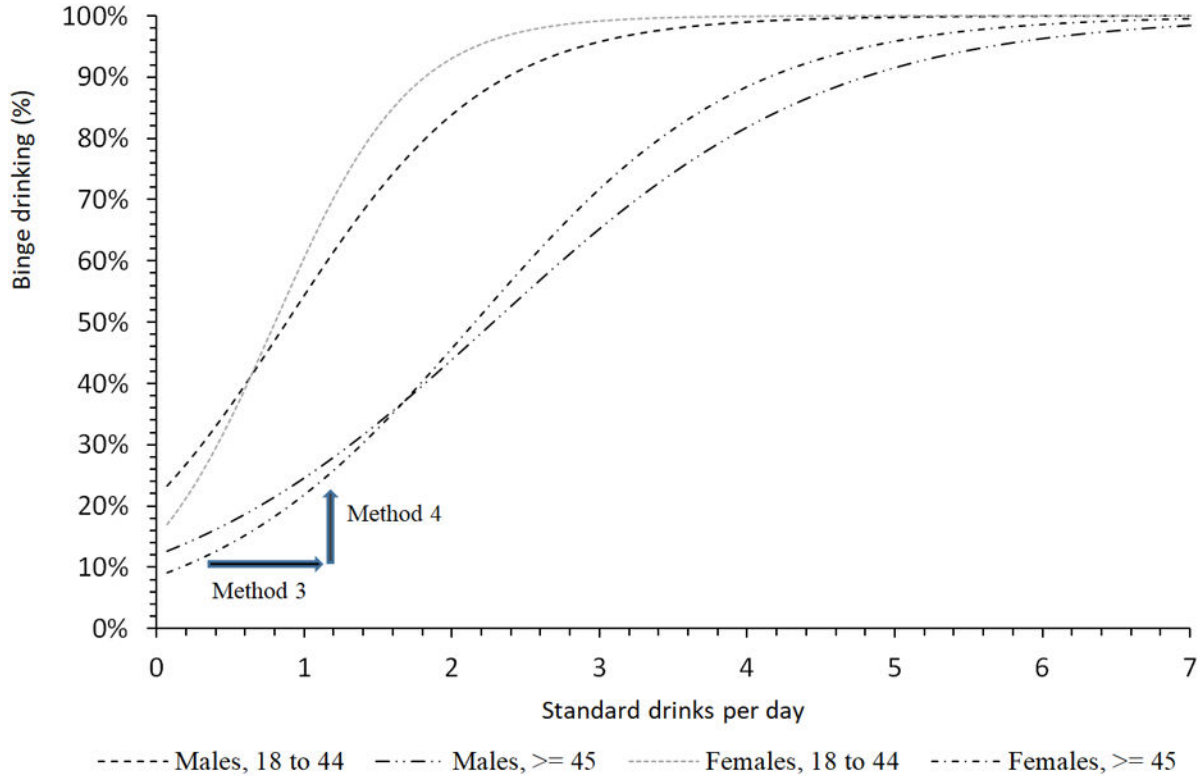

Figure 1. Probability function for past 30-day binge drinking by average alcohol use in standard drinks per day, by sex and age

The lines represent the population-weighted relationships between average consumption in U.S. standard drinks per day (x-axis) and the probability of binge drinking (y-axis) calculated using logistic regression. Arrows indicate implemented changes to the estimated average consumption and prevalence of binge drinking in methods 3 and 4, respectively. In method 3, the average consumption based on survey data is adjusted based on per capita consumption from alcohol sales data; the rightward horizontal arrow represents this shift in average consumption. In method 4, a new binge drinking probability is calculated based on the new level of average consumption obtained in method 3; the upward vertical arrow represents this shift in binge drinking probability.

Table 1.

Number and proportion of average alcohol use and binge drinking, by adjustment method and sex, 2015–2019

	Average Alcohol Use[a]				
	None	**Low**	**Medium**	**High**	**Overall**
Males					
Unadjusted BRFSS survey data (method 2)[b]					
No. people, annual average	46,479,673	58,766,643	4,972,977	2,650,060	112,869,353
Proportion of population (%)	41.2	52.1	4.4	2.4	100.0
No. who binge drink, annual average	0	17,400,719	3,989,666	2,596,549	23,986,935
Proportion who binge drink (%)	0.0	29.6	80.2	98.0	21.3
Average consumption adjusted based on per capita sales data (method 3)[b]					
No. people, annual average	46,479,673	44,674,347	10,850,634	10,864,699	112,869,353
Proportion of population (%)	41.18	39.58	9.61	9.63	100.00
No. who binge drink, annual average	0	10,428,457	5,089,532	8,468,946	23,986,935
Proportion who binge drink (%)	0.0	23.3	46.9	78.0	21.3
Average consumption and binge drinking adjusted based on per capita sales data (method 4)[b]					
No. people, annual average	46,479,673	44,674,347	10,850,634	10,864,699	112,869,353
Proportion of population (%)	41.2	39.6	9.6	9.6	100.0
No. who binge drink, annual average	0	14,975,603	8,497,418	10,558,987	34,032,008
Proportion who binge drink (%)	0.0	33.5	78.3	97.2	30.2
Females					
Unadjusted BRFSS survey data (method 2)[b]					
No. people, annual average	63,586,681	49,775,154	4,919,058	1,935,948	120,216,840
Proportion of population (%)	52.9	41.4	4.1	1.6	100.0
No. who binge drink, annual average	0	9,376,224	2,824,610	1,719,811	13,920,645
Proportion who binge drink (%)	0.0	18.8	57.4	88.8	11.6
Average consumption adjusted based on per capita sales data (method 3)[b]					
No. people, annual average	63,586,681	37,747,499	9,311,094	9,571,567	120,216,840
Proportion of population (%)	52.9	31.4	7.8	8.0	100.0
No. who binge drink, annual average	0	5,657,792	2,758,245	5,504,607	13,920,645
Proportion who binge drink (%)	0.0	15.0	29.6	57.5	11.6
Average consumption and binge drinking adjusted based on per capita sales data (method 4)[b]					
No. people, annual average	63,586,681	37,747,499	9,311,094	9,571,567	120,216,840
Proportion of population (%)	52.9	31.4	7.8	8.0	100.0
No. who binge drink, annual average	0	7,868,465	5,395,267	8,260,102	21,523,835
Proportion who binge drink (%)	0.0	20.8	57.9	86.3	17.9

BRFSS: Behavioral Risk Factor Surveillance System

[a]Persons in the low consumption group consumed an average of >0–≤1 drinks daily (females) or >0–≤2 drinks daily (males); those in the medium consumption group consumed an average of >1–≤2 drinks daily (females) or >2–≤4 drinks daily (males), and those in the high consumption group consumed an average of >2 drinks daily (females) or >4 drinks daily (males). Binge drinking was defined as consuming 5 or more drinks (for males) or 4 or more drinks (for females) during one or more drinking occasions in the past 30 days.

[b] In method 2, unadjusted BRFSS data refers to unadjusted weighted data on average daily alcohol consumption and binge drinking from the 2015–2019 BRFSS. In method 3, average alcohol use from the BRFSS was adjusted to account for 73% of per capita consumption based on alcohol sales data. In method 4, average alcohol use data were further adjusted using an updated binge drinking probability based on the change in average consumption from method 3.

Table 2.

Average annual number of alcohol-attributable injury deaths, by method and cause of death, United States, 2015–2019

Cause of Death	ICD-10 Codes	Direct Method[a]	Indirect Methods Using Population-Attributable Fractions[b]		
		Method 1	Method 2	Method 3	Method 4
Unintentional Injury Deaths					
Air-space transport	V95-V97	12	73	79	102
Alcohol poisoning[c]	X45, Y15	2,346	2,346	2,346	2,346
Aspiration	W78-W79	406	271	291	383
Drowning	W65-W70, W73, W74, Y21	1,019	585	631	816
Fall injuries	W00-W19, Y30	2,622	1,218	1,313	1,708
Firearm injuries	W32-W34, Y22-Y24	175	134	144	186
Fire injuries	X00-X06, X08, X09, Y26	910	438	471	618
Hypothermia	X31	258	150	162	211
Occupation/ machine injuries	W24-W31, W45	54	130	141	180
Motor vehicle non-traffic crashes	V02.0, V03.0, V04.0, V09.0, V12-V14(.0-.2), V19.0-V19.2, V20-V28(.0-.2), V29.0-V29.3, V30-V39(.0-.3),V40-V49(.0-.3), V50-V59(.0-.3), V60-V69(.0-.3), V70-V79(.0-.3), V81.0, V82.0, V83-V86(.4-.7, .9), V88.0-V88.8, V89.0	426	178	192	249
Other road vehicle crashes[a]	V01, V05-V06, V09.1, V09.3, V09.9, V10-V11, V15-V18, V19.3, V19.8-V19.9, V80.0-V80.2, V80.6-V80.9, V81.2-V81.9, V82.2-V82.9, V87.9, V88.9, V89.1, V89.3, V89.9	36	182	197	254
Poisoning (not alcohol)	X40-X44, X46-X49, Y10-Y14, Y16-Y19	12,187	10,365	11,170	14,554
Water transport	V90-V94	120	83	90	115
Subtotal		**20,886**	**16,154**	**17,227**	**21,722**
Intentional Injury Deaths					
Suicide by alcohol[c]	X65	41	41	41	41
Child maltreatment	X85-X99, Y00-Y09, Y87.1	82	117	129	170
Homicide	X85-X99, Y00-Y09, Y87.1	5,221	2,592	2,848	3,698
Suicide	X60-X64, X66-X84, Y87.0	9,636	6,520	7,159	9,315
Subtotal		**14,980**	**9,270**	**10,177**	**13,224**
Motor Vehicle Traffic Crash Deaths *by Age Group*					
0-14	V02(.1, .9), V03(.1, .9), V04(.1, .9), V09.2, V12-V14(.3-.5, .9), V19.4-V19.6, V20-V28(.3-.5, .9), V29.4-V29.6, V29.8, V29.9, V30-V38(.4-.7, .9), V39 (.4-.6, .8, .9), V40-V48(.4-.7, 9), V49 (.4-.6, .8, .9), V50-	231	271	292	374
15-19		619	599	648	820

Cause of Death	ICD-10 Codes	Direct Method[a]	Indirect Methods Using Population-Attributable Fractions[b]		
		Method 1	Method 2	Method 3	Method 4
20-24	V58(.4-.7, .9), V59 (.4-.6, .8, .9), V60-V68(.4-.7, .9), V69 (.4-.6, .8, .9), V70-V78(.4-.7, .9), V79 (.4-.6, .8, .9), V80.3-V80.5, V81.1, V82.1, V83-V86(.0-.3), V87.0-V87.8, V89.2	1,707	1,040	1,126	1,415
25-34		3,000	1,718	1,861	2,337
35-44		2,116	1,283	1,389	1,746
45-54		2,078	1,354	1,466	1,844
55-64		1,726	1,387	1,502	1,886
≥65		1,173	1,832	1,980	2,511
Subtotal		**12,650**	**9,484**	**10,264**	**12,933**
Total Average Annual Alcohol-Attributable Injury Deaths		**48,516**	**34,908**	**37,668**	**47,879**

ICD: International Classification of Diseases

[a] Method 1 is the direct alcohol-attributable fraction (AAF) method, which uses alcohol-attributable fractions based on the proportion of decedents who had a high blood alcohol concentration for each cause of death. For all acute causes of death, except motor vehicle and other road vehicle crashes, the condition-specific alcohol-attributable fractions were based on the proportion of decedents with a blood alcohol concentration ≥0.10% and AAFs were from Alpert et al., 2022 (see references). AAFs for motor vehicle traffic crashes and other road vehicle crashes were from the Fatality Analysis Reporting System, and represented the proportion of crash decedents in which one or more drivers had a BAC ≥0.08%.

[b] In method 2, unadjusted survey data are used to calculate average daily alcohol use and binge drinking status using data from the 2015–2019 Behavioral Risk Factor Surveillance System. In method 3, average alcohol use from the BRFSS was adjusted to account for 73% of per capita consumption based on alcohol sales data. In method 4, average alcohol use data were further adjusted using an updated binge drinking probability based on the change in average consumption from method 3.

[c] For 'alcohol poisoning' and 'suicide by alcohol', the number of alcohol-attributable deaths is identical across all methods because these conditions are fully attributable to alcohol use.

Table 3.

Average annual number of alcohol-attributable non-motor vehicle traffic crash injury deaths by alcohol use level, sex and population-attributable fraction adjustment methodology, United States, 2015–2019

	Alcohol Use Level[a]		
Method[b]	**Low (% of total)**	**Excessive (% of total)**	**Total**
Unadjusted BRFSS survey data (method 2)[b]			
Males	13,019 (62.8)	7,705 (37.2)	20,724
Females	2,675 (56.9)	2,025 (43.1)	4,700
Total	**15,694 (61.7)**	**9,730 (38.3)**	**25,424**
Average consumption adjusted based on per capita sales data (method 3)[b]			
Males	7,721 (34.4)	14,718 (65.6)	22,439
Females	1,617 (32.6)	3,348 (67.4)	4,965
Total	**9,338 (34.1)**	**18,066 (65.9)**	**27,404**
Average consumption and binge drinking adjusted based on per capita sales data (method 4)[b]			
Males	10,200 (36.2)	17,945 (63.8)	28,145
Females	2,101 (30.9)	4,700 (69.1)	6,801
Total	**12,301 (35.2)**	**22,645 (64.8)**	**34,946**

BRFSS: Behavioral Risk Factor Surveillance System

[a] Persons in the low consumption group consumed an average of >0–≤1 drinks daily (females) or >0–≤2 drinks daily (males). Excessive consumption was defined as medium or high consumption; those in the medium consumption group consumed an average of >1–≤2 drinks daily (females) or >2–≤4 drinks daily (males), and those in the high consumption group consumed an average of >2 drinks daily (females) or >4 drinks daily (males). Binge drinking was defined as consuming 5 or more drinks (for males) or 4 or more drinks (for females) during one or more drinking occasions in the past 30 days.

[b] In method 2, unadjusted BRFSS data refers to unadjusted weighted data on average daily alcohol consumption and binge drinking from the 2015–2019 BRFSS. In method 3, average alcohol use from the BRFSS was adjusted to account for 73% of per capita consumption based on alcohol sales data. In method 4, average alcohol use data were further adjusted using an updated binge drinking probability based on the change in average consumption from method 3.