Societal Costs of Underage Drinking*

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ABSTRACT. Objective: Despite minimum-purchase-age laws, young people regularly drink alcohol. This study estimated the magnitude and costs of problems resulting from underage drinking by category—traffic crashes, violence, property crime, suicide, burns, drownings, fetal alcohol syndrome, high-risk sex, poisonings, psychoses, and dependency treatment—and compared those costs with associated alcohol sales. Previous studies did not break out costs of alcohol problems by age. **Method:** For each category of alcohol-related problems, we estimated fatal and nonfatal cases attributable to underage alcohol use. We multiplied alcohol-attributable cases by estimated costs per case to obtain total costs for each problem. **Results:** Underage drinking accounted for at least 16% of alcohol sales in 2001. It led to 3,170 deaths and 2.6 million other harmful events. The estimated $61.9 billion bill (relative SE = 18.5%) included $5.4 billion in medical costs, $14.9 billion in work loss and other resource costs, and $41.6 billion in lost quality of life. Quality-of-life costs, which accounted for 67% of total costs, required challenging indirect measurement. Alcohol-attributable violence and traffic crashes dominated the costs. Leaving aside quality of life, the societal harm of $1 per drink consumed by an underage drinker exceeded the average purchase price of $0.90 or the associated $0.10 in tax revenues. **Conclusions:** Recent attention has focused on problems resulting from youth use of illicit drugs and tobacco. In light of the associated substantial injuries, deaths, and high costs to society, youth drinking behaviors merit the same kind of serious attention. (*J. Stud. Alcohol* **67:** 519-528, 2006)

THIRTY STATES LOWERED THE LEGAL DRINKING age to 18 during the 1970s. In response to evidence of increased traffic fatalities (Wagenaar, 1983; Williams et al., 1974), however, almost all states raised their minimum drinking age between 1978 and 1987. In 1984, federal legislation was enacted that threatened withholding a portion of federal highway funds from states with a minimum drinking age lower than 21. All states eventually complied (Chaloupka et al., 2002). Evidence indicates that the uniform higher drinking age reduced alcohol-related car crashes among young people (General Accounting Office, 1987), as well as deaths from suicide, pedestrian injuries, homicide, and other unintentional injuries (Birckmayer and Hemenway, 1999; Jones et al., 1992; Parker and Rebhun, 1995).

Despite minimum-purchase-age laws, young people continue to have access to alcohol, and many of them drink. In 2001, more than half of high school seniors reported having drunk alcohol in the last 30 days; 36% reported consuming at least five drinks in one session during the month, a frequently used indicator of a heavy drinking day (Grunbaum et al., 2004).

Alcohol use by youth continues to lead to a substantial number of hospitalizations, disabilities, and premature deaths (Chaloupka et al., 2002; Perkins, 2002). Foremost among short-term consequences of alcohol use are motor vehicle crashes, the leading cause of death for teenagers (Centers for Disease Control and Prevention [CDC], 2005). Other acute problems are suicides, rapes, assaults, and unintentional injuries as well as alcohol poisonings, psychoses, dependence, and fetal alcohol syndrome. In addition, youth alcohol use can lead to property crimes and risky sexual behavior (Perkins, 2002).

Little has been known about the magnitude and costs of problems associated with underage drinking. Previous studies of the costs of alcohol use (e.g., Harwood et al., 1998; Manning et al., 1991) did not report costs by age. We estimated the magnitude of the general problem and of specific problems resulting from drinking by those under the legal drinking age of 21 and provided the first peer-reviewed estimate of the resulting costs. We compared those costs with associated alcohol sales to provide a yardstick that helps interpret the size of the problem.

Method

General approach

Although evidence is accumulating that underage drinking initiation increases alcohol-related problems in later life

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(DeWit et al., 2000; Grant and Dawson, 1998; Hingson et al., 2003), we limited costs to alcohol-related problems that can be directly tied to immediate or acute use to develop conservative estimates. We separately examined injuries and acute illnesses associated with underage drinking. For each problem, we first estimated fatal and nonfatal cases involving underage drinking. We then attempted to isolate those alcohol-involved cases actually attributable to or caused by alcohol use, as opposed to other contributing factors. Table 1 summarizes the sources of incidence data and the percentages used for alcohol involvement and attribution. We multiplied the number of alcohol-attributable cases by the costs per case to obtain total costs. The methodology for estimating attributable cases and costs is detailed below for each cause category.

Costs may be direct, indirect, or intangible. Medical costs are direct. In addition, alcohol-involved traffic crashes and crime lead to property loss, the need for emergency and other victim services, and criminal justice expenses. Indirect costs are the work loss from an individual's present and future inability to work as a result of injury or premature death. Intangible costs value the pain, suffering, and lost quality of life. This article places a monetary value on those losses, an increasingly common practice (Cutler and Richardson, 1998; French et al., 1996; Miller and Levy, 2000; Tolley et al., 1994). Because valuing quality-of-life losses is controversial, we also offer a nonmonetary estimate of these losses in quality-adjusted life years (QALYs; Gold et al., 1996).

Our cost estimates adopted a societal viewpoint and a cost framework similar to those of Manning et al. (1991). Unlike Manning et al., however, following several studies (e.g., Miller et al., 1998, 2001), we decomposed the value people place on their health and safety (their willingness to pay to prevent morbidity and mortality) into work-loss and quality-of-life components, which also provides readers with values in a cost-of-illness framework (Harwood et al., 1998) and a QALY framework (Gold et al., 1996).

In this article, medical care includes payments for hospital and physician care, rehabilitation, prescriptions, allied health services, medical devices, insurance-claims-processing costs, and costs associated with emergency medical transport. Costs for alcohol treatment are included only under that category.

Property losses arise in traffic crashes and crimes. They include costs to repair and replace lost or damaged property, as well as to process insurance claims. Public programs involve costs of police, fire, and victim services; criminal justice (adjudication, probation, incarceration, etc.); and foster care.

Lost work places a value on economic losses in the workplace or home due to mortality or impaired functioning (e.g., due to injury). It is measured in terms of the monetary value of lost wages plus the value of lost housework.

TABLE 1. The sources of numbers of cases, percentage alcohol involvement, and percentage alcohol attributable

Cause/disease	Source of numbers of cases	% alcohol-involved	Sources	% alcohol-attributable among cases alcohol-involved	Sources
Motor vehicle crashes	FARS, CDS, NASS[a,b]	Fatal = 24.2% Nonfatal = 8%	Analysis of FARS, CDS, and NASS	BAC ≥ .10: 91.0% .08 ≤ BAC < 1.0: 43.5% .01 ≤ BAC < .08: 24.0%	[c,d,e]
Fatal drownings	U.S. Vital Statistics[f]	30%	[g]	80%	[h]
Nonfatal drownings	NHAMCS[i]	7%	[g]	80%	[h]
Fatal burns	U.S. Vital Statistics[f]	30%	[g]	60%	[h]
Nonfatal burns	NHAMCS[i]	7%	[g]	60%	[h]
Property crime	DOJ[k]	24.4%	[l,m]	50%	[n,o]
Homicide	DOJ[k,p]	41.3%	[l,m]	50%	[n,o]
Sexual assault	DOJ[k,p]	43.4%	[l,m]	50%	[n,o]
Other assault	DOJ[k,p]	37.3%	[l,m]	50%	[n,o]
Suicide	U.S. Vital Statistics;[f] analysis of 19 states' hospital discharge data	9.1%	Analysis of 19 states' hospital discharge data	72%	[h]
FAS	[n,q]	100%		100%	
Risky sex behavior	[r]	20%	[s,t]	50% (of alcohol only) 25% (of alcohol and other drugs)	Assumption by authors
Poisoning and psychosis	U.S. Vital Statistics;[f] NHAMCS[i]	100%		100%	
Alcohol dependence and alcohol abuse	Data Analysis System Treatment Episode Data Set[u]	100%		100%	

Notes: FARS = Fatal Analysis Reporting System; CDS = Crashworthiness Data System; NASS = National Automotive Sampling System; BAC = blood alcohol concentration; NHAMCS = National Hospital Ambulatory Medical Care Survey; DOJ = Department of Justice; FAS = fetal alcohol syndrome. [a]Blincoe et al. (2002); [b]Zaloshnja et al. (2004); [c]Levy and Miller (1995); [d]Miller et al. (1999); [e]Reed (1981); [f]Centers for Disease Control and Prevention (2003); [g]Levy et al. (2004); [h]Miller et al. (2005); [i]McCaig and Ly (2002); [k]Bureau of Justice Statistics (2003); [l]Bureau of Justice Statistics and Federal Bureau of Prisons (2001); [m]Bureau of Justice Statistics (1994); [n]Harwood et al. (1998); [o]Miller et al. (2003); [p]Administration for Children and Families (2003); [q]Cordero et al. (1994); [r]Biglan et al. (2004); [s]Perkins (2002); [t]Cooper (2002); [u]Substance Abuse and Mental Health Services Administration (2003).

We offer nonmonetary and monetary estimates of the pain, suffering, and quality-of-life losses experienced by substance users, their victims, and their families due to illness, injury, and death. Extensive theoretical literature supports the inclusion of these costs (Manning et al., 1991; Miller and Levy, 2000), and the Office of Management and Budget (1989) requires including these costs whenever a regulatory cost-benefit analysis places a dollar value on saving human lives.

For fatalities, the value of pain, suffering, and lost quality of life was computed based on what people actually and routinely pay for small reductions in their chance of dying. An extensive literature containing more than 65 sound studies estimated that the value of a statistical life is at least $3.5 million 2001 U.S. dollars (Miller, 1990, 2000; Viscusi and Aldy, 2003).

The QALY loss to nonfatal injury was valued in four steps (Miller et al., 1995). First, physician ratings of the functional capacity typically lost over time by victims of every injury diagnosis cataloged in a common diagnosis system (Association for the Advancement of Automotive Medicine, 1985) were obtained. The ratings cover six dimensions of functioning: cognitive, mobility, bending/grasping/lifting, sensory, cosmetic, and pain. Second, data were added about the probability of permanent work-related disability by diagnosis. Third, guided by surveys of the general population, the functional capacity losses were converted into estimates of the percentage loss in quality of life, measured on a QALY scale. Fourth, the QALY losses were valued at $113,150 per QALY, computed using a 3% discount rate from the value of statistical life. To avoid double counting, this value and the associated QALY loss estimate excluded work loss.

We converted all costs to 2001 dollars using a health expenditures index for medical costs, a wage index for wage and quality-of-life loss, and the Consumer Price Index for other items. Future costs are stated in present value at the 3% discount rate recommended by the Panel on Cost-Effectiveness in Health and Medicine (Gold et al., 1996).

Traffic crashes

Although the sale of alcohol to minors under 21 is now illegal in all states, almost 20% of traffic crashes with a driver under age 21 involved youth drinking (Miller et al., 1998). Tabulating Fatality Analysis Reporting System census data (National Highway Traffic Safety Administration, 2003) on fatal crashes in 2001 suggested that alcohol-involved underage drivers and nonoccupants accounted for 12.8% of alcohol-impaired driving costs. Substantial evidence indicates that alcohol use increases motor vehicle occupant, pedestrian, and cyclist risk (National Institute on Alcohol Abuse and Alcoholism [NIAAA], 1997; Zador, 1991). An estimated 91% of crashes involving drivers with a .10 blood alcohol concentration (BAC) or higher, 43.5% of crashes involving drivers with a BAC of .08 to .099, and 24% of crashes involving drivers with a BAC level of .01 to .0799 were directly attributable to drinking (Levy and Miller, 1995; Miller et al., 1999; Reed, 1981).

To estimate alcohol-attributable crash costs, fatal and nonfatal injuries in crashes and costs per fatal and nonfatal victim were computed with published methods and data at a 3% discount rate (Blincoe et al., 2002; Zaloshnja et al., 2004). The estimates of injuries and costs were specifically for crashes involving drivers under age 21 with positive BAC levels. The attribution rates (Miller et al., 1999) were based on drivers of all ages. Because youth are more likely than adults to be the cause of a crash when alcohol is involved, these attribution rates are conservative (Zador, 1991).

Unintentional drownings and burns

Alcohol involvement in fatal burns and drownings has been well studied, but the detected rates of involvement vary from 25% to 50% for drownings and 33% to 61% for fatal burns (Hingson and Howland, 1993; Howland and Hingson, 1987, 1988). Alcohol involvement in youth drownings is especially high (Smith and Brenner, 1995).

For drownings and burns among those under age 21, the number of fatal cases was obtained from CDC (2005) U.S. Vital Statistics, and the number of nonfatal cases was obtained from the National Hospital Ambulatory Medical Care Survey (NHAMCS; McCaig and Ly, 2002). Burns were limited to those from fire; scalds were omitted. For drownings and burns, percentages of youth cases that were alcohol-involved (7% for nonfatal and 30% for fatal cases) were taken from a comprehensive Oklahoma surveillance system (Levy et al., 2004).

Among individuals of all ages, an estimated 89% of alcohol-involved drownings (6.2% of all nonfatal and 26.7% of all fatal cases) and 58% of alcohol-involved burns (4.1% of all nonfatal and 17.4% of all fatal cases) were alcohol-attributable (Miller et al., 2003). These attribution estimates were based on the ratio of the injury rate per alcohol-positive hour relative to the injury rate per sober hour. Our attributable fractions are considerably lower than the fractions used by Harwood et al. (1998; 10% for nonfatal injuries, 38% for drownings, and 45% for fire deaths), primarily due to the lower alcohol-involvement rates for youth. The costs of burns and drownings were based on Miller et al. (2000).

Interpersonal violence and property crime

A large percentage of crimes involve youth. Police and Child Protective Services records suggest that perpetrators under age 21 committed 29.7% of murders, 30.8% of rapes,

45.7% of robberies, 27.4% of other assaults, 16% of child abuse cases, 49.7% of burglaries, 45.1% of larcenies, and 51.8% of motor vehicle thefts (Bureau of Justice Statistics, 2003; Miller et al., 2001). Relying on victim reports rather than agency records would yield higher estimates of 36.6% for rape, 41.4% for robbery, and 37.7% for assault (Bureau of Justice Statistics, 2003). We used federally compiled 2001 incidence data (Administration for Children and Families, 2003; Bureau of Justice Statistics, 2003), adjusted for underreporting of sexual assault and child abuse and neglect, and added violence against victims under 12 with published factors (Miller et al., 1996, 2001).

To estimate alcohol involvement in youth crime, we tabulated data on perpetrators under age 21 from the 1997 Survey of Inmates in State and Federal Correctional Facilities (Bureau of Justice Statistics and Federal Bureau of Prisons, 2001) and the 1987 Survey of Youths in Custody (the only national survey of this population; Bureau of Justice Statistics, 1994). These surveys indicated the percentage of youth using alcohol only or both alcohol and other drugs at the time of their crime. Convicted youth in custody reported being under the influence in 41.3% of homicides, 43.4% of sexual assaults, 37.3% of other assaults, and 24.4% of robberies and property crimes. These estimates exclude the 18.2% of homicides, 16.7% of sexual assaults, 16.7% of other assaults, and 22.3% of robberies and other property crimes committed by youth while using heroin or cocaine as well as alcohol. Following Harwood et al. (1998) and Miller et al. (in press), we attributed half of the remaining alcohol-involved crimes to alcohol.

We added published criminal justice costs (Cohen, 1998) to published victim costs computed at a 3% discount rate (Miller et al., 1996, 2001, in press). The criminal justice costs were computed with incidence data from the National Crime Victimization Survey (NCVS; Rand and Rennison, 2002). Like the published victim costs, our crime counts included NCVS crimes, plus additional rapes and domestic assaults and crimes with victims under age 12 that are not reported in the NCVS. To the extent that arrests occurred in non-NCVS crimes, their consequences were included in the criminal justice costs. Therefore, we multiplied the published criminal justice costs per crime by 0.1195 for rape and by 0.724 for assault to obtain average costs per crime that applied to both the NCVS and non-NCVS cases. The cost estimates excluded medical and other costs of the perpetrators of crime.

Suicide

In the year 2000, 2,401 suicide victims were under the age of 21 (CDC, 2005). Hospitalized incidents and their costs were computed from pooled, cause-coded 1997 hospital discharge censuses from 19 states. These states housed 52% of American youth. We assumed that their youth-suicide-act rate matched the U.S. rate, thus estimating 63,000 nonfatal youth attempts in 1997. Estimating incidence with published methods (Miller et al., 2000) would change this estimate by less than 5%. We adjusted estimates of nonfatal incidence in 1997 to 2000 in proportion to the relative numbers of youth-suicide deaths by year. The association between heavy alcohol use, suicide attempts, and completed suicide has been established by numerous studies (Andreasson et al., 1988; English et al., 1995; Birckmayer and Hemenway, 1999). From the 19-state file, which includes toxicology screens for more than 90% of suicide acts, 9.1% of hospital-admitted suicide acts by youth were alcohol-involved. An estimated 72% of these cases were alcohol-attributable (Miller et al., 2003). The unit costs, computed with published methods (Miller et al., 2000), excluded psychological harm from nonfatal attempts.

Fetal alcohol syndrome (FAS) and risky sexual behavior

Prenatal alcohol exposure is known to be toxic to the developing fetus and is one of the leading causes of mental retardation (NIAAA, 1991). The incidence of FAS among the 4 million live births in the United States in 2001 (Hamilton et al., 2003) was calculated, assuming two cases of FAS per 1,000 live births (Harwood et al., 1998) and about 15% of FAS births are to mothers under age 21 (Cordero et al., 1994). The costs of FAS attributable to drinking were computed using Harwood et al.'s (1998) estimate of lifetime FAS costs converted to 2001 dollars. To estimate pain and suffering loss to nonfatal FAS, we applied the lowest ratio of pain and suffering to work loss among the problems where both losses had been estimated. Because of lack of data, this estimate excluded less severe fetal alcohol effects and other non-FAS alcohol-related birth problems.

Alcohol use has been associated with a higher incidence of unprotected sex, especially by the young, leading to a higher incidence of AIDS, other sexually transmitted diseases (STDs), and unwanted pregnancy (Chesson et al., 2003; Cooper, 2002; Hingson et al., 2003; Perkins, 2002; Sen, 2003; Stinson et al., 1992). About 20% of sexual acts by youth involved alcohol (Cooper, 2002; Perkins, 2002). Tabulating Waves 1 and 2 data from the National Adolescent Health (AdHealth) Survey (Billy et al., 1998), alcohol was involved in 10.1% of first sexual encounters and 20.2% of most recent sexual encounters (excluding first sex) between ages 12 and 20. Alcohol-involved participants reported that they were "drunk" during 50.9% of first sex and 51.9% of most recent sex. (More than 99% of sexually active respondents had had intercourse at least twice by Wave 2.) Of the alcohol-involved incidents, 15.2% of first sex and 17.1% of most recent sex also involved drugs. Tabulating 1999 Youth Risk Behavior Survey (YRBS) data (Grunbaum et al., 2004) for youth ages 14-18, we found that 23.6% of most recent sexual acts involved alcohol or

drugs, matching the AdHealth percentage. The involvement rates were 25.4% for sex without a condom and 26.2% for sex using an unreliable birth control method. We treated 20% of high-risk sex as alcohol-involved, and we assumed that 50% of the cases involving only alcohol and 25% of the cases involving alcohol and other drugs would not have occurred absent alcohol (translating to 9.15% of the cost being alcohol-attributable). We applied this percentage to published incidence and cost estimates (at a 3% discount rate) for adolescent high-risk sex (Biglan et al., 2004).

Poisonings and psychoses

Heavy drinking may lead to alcohol poisonings and psychoses. The number of fatal alcohol poisonings and psychoses was obtained from Vital Statistics (CDC, 2005), and the number of nonfatal cases was obtained from NHAMCS (average of 1999-2000) and the Healthcare Cost and Utilization Project, National Inpatient Sample, HCUP/NIS (Agency for Healthcare Research and Quality, 2002). Medical costs were based on payments data from a large third-party payer, the Civilian Health and Medical Program of the Uniformed Services. Work-loss costs came from the diagnosis-specific database underlying Miller et al. (2000) and were computed from information on days lost tabulated from 1987-1993 National Health Interview Survey data (Modi, 2000). Quality-of-life costs for hospitalized cases were computed using regression equations built into the U.S. Consumer Product Safety Commission's Injury Cost Model (Lawrence et al., 2000), then factored down for nonadmitted cases in proportion to the ratio of nonadmitted to admitted medical and work-loss costs. The procedure used for the nonadmitted cases was conservative, yielding values that were less than one fourth of the values that the regression equation would suggest for these low-severity cases.

Alcohol dependence and abuse

In 2000, people in treatment for alcohol problems included 262,000 for alcoholism only and 405,000 for alcohol with secondary drug involvement (Substance Abuse and Mental Health Services Administration [SAMHSA], 2002b); 6.1% of clients with alcoholism only and 12.4% of clients with alcohol and other drug involvement were under age 21 (SAMHSA, 2002b). The cost of treatment for alcohol-dependence syndrome, including detoxification, averaged $17,760 (converted to 2001 dollars; Goodman et al., 1997). Work and quality-of-life losses associated with youth treatment were omitted.

Uncertainty range

To gauge uncertainty surrounding the estimates, we performed a 12,500-iteration Monte Carlo simulation using the Crystal Ball (Decisioneering Inc., Denver, CO) add-in to Microsoft Excel to estimate the uncertainty in the aggregate cost estimate. We input uncertainty ranges for nonfatal incidence, cost per incident, and percentage alcohol-involved. Standard errors for incidence were computed from documentation by data source. For most costs, relative standard errors (RSEs) mirrored the standard errors in quality of life, which is the largest and most uncertain cost component. (RSEs used were 20% for violence from the regressions underlying the estimates and 27% for other outcomes, based on Miller, 1990.) RSEs for costs were set at 10% for property crimes, 30% for FAS and alcohol treatment, and 40% for alcohol poisonings and psychoses. The percentage of incidents that involved alcohol was assumed to have a 20% RSE, with wider ranges of 30% for suicide acts and 50% for risky sex. We assumed normal distributions (truncated at 0 for all inputs and at 1 for fractions alcohol-involved) for all parameters except youth receiving alcohol treatment and the percentages of motor vehicle crashes, nonfatal burns, and near-drownings involving alcohol (entered as skewed triangular distributions because of known data capture issues or ranges across studies). In our uncertainty analysis, following Miller et al. (2003), the percentage of events attributable to alcohol was computed from an odds ratio measured as the percentage of events alcohol-involved (determined probabilistically) divided by the percentage of hours that underage drinkers have alcohol on board (ignoring secondary alcohol metabolism channels). The RSE for underage alcohol consumption (used to compute the odds ratios) was 25%. In computing attribution for crime, we classified no cases involving heroin or cocaine and only half of cases involving alcohol and other drugs as "alcohol-involved."

Alcohol consumption and costs

To calculate consumption by underage drinkers, we multiplied 1999 industry data on consumption (Miller Brewing Company, 2000) by the percentage of alcohol consumed by those under age 21. We started with a 12.9% estimate of underage consumption, computed from consumption quantity and frequency data in the 2001 National Household Survey on Drug Abuse (NHSDA; SAMHSA, 2002a). The NHSDA, however, polled 41% of youth with a family member in the room in 1998 (the last year that this information was reported). Comparisons with data from three youth surveys conducted in private—the 1999 YRBS, the 1999 Monitoring the Future (MTF) Survey (Johnston et al., 2003) (which covers only the past 2 weeks), and the 1997-1998 Health Behaviors of School Children (HBSC) survey (World Health Organization, 2003)—show that it underreports underage drinking. Because only the NHSDA polled a representative sample of people ages 19-20, we accepted its count of underage drinkers in that age range, and we

considered only underreporting for those ages 14-18. To correct it, we computed the percentage of youth by age that drank heavily (at least five drinks in one session) in the past month averaged from the other three surveys, then divided by the NHSDA percentage that drank heavily. The ratio for drinkers ages 14-18 is 1.46, which equates to a 1.308 ratio for drinkers ages 14-20. Multiplying the consumption estimate by this ratio raised the estimated underage consumption to 16.2% (12.9% × 1.308 / [100 + 12.9% × 0.308]). This estimate was conservative, because omitting the MTF from the average would increase the ratio to 1.404 and consumption to 17.2%. Adjusting the NHSDA data on drinkers ages 12 and 13 as well (ages polled only in HBSC and NHSDA) would increase the ratio to 1.411 and consumption to 17.4%, and using the ratio of past-month drinkers ages 14-18 from the 2001 YRBS versus the 2001 NHSDA rather than a heavy drinking ratio would increase the ratio to 1.518 and consumption to 18.4%.

Total alcohol consumption for the year 2000 came from tax revenues (Nephew et al., 2003). Average price per drink came from industry data (Miller Brewing Company, 2000; inflated to 2001 dollars using the Consumer Price Index, All Items). We assumed two drinks per ounce of ethanol.

Results

In a typical month in 2001, an estimated 13.2 million underage drinkers drank alcohol. Of American youth ages 14-20, 47% imbibed. YRBS data indicated that 63% of the underage drinkers drank heavily (Grunbaum et al., 2004). Daily consumption averaged 4.3 drinks for youth who drink compared with 2.9 drinks for adults. Alcohol consumed by underage drinkers in 2001 accounted for at least 16.2% of U.S. alcohol sales. It cost an estimated $18.1 billion, generating $2.0 billion in tax revenues.

Alcohol sales to youth led to an estimated 3,170 deaths and almost 2.6 million injuries and other costly events in 2001. As Table 2 shows, they caused $61.9 billion in harm. With the alternate method of computing attribution used in the uncertainty analysis, aggregate costs averaged $62.4 billion for 12,500 simulated cases, with a standard deviation of $11.75 billion (coefficient of variation = 18.7%). The 95% confidence limit around the costs is $39.2-$85.4 billion. The largest uncertainty factor is attribution to alcohol, followed by uncertainty in the value of lost quality of life.

The $61.9 billion cost included an estimated $5.4 billion in medical spending, $7.8 billion in property losses and other resource costs, $7.1 billion in work losses, and the loss of nearly 368,000 QALYs valued at $41.6 billion. Putting the life-year loss into perspective, the fatal and nonfatal health losses were the equivalent of losing 13,297 young lives, because a life span of 27.7 life years awaits those at age 18 (the present value of 59 years of undiscounted life expectancy). Alcohol-related problems cost an average of $4,680 per underage drinker in 2001, or $2,210 per U.S. resident ages 14-20.

Table 2 also summarizes the estimated costs by problem and cost category. Crime and impaired driving dominated the costs. The $13.7 billion in traffic crash costs included $0.75 billion in medical costs, $2.05 billion in property damage and traffic delay, $3.1 billion in work losses, and $7.8 billion in lost quality of life. The $34.7 billion in violence costs included $1.6 billion in medical costs, $2.7 billion in property losses and criminal justice costs (including prison costs), $2.4 billion in work losses, and $28.0 billion in lost quality of life. The $3.2 billion in property crime

TABLE 2. Incidence and costs of alcohol-attributable youth problems, 2001 (in 2001 dollars)

Problem	Deaths	Injuries and other events	Medical care costs (in millions)	Lost work and other monetary costs (in millions)	Quality-of-life costs (in millions)	Total costs (in millions)	Quality-adjusted life years (QALYs) lost
Drinking driver traffic crashes	1,737	297,700	$745	$5,136	$7,818	$13,699	69,100
Burns	25	7,500	$3	$71	$147	$221	1,300
Drowning	136	300	$4	$206	$361	$571	3,190
Interpersonal violence	1,097	536,700	$1,582	$5,116	$28,049	$34,747	247,890
Property crime	NA	1,176,700	$11	$3,082	$105	$3,198	930
Suicide	157	5,900	$17	$164	$858	$1,039	7,580
Fetal alcohol syndrome	NA	12,100	$463	$168	$295	$926	2,600
High-risk sex	NA	387,300	$691	$807	$3,309	$4,807	29,240
Alcohol poisoning and psychosis	18	99,100	$63	$145	$675	$883	5,970
Treatment for dependence and abuse	NA	70,200	$1,811	NA	NA	$1,811	NA
Totals	3,170	2,593,500	$5,390	$14,895	$41,617	$61,902	367,800

Note: NA = not applicable.

TABLE 3. Costs of alcohol-attributable crimes by youth, 2001 (in millions of 2001 dollars)

Crime	Medical	Work	Public programs	Property damage	Criminal justice	Quality of life	Total
Rape	591.8	320.3	10.4	16.5	457.6	12,762.4	14,159.0
Robbery	25.7	40.4	8.1	37.8	276.3	281.2	669.5
Assault	316.0	430.9	41.9	13.8	1,443.0	4,070.1	6,315.7
Murder	30.0	1,279.4	2.0	0.2	189.4	2,737.5	4,238.6
Abuse and neglect	618.1	343.0	205.3	0.0	0.0	8,197.9	9,364.2
Violent crime	1,581.6	2,414.1	267.7	68.3	2,366.3	28,049.1	34,747.0
Burglary	1.8	3.3	38.4	262.8	523.5	77.2	907.0
Larceny	8.2	7.8	90.0	290.3	1,229.2	0.0	1,625.5
Motor vehicle theft	0.7	4.8	15.3	353.9	262.4	27.9	665.0
Property crime	10.7	15.9	143.7	907.0	2,015.1	105.1	3,197.5

costs largely comprised $2.0 billion in criminal justice costs and $1.0 billion in property losses.

Table 3 elaborates on the crimes and associated costs that resulted from underage drinking. Notable are 500,000 rapes and assaults. The $4.8 billion in costs of high-risk sex include $3.1 billion due to unplanned pregnancies, $1.2 billion due to HIV/AIDS, and $0.5 billion due to other STDs.

Discussion

Although alcohol consumption by those under the age of 21 is illegal, we estimated that 47% of youth ages 14-20 drank and at higher rates than adults. These youth comprised 12.3% of the population ages 14 and over but consumed at least 16.2% of the alcohol. Had we adopted the less conservative consumption adjustments described in the Method section, we instead would have arrived at estimates of 17.2% to 18.4% consumed. Indeed, Foster et al. (2003) arrived at an even higher 19.7% consumption estimate by using our most aggressive adjustment method and also adjusting reported use upward at ages 19-20. The wide uncertainty in estimated consumption is reflected in our use of a 20% RSE for this estimate in our uncertainty analysis, implying that the one standard deviation range is roughly bounded by the unadjusted NHSDA data and the Foster et al. (2003) estimate.

Underage drinking had costly consequences. Estimated losses resulting from the $18.1 billion in alcohol consumed by underage drinkers included 368,000 quality-adjusted life years plus $20.3 billion in medical spending, property damage, work loss, and other resource costs.

Violence accounted for more than half of the costs and of the uncertainty in the cost estimates. Uncertainty around the value placed on quality of life and the percentage of alcohol-involved incidents that are attributable to alcohol were the dominant uncertainties. Despite these uncertainties, the 18.7% RSE around the overall cost estimate was no larger than the RSE around many estimates of intervention effectiveness.

Put into perspective, the total cost to society of underage drinking translates to $3 per illegal drink, of which $1 is for medical spending, property damage, work losses, and other resource costs. These costs to society are far more than the taxes paid per drink, which are an estimated $0.10 of the average purchase price of $0.90 (Miller Brewing Company, 2000).

The United States has begun to curb youth drinking and its harm. Raising the minimum-alcohol-purchase age has been an effective public health policy (Jones et al., 1992). Nevertheless, people under age 21 continue to drink and to develop a range of health and social problems as a consequence. Underage drinking leads to substantial death, injury, medical costs, and work loss from traffic crashes, burns, drownings, crime, suicides, STDs, unplanned pregnancies, FAS, poisonings, psychoses, and treatment for dependence.

Limitations

In examining problems associated with underage drinking, we isolated the role of alcohol in terms of involvement rates specifically for youth. The percentages of alcohol-involved cases that are attributed to alcohol were generally developed for the entire population, rather than specifically for youth. For example, the percentage of alcohol-involved traffic crashes attributed to alcohol by BAC was based on drivers of all ages, but may be conservative for underage drinkers who tend to be less habituated to alcohol and therefore more impaired. Alcohol poisonings are likely to be heavily underreported, because physicians' reports often fail to mention alcohol to avoid family embarrassment (DuFour and Caces, 1993). Alcohol attribution in crime and risky sexual behavior also warrants further research. In particular, the crime estimates excluded cases where victim alcohol use may be a contributing factor.

Our calculations excluded problems for which the relationship with alcohol use is not well established for youth, notably for falls. In addition, "early age of drinking onset has been associated with a greater likelihood among adults

of experiencing alcohol dependence, frequent heavy drinking even among nondependent drinkers, and an increased risk of motor vehicle crashes, unintentional injuries, and physical fights after drinking" and of "college students reporting that they had unplanned or unprotected sexual intercourse because of their drinking" (Hingson et al., 2003, p. 34). Heavy use at early ages also is associated with reduced educational attainment, which affects future wages (NIAAA, 1997). Dependence brings further long-term problems due to chronic use, such as cirrhosis and various cancers (Driver and Swann, 1987; Grant et al., 1988; Robins, 1978). To be conservative, we excluded these long-term consequences from the cost estimates. Alcohol use also may contribute to other problem behaviors such as tobacco use and illicit drug use, but these other substances also may contribute to the problems included in our cost estimates.

It may be desirable to exclude costs directly borne by the drinker on the basis that they result from the substance user's decision to partake. Youth drinking is illegal, however, and the ability of youthful drinkers to make informed decisions is questionable. Furthermore, much of the costs are borne by other parties. Youth drinkers impose costs on others through Medicaid and other public programs, private insurance, noninsured costs to employers, noninsured medical and property loss to other victims, and pain and suffering to other family members and to victims.

Policy implications

Loopholes in the legal drinking laws and lack of enforcement contribute to the problem of underage drinking (Office of the Inspector General, 1991; Wagenaar and Wolfson, 1994). Another approach to reducing underage drinking is to control general access to alcoholic beverages (Carmona and Stewart, 1996). For example, studies have found that higher alcoholic beverage taxes and reductions in the number and location of retail outlets are associated with reduced alcohol consumption, especially among youth (Chaloupka et al., 2002; Gruenewald et al., 1993; Weitzman et al., 2003). Improved enforcement through regular police compliance checks of servers and retailers has been shown to effectively decrease alcohol accessibility to underage youth (Preusser et al., 1994). Aggressively prosecuting fake-identification vendors and improving age-checking technology could further reduce youth access to alcohol.

Studies of school-based or related family interventions have reported reductions in the prevalence of alcohol use for students who received the program (Komro and Toomey, 2002; Spoth et al., 2002; Wu et al., 2003). Programs aimed at the harms of alcohol use, such as zero alcohol tolerance for drivers under age 21 and a .08 legal BAC limit for all drivers, have been effective in preventing alcohol-related crashes and youth fatalities (Hingson et al., 1994; Voas et al., 1999). Brief interventions by doctors have been effective at identifying and curtailing problem drinking among older adolescents (Baer et al., 2001; Monti et al., 1999).

Recent attention has focused on youth problems from illicit drug and tobacco use. In light of the associated substantial injuries, deaths, and high costs to society, youth drinking behaviors merit the same kind of serious attention.

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