ALCOHOLISM CLINICAL & EXPERIMENTAL RESEARCH

Using Death Certificates to Explore Changes in Alcohol-Related Mortality in the United States, 1999 to 2017

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Background: Alcohol consumption, alcohol-related emergency department visits, and hospitalizations have all increased in the last 2 decades, particularly among women and people middle-aged and older. The purpose of this study was to explore data from death certificates to assess whether parallel changes in alcohol-related mortality occurred in the United States in recent years.

Methods: U.S. mortality data from the National Center for Health Statistics were analyzed to estimate the annual number and rate of alcohol-related deaths by age, sex, race, and ethnicity between 1999 and 2017 among people aged 16+. Mortality data contained details from all death certificates filed nationally. For each death, an underlying cause and up to 20 multiple or contributing causes were indicated. Deaths were identified as alcohol-related if an alcohol-induced cause was listed as either an underlying or multiple cause. Joinpoint analyses were performed to assess temporal trends.

Results: The number of alcohol-related deaths per year among people aged 16+ doubled from 35,914 to 72,558, and the rate increased 50.9% from 16.9 to 25.5 per 100,000. Nearly 1 million alcohol-related deaths (944,880) were recorded between 1999 and 2017. In 2017, 2.6% of roughly 2.8 million deaths in the United States involved alcohol. Nearly half of alcohol-related deaths resulted from liver disease (30.7%; 22,245) or overdoses on alcohol alone or with other drugs (17.9%; 12,954). Rates of alcohol-related deaths were highest among males, people in age-groups spanning 45 to 74 years, and among non-Hispanic (NH) American Indians or Alaska Natives. Rates increased for all age-groups except 16 to 20 and 75+ and for all racial and ethnic groups except for initial decreases among Hispanic males and NH Blacks followed by increases. The largest annual increase occurred among NH White females. Rates of acute alcohol-related deaths increased more for people aged 55 to 64, but rates of chronic alcohol-related deaths, which accounted for the majority of alcohol-related deaths, increased more for younger adults aged 25 to 34.

Conclusions: Death certificates suggest that alcohol-related mortality increased in the United States between 1999 and 2017. Given previous reports that death certificates often fail to indicate the contribution of alcohol, the scope of alcohol-related mortality in the United States is likely higher than suggested from death certificates alone. Findings confirm an increasing burden of alcohol on public health and support the need for improving surveillance of alcohol-involved mortality.

Key Words: Alcohol, Death, Mortality, Cause of Death, Trend.

IN THE UNITED States, 70.1% of the population aged 18 and older (about 173.3 million people) consumed alcohol in 2017, averaging approximately 3.6 gallons of pure alcohol per drinker, or about 2.1 standard U.S. drinks per day (Center for Behavioral Health Statistics and Quality, 2018; Slater and Alpert, 2019). Per capita consumption increased roughly 8% since the beginning of the new millennium (Martinez et al., 2019; Slater and Alpert, 2019). A meta-analysis of 6 national surveys suggests that between 2000 and 2016, the prevalence of alcohol use among people aged 18 and older in the United States increased roughly 4.4%, while binge drinking increased approximately 7.7% (Grucza et al., 2018). Trends in alcohol consumption were different for men than for women. While the overall prevalence of drinking and binge drinking did not change for men, there was a 10.1% increase in the prevalence of drinking and a 23.3% increase in binge drinking among women. Increases in consumption were larger for people aged 50 and older relative to younger age-groups.

Along with recent increases in alcohol consumption in the United States, there have been significant increases in alcohol-related harms. Between 2006 and 2014, rates of emergency department (ED) visits involving alcohol increased 47.3% among persons aged 12+ (from 1,223 to 1,803 per 100,000 population) and the number of such visits increased 61.6% (from 3,080,214 to 4,976,136; White et al., 2018). Similarly, from 2000 to 2015, rates of hospitalizations related to alcohol consumption increased 51.4% among persons aged 12+ (from 62.5 to 94.6 per 100,000 population) and the number of such visits increased 76.3% (from 1,461,700 to 2,576,600; Chen and Yoon, 2018). Increases in alcohol-

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related ED visits and hospitalizations were larger for females than for males and greater in older relative to younger age-groups (Chen and Yoon, 2018; White et al., 2018).

Evidence suggests that deaths related to alcohol consumption are increasing, as well. Between 2000 and 2015, the rate of deaths from alcohol-related liver cirrhosis in the United States increased 34.9% (from 4.3 to 5.8 per 100,000 population), with the number of deaths growing 73.7% (from 12,109 to 21,028; Yoon and Chen, 2018). The full magnitude of alcohol-related mortality in the United States is difficult to determine, in part because the contribution of alcohol is not always apparent at the time that a death certificate is completed. The Centers for Disease Control and Prevention (CDC) estimated the number of alcohol-related deaths between 2006 and 2010 using a combination of data obtained from death certificates and the use of alcohol-attributable fractions (AAFs), which specify the proportion of deaths from various causes that, based on previous research, likely involved alcohol. For instance, the AAFs used by the CDC indicate that alcohol likely contributes to 84% of deaths each year due to chronic pancreatitis, 34% of deaths from drownings, and 32% of deaths from falls. Using this approach, the CDC (2013) calculated that excessive alcohol consumption contributed to an average of 88,129 deaths per year between 2006 and 2010, with 49,544 deaths resulting from acute causes (e.g., car crashes, falls, and drownings) and 38,584 resulting from chronic causes (e.g., liver disease, heart conditions, and cancers). Most AAFs were derived from research published prior to the year 2000 and have not been updated to reflect current alcohol consumption data and new knowledge about the contribution of alcohol to deaths from various injuries and disease states.

Using their own strategy for generating AAFs and estimating the contribution of alcohol to mortality in the United States, the World Health Organization (WHO) Global Burden of Disease Study arrived at an estimate of 60,000 alcohol-related deaths in 2007 (range 32,000 to 89,000), increasing to 81,000 deaths in 2017 (range 39,000 to 129,000; GBD 2017 Risk Factor Collaborators, 2018). While the CDC and WHO calculations provide gross estimates of the scope of alcohol-related mortality, a deeper exploration of changes over time between males and females and by age-groups, race, and ethnicity would be helpful for understanding the public health burden of alcohol in the United States.

Death certificates have long been the primary source of data for tracking U.S. mortality (e.g., National Center for Health Statistics [NCHS], 2018a; Xu et al., 2018). Each record contains demographic information and cause-of-death information certified by a physician, coroner, or medical examiner. The cause-of-death information represents the medicolegal opinions on "the chain of events—diseases, injuries, or complications—that directly caused the death" and "other significant conditions contributing to death" (NCHS, 2004a, 2004b). For each state, vital statistics jurisdictions, and the NCHS, process and code the cause-of-death information in accordance with WHO regulations, the International Classification of Diseases (tenth Revision, ICD-10, since 1999), and selection rules and modifications (Xu et al., 2018). Each death certificate lists a single code indicating an underlying cause of death and up to 20 additional codes indicating multiple causes. Alcohol can directly cause death, in which case an alcohol-induced cause is listed as the underlying cause in a death certificate, or it can contribute to a death as part of a chain of events, in which case an alcohol-induced cause is listed as a multiple, or contributing, cause. Research suggests that death certificates often fail to capture the contribution of alcohol. For instance, only about 1 in 6 drunk driving fatalities are reported as alcohol-related on death certificates (Castle et al., 2014). As such, death certificates alone underestimate the full scope of alcohol-related mortality, but they remain the primary data source available for exploring temporal trends within demographic subgroups.

The present study uses data from death certificates to examine trends in alcohol-related deaths in the United States between 1999 and 2017. We include all deaths involving alcohol as an underlying or contributing cause and examine trends by race and ethnicity, age-group, and sex. Given evidence of increases in alcohol consumption and alcohol-related harms in recent years, and larger increases in these outcomes for women and older drinkers, we anticipate that alcohol-related deaths have increased in the United States and that the increases were larger in these groups.

MATERIALS AND METHODS

We obtained U.S. mortality data from the NCHS (Mortality Multiple Cause Files, 2018). Data include all death certificates filed in the 50 states and the District of Columbia. To be consistent with U.S. mortality statistics (Xu et al., 2018), our analysis excluded deaths of non-U.S. residents.

A death was identified as alcohol-related if an alcohol-induced cause was listed as the underlying cause and/or as a multiple cause of death. We grouped the ICD-10 codes for alcohol-related deaths according to the latency period into acute and chronic causes (Table 1). All acute cause deaths (e.g., alcohol poisoning) involved acute alcohol consumption. However, chronic cause deaths (e.g., alcoholic liver disease) could be associated with chronic alcohol consumption with or without acute alcohol consumption. A death was assigned to both groups when both acute and chronic alcohol-related causes were reported on a death certificate, but the death would be counted once toward overall alcohol-related deaths. Our analysis focused on alcohol-related deaths at ages 16 years and older because few alcohol-related deaths occurred under the age of 16.

Two key measures of mortality are reported: number of deaths and death rate (age-specific and age-adjusted). An age-specific death rate was expressed as the number of deaths for a specific age-group in each calendar year per 100,000 estimated population of that age-group. Population estimates were obtained from the NCHS's Bridged-Race Population online database through the CDC and Prevention's Wide-ranging Online Data for Epidemiologic Research (CDC WONDER). Age-adjusted death rates for ages 16 years and older are weighted averages of the age-specific death rates, where the weights were based on the 2000 U.S. Standard Population using 7 age-groups (16 to 24, 25 to 34, 35 to 44, 45 to 54, 55 to 64, 65 to 74, and 75+). Numbers and rates are presented for the

Table 1. ICD-10 Codes for Alcohol-Induced Causes

Grouping	ICD-10	Term
Acute causes	F10.0[a]	Mental and behavioral disorders due to use of alcohol, acute intoxication
	R78.0	Finding of alcohol in blood
	T51.0[b]	Toxic effects of ethanol
	T51.9[b]	Toxic effects of alcohol, unspecified
	X45	Accidental poisoning by and exposure to alcohol
	X65	Intentional self-poisoning by and exposure to alcohol
	Y15	Poisoning by and exposure to alcohol, undetermined intent
Chronic causes	E24.4	Alcohol-induced pseudo-Cushing's syndrome
	F10.1	Mental and behavioral disorders due to use of alcohol, harmful use
	F10.2	Dependence syndrome
	F10.3	Withdrawal state
	F10.4	Withdrawal state with delirium
	F10.5	Psychotic disorder
	F10.6	Amnesic syndrome
	F10.7	Residual and late-onset psychotic disorder
	F10.8	Other mental and behavioral disorders
	F10.9	Unspecified mental and behavioral disorder
	G31.2	Degeneration of nervous system due to alcohol
	G62.1	Alcoholic polyneuropathy
	G72.1	Alcoholic myopathy
	I42.6	Alcoholic cardiomyopathy
	K29.2	Alcoholic gastritis
	K70.0	Alcoholic fatty liver
	K70.1	Alcoholic hepatitis
	K70.2	Alcoholic fibrosis and sclerosis of liver
	K70.3	Alcoholic cirrhosis of liver
	K70.4	Alcoholic hepatic failure
	K70.9	Alcoholic liver disease, unspecified
	K85.2	Alcohol-induced acute pancreatitis
	K86.0	Alcohol-induced chronic pancreatitis

[a]The code was valid and used in 1999 to 2006.
[b]The codes were used for multiple cause of death only.

population aged 16 and older and by sex, age-group (16 to 20, 21 to 24, 25 to 34, 35 to 44, 45 to 54, 55 to 64, 65 to 74, and 75+), and race/ethnicity (non-Hispanic [NH] White, NH Black, NH American Indian or Alaska Native [AIAN], NH Asian or Pacific Islander [API], and Hispanic). Deaths with missing information on race or ethnicity (about 0.3% on average) were excluded from analyses when stratified by race/ethnicity. Standard errors of death rates were calculated to reflect random variations based on the assumption that death counts have Poisson distributions (Xu et al., 2018). Rates are considered unreliable if they are based on fewer than 20 deaths, and a period is shown in place of rates.

We used the National Cancer Institute Joinpoint Trend Analysis Software (Desktop version 4.6.0.0; https://surveillance.cancer.gov/joinpoint/) to examine temporal trends and identify an apparent change (i.e., inflection point, aka joinpoint) in trends in age-specific and age-adjusted death rates from 1999 to 2017. The software used the grid search method and permutation tests to fit the simplest model of joined line segments to the natural log of rates, weighted by the square of the rate divided by the square of the standard error at each year. We set the grid search method to allow for a minimum of 4 data points between 2 joinpoints as well as from a joinpoint to either end of the data, and to allow for a maximum of 2 joinpoints and 3 line segments. The significance level was set at 0.05 for all 2-sided tests. The slope of each line segment was used to estimate an annual percent change (APC) in rates. In the presence of multiple line segments, a summary measure, average APC (AAPC), was calculated as the average of the APCs over the whole period weighted by the length of the APC interval. In the case of single line segments, AAPC was identical to APC. Death rates were considered to increase over a specific time period if the APC > 0 and p-value < 0.05, to decrease if the APC < 0 and p-value < 0.05, and to have no significant change if p-value > 0.05. Observed differences in AAPCs between females and males noted in the results below were based on nonoverlapping 95% confidence intervals. Trend analysis was not conducted if 1 or more of the annual death rates were unreliable.

To further understand which disease or injury led directly to alcohol-related deaths and whether it changed over time, we compared the distributions of underlying causes of alcohol-related deaths from 1999 and 2017. Underlying causes of deaths were divided into 15 categories: alcohol overdose; mental and behavioral disorders due to alcohol use; alcoholic liver diseases; other alcohol-induced causes; drug overdose; other drug-induced causes; motor vehicle traffic injuries; other unintentional injuries; intentional self-harm (suicide); assault (homicide) and other injuries; diseases of heart; other chronic hepatitis, liver fibrosis, and cirrhosis; malignant neoplasms; chronic lower respiratory diseases; and others. ICD-10 codes for each category are provided in Table S1.

In addition to the Joinpoint Trend Analysis Software, we used SAS 9.4 (TS Level 1M3) for data processing, analysis, and visualization.

RESULTS

The total number of alcohol-related deaths for ages 16+ doubled from 35,914 in 1999 to 72,558 in 2017 (Table S2). Correspondingly, the overall age-adjusted death rates increased 50.9% from 16.9 to 25.5 per 100,000 (Table S3). Alcohol-related deaths accounted for 1.5% of roughly 2.4 million deaths among all decedents 16+ in 1999 and 2.6% of 2.8 million deaths in 2017. Nearly 1 million (944,880) alcohol-related deaths were recorded across the study period.

Males accounted for the majority (76.4%) of alcohol-related deaths over the years (721,587 deaths for males; 223,293 deaths for females). However, a greater increase was observed for females (135.8% in numbers and 85.3% in age-adjusted rates) than for males (92.9% in numbers and 38.7% in rates). The rate of increase in death rates accelerated around 2010 for females (APCs: 2.1% per year during 1999 to 2010 and 5.2% per year during 2010 to 2017) and around 2011 for males (APCs: 0.7% per year during 1999 to 2011 and 4.2% per year during 2011 to 2017; Fig. 1*A* and Table S4). The larger increase for females caused the ratio of the number of male/female alcohol-related deaths to decrease from 3.7:1 in 1999 to 3.0:1 in 2017, and the ratio of the rate of male/female deaths to decrease from 4.2:1 in 1999 to 3.1:1 in 2017.

Among females, the age-specific rate of alcohol-related deaths in 1999 was highest for ages 65 to 74 followed by ages 55 to 64, but in 2017, the rate was highest for ages 55 to 64 followed by ages 45 to 54 (Table S3). Death rates increased across all age-groups except for ages 16 to 20 and 75+ (Fig. 1*A* and Table S4). Acceleration in rate increases was observed for ages 55 to 64. On average, the largest annual increase from 1999 to 2017 was in ages 25 to 34 (AAPC: 5.9%; Fig. 3 and Table S4).

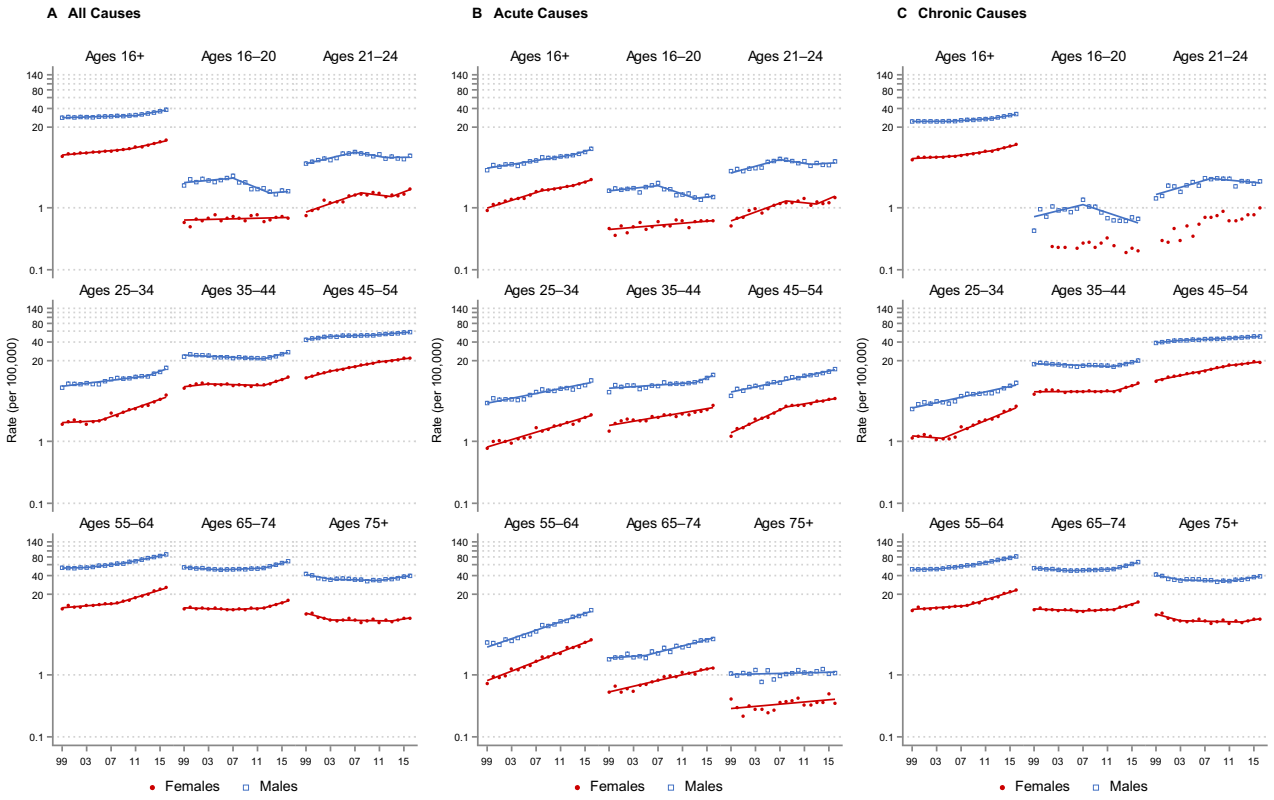

Fig. 1. Age-adjusted (for ages 16+) and age-specific death rates by sex for (**A**) all alcohol-induced causes, (**B**) acute causes, and (**C**) chronic causes, fitted with joinpoint log-linear regression: United States, 1999 to 2017. Rate is shown on a natural log scale to depict a relative change over time (i.e., APC). Trend analysis was not conducted for (**C**) females aged 16 to 20 and 21 to 24 because 1 or more death rates were unreliable. See Table S3 for rates and Table S4 for estimates of APC for each segment and AAPC.

Among males, the age-specific rate of alcohol-related deaths in 1999 was highest for ages 65 to 74 followed by ages 55 to 64, but in 2017, the rate was highest for ages 55 to 64 followed by ages 65 to 74 (Table S3). Acceleration in rate increases was observed for ages 25 to 34 and 55 to 64 (Fig. 1*A* and Table S4). Death rates declined for a period of time and then increased for ages 35 to 44, 65 to 74, and 75+. There was no overall change for males 16 to 20, but there was a significant decline by 8.8% per year between 2007 and 2013 followed by a plateau. The largest annual increase was in ages 25 to 34 (AAPC: 4.1%; Fig. 3 and Table S4).

Across racial and ethnic groups, NH AIAN had the highest alcohol-related death rates (females: 63.4 and males: 141.2 per 100,000 in 2017) and NH API had the lowest (females: 1.7 and males: 9.7 per 100,000 in 2017; Fig. 2*A* and Table S3). A steady increase over time was seen in NH AIAN females and NH API (Table S4). Rates increased and accelerated for NH Whites and NH AIAN males. Rates for Hispanic females were stable from 1999 to 2011 and then increased from 2011 to 2017. Rates declined for a period of time and then increased from 2012/2013 to 2017 for Hispanic males and NH Blacks. On average, the largest annual increase from 1999 to 2017 was in NH White females (AAPC: 4.4%), among whom rates increased across all age-groups.

Chronic causes were reported for the majority of alcohol-related deaths (86.5%, 31,075 of 35,914 in 1999; and 86.3%, 62,636 of 72,558 in 2017), so the trend patterns for rates of chronic cause deaths were generally similar to the trend patterns in rates of all alcohol-related deaths (Figs 1 and 2). As with all alcohol-related deaths, the largest increase in chronic cause deaths occurred in the age-group 25 to 34 (female AAPC: 6.5% and male AAPC: 5.1%; Fig. 3; Table S4).

Acute causes were listed in 14.6% of all alcohol-related deaths (5,258 of 35,914) in 1999 and 21.5% (15,596 of 72,558) in 2017. For age-groups 16 to 20 and 21 to 24, acute causes accounted for 88.2 and 82.8%, respectively, in 2017 (Fig. 1; Table S2). Rates increased over time for nearly all demographic subgroups except for males aged 16 to 20 and 75+ (Figs 1–3; Table S4). It is worth noting a sharp increase in acute cause death rates among NH Blacks in recent years (female APC: 15.1% during 2012 to 2017, and male APC: 13.9% during 2011 to 2017; Fig. 2*B*; Table S4). The largest annual increase in deaths related to acute causes was in ages 55 to 64 (female AAPC: 9.2% and male AAPC: 8.2%; Fig. 3; Table S4).

In 2017, nearly half of alcohol-related deaths resulted from liver disease (30.7%; 22,245) or overdoses on alcohol alone or with other drugs (17.9%; 12,954) (Table 2). Differences

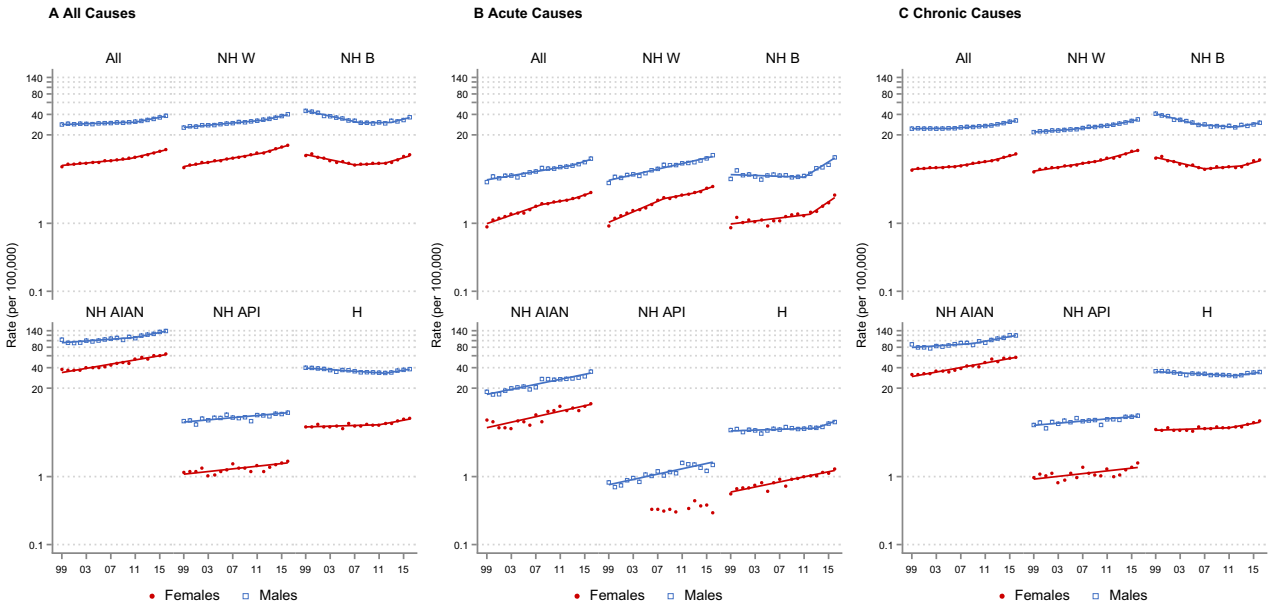

Fig. 2. Age-adjusted death rates by sex and race/ethnicity for (**A**) all alcohol-induced causes, (**B**) acute causes, and (**C**) chronic causes, fitted with joinpoint log-linear regression: United States, 1999 to 2017. Rate is shown on a natural log scale to depict a relative change over time (i.e., APC). Trend analysis was not conducted for (**B**) NH API because 8 death rates were unreliable. See Table S3 for rates and Table S4 for estimates of APC for each segment and AAPC. AIAN, American Indians or Alaska Natives; API, Asians or Pacific Islanders; B, Blacks; H, Hispanics; NH, non-Hispanic; W, Whites.

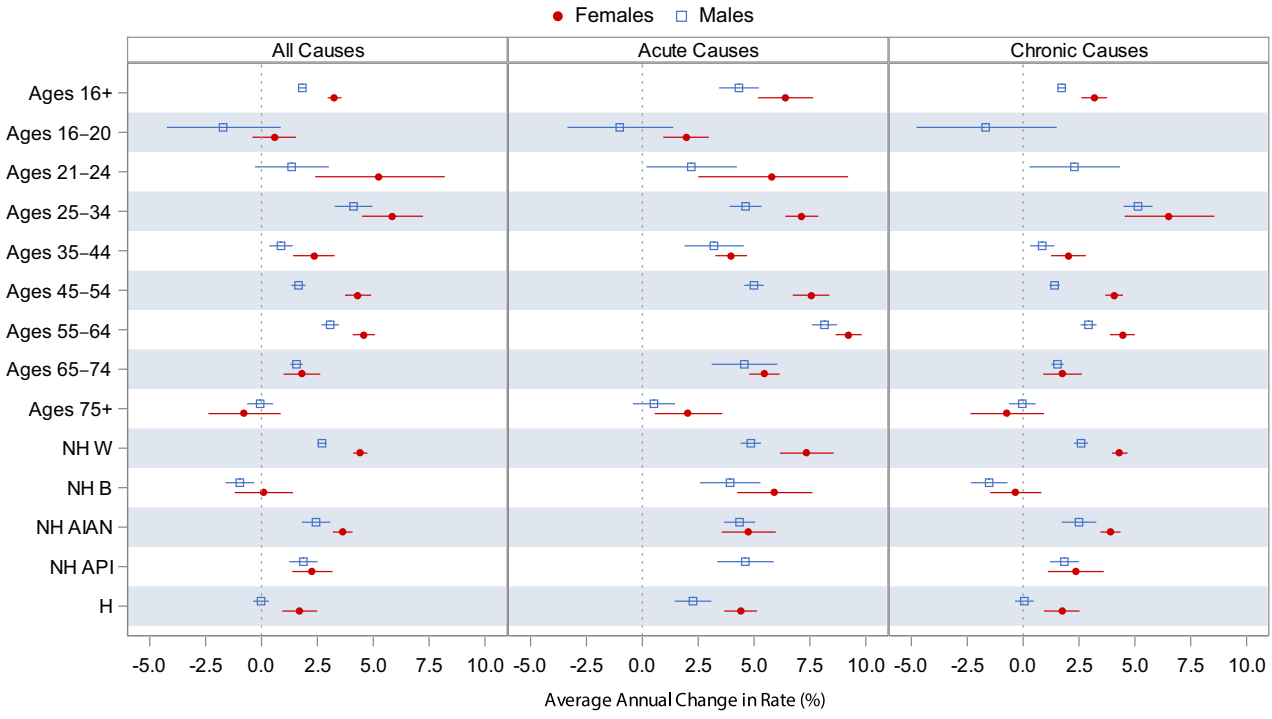

Fig. 3. Estimated AAPC in age-adjusted or age-specific death rates by sex and age-group or race/ethnicity for (**A**) all alcohol-induced causes, (**B**) acute causes, and (**C**) chronic causes: United States, 1999 to 2017. **Error bars** represent 95% confidence intervals. Trend analysis was not conducted for acute causes in female NH API and for chronic causes in females aged 16 to 20 and 21 to 24 because 1 or more death rates were unreliable in these subgroups. See Table S4 for estimates.

over time in the distribution of underlying causes of alcohol-related deaths between 1999 and 2017 were mainly driven by a large increase in the proportion of such deaths involving drug overdoses (4.3 to 14.6%) and a decline in the proportion involving motor vehicle traffic injuries (3.7 to 1.7%; Tables 2 and S5).

DISCUSSION

The number of death certificates indicating alcohol involvement in mortality in the United States doubled between 1999 and 2017, and the rate increased by roughly half. More males than females died of alcohol-related causes each year, but the increase over time was larger for women than for men. This is consistent with recent reports of larger increases in the prevalence of alcohol consumption, binge drinking, ED visits, and hospitalizations for women (Chen and Yoon, 2018; Grucza et al., 2018; White et al., 2018). Increases in alcohol use and related harms among women are concerning given growing evidence that women are at greater risk than men at comparable levels of alcohol exposure for alcohol-related cardiovascular diseases, certain cancers, alcohol-related liver disease, and acute liver failure due to excessive drinking (Guy and Peters, 2013; Nolen-Hoeksema, 2004; Szabo, 2018). Because women reach higher blood alcohol levels than men of comparable weights after consuming the same amount of alcohol, their body tissues are exposed to more alcohol and acetaldehyde, a toxic metabolite of alcohol, after each drink (Gochfeld, 2017).

Recent studies suggest that alcohol use is increasing more among middle-aged and older adults than among younger drinkers. Results of a meta-analysis of 6 national surveys suggest that the biggest increases in the prevalence of alcohol use and binge drinking between 2000 and 2016 occurred among people 50+ (Grucza et al., 2018). Alcohol-related ED visits increased more for adults aged 55 to 64 than those in other age-groups between 2006 and 2014 (White et al., 2018). Similarly, increases in alcohol-related hospitalizations between 2000 and 2015 were larger for people aged 45 to 64 and 65+ (Chen and Yoon, 2018). Larger increases in excessive alcohol consumption and alcohol-related medical events among middle-aged and older adults led us to expect that increases in alcohol-related mortality might be larger in these groups, as well. This was the case for deaths related to acute consumption, but deaths related to chronic consumption, which accounted for the majority of alcohol-related deaths each year, increased more for younger adults aged 25-34. While not anticipated, a faster increase in deaths in the younger age-group is consistent with a previous report suggesting that cirrhosis deaths increased faster for people aged 25-34 than for other age-groups between 2000 and 2015 (Yoon and Chen, 2018). Despite the faster increase in alcohol-related deaths among younger adults, it should be noted that overall rates of alcohol-related deaths remain more than 4 times higher among middle-aged and older adults aged 45 to 74 than among those aged 25 to 34.

The consistently high rates of alcohol-related deaths among middle-aged and older drinkers are concerning given the increasing size of the aging population. The number of people aged 65 and older in the United States is expected to nearly double from 51 million in 2017 to 95 million by 2060. By 2034, there will be more people in the United States over the age of 65 than under 65 for the first time (U.S. Census Bureau, 2018). Even if rates of alcohol consumption and alcohol-related harms stay the same, the number of alcohol-related healthcare visits and fatalities could increase substantially, thereby increasing the overall burden of alcohol on public health. Despite the fact that the majority of adults aged 50 and older see a healthcare provider at least once each year (NCHS, 2018b), few are asked about their alcohol use. Only about 1 in 4 people aged 50 to 64 and 1 in 5 people aged 65 and older report being asked how often or how much they drink (SAMHSA, 2019). Discussions with patients about alcohol are important given that roughly 4 of 5 drinkers aged 65 and older are prescribed medications that could interact negatively with alcohol (Breslow et al., 2017; Holton et al., 2017). An increase in rates of ED visits for alcohol-medication interactions was observed among women aged 55 and older between 2005 and 2011 (Castle et al., 2016).

Falls are the leading cause of injuries among adults aged 65+ (Burns and Kakara, 2018). Alcohol impairs balance on its own (Wu et al., 2017) and is a known risk factor for fatal and nonfatal fall injuries (Chen and Yoon, 2017; Hingson and Howland, 1987). Alcohol also exacerbates the impairments in balance and coordination caused by sedative-hypnotics and other medications (de Jong et al., 2013; van Steveninck et al., 1996). Because alcohol impairs balance and coordination more in older than younger drinkers, alcohol either alone or in combination with other substances could contribute to falls at lower doses as people age (Vogel-Sprott and Barrett, 1984). The CDC estimates that alcohol contributes to 32% of all fatalities from falls in the United States (CDC, 2013). According to death certificates, there were 31,190 fatalities from falls among people aged 65 and older in 2017. Only 566, or about 1.8%, list alcohol as a contributing factor (CDC, 2018). It certainly appears that death certificates do not capture the full extent of the contribution of alcohol to fatalities from falls.

Table 2. Underlying Cause of Alcohol-Related Deaths (Ages 16+): United States, 1999 and 2017

	1999		2017	
Underlying cause	Number	%	Number	%
Total	35,914	100.0	72,558	100.0
Alcohol overdose	929	2.6	2,358	3.2
Alcohol mental and behavioral disorders	5,560	15.5	10,060	13.9
Alcoholic liver diseases	11,947	33.3	22,245	30.7
Other alcohol-induced causes	989	2.8	1,149	1.6
Drug overdose	1,557	4.3	10,596	14.6
Other drug-induced causes	209	0.6	162	0.2
Motor vehicle traffic injuries	1,335	3.7	1,238	1.7
Other unintentional injuries	1,707	4.8	3,149	4.3
Intentional self-harm (suicide)	589	1.6	1,026	1.4
Assault (homicide) and other injuries	268	0.7	315	0.4
Diseases of heart	3,864	10.8	8,027	11.1
Other chronic hepatitis and liver fibrosis and cirrhosis	78	0.2	35	0.0
Malignant neoplasms	1,659	4.6	3,117	4.3
Chronic lower respiratory diseases	837	2.3	1,552	2.1
Others	4,386	12.2	7,529	10.4

Nearly 9 of 10 alcohol-related deaths among people aged 16 to 20 involved acute alcohol consumption. The rate of such deaths increased for females across the study period but did not change significantly for males. A narrowing gender gap in alcohol-related deaths in this age-group is consistent with narrowing gaps in alcohol use among adolescent males and females. For instance, in 1999, 55.3% of males and 46.8% of females in twelfth grade consumed alcohol each month. The prevalence decreased to 34.1% for males and 32.3% for females in 2017, a bigger decline for males. Similarly, self-reported past-month drunkenness among twelfth graders declined more for males (from 37.9 to 20.4%) than females (27.7 to 18.1%) during that time period (Johnston et al., 2019). Reasons for an increase in acute alcohol-related deaths among 16- to 20-year-old females at a time when alcohol use is declining in this group are unclear. However, because the number of deaths each year is quite small compared to the number of people in this age range who consume alcohol, it is easy to imagine how there could be a disconnect in the trends. There were 59 acute alcohol-related deaths in 2017 for females and 172 for males. Roughly 4.1 million people aged 16 to 20 engaged in binge drinking (4+ drinks for females, 5+ drinks for males) in a typical month that year (CBHSQ, 2018). The increase in deaths would not require a population-level shift in drinking patterns.

Alcohol-related deaths increased among NH Whites aged 25 and older, and the rate of increase accelerated toward the end of the study period. An increase in alcohol-related mortality is consistent with a general increase in mortality among NH Whites aged 25 to 64 during a similar time period (Woolf et al., 2018). As with alcohol-related deaths, total mortality among NH Whites increased more for women than for men, leading to a narrowing gender gap in life expectancy (Elo et al., 2019). Increased mortality among NH Whites in midlife has been attributed in part to drug overdoses, alcohol-related liver disease, and suicides (Case and Deaton, 2015; Ma et al., 2015; Woolf et al., 2018). Case and Deaton (2015) referred to these deaths as "deaths of despair" because they appear to be related to declining quality of life, including reduced physical and mental health, increases in chronic pain, financial difficulties, and serious mental illness. Alcohol plays a prominent role in deaths of despair, contributing to an estimated 15% of all drug overdoses (Warner et al., 2016), 26% of suicides (Ertl et al., 2019), and 50% of deaths from liver diseases (Yoon and Chen, 2018). Deaths of despair are particularly prominent among NH Whites aged 45-54 with less than a high school education who live in geographic areas hit by economic decline (Case and Deaton, 2017; Shanahan et al., 2019). However, recent reports suggest that measures of despair (e.g., depressive symptoms and suicidal ideation) and deaths due to a wide variety of causes, including those related to despair, are increasing among people in midlife across racial and ethnic groups (Gaydosh et al., 2019; Woolf et al., 2018).

In contrast to overall increases in alcohol-related mortality for NH White males and females, there were initial declines in alcohol-related mortality early in the study period followed by increases for NH Black males and females and Hispanic males. This is consistent with changes in all-cause mortality among NH Blacks and Hispanics, which decreased from 1999 to 2009 before leveling off around 2010 to 2011 and then increasing (Woolf et al., 2018). The trends also are consistent with declines in cirrhosis deaths among NH Black men and women between 1999 and 2008 and Hispanic men and women between 1999 and 2007 followed by increases (Tapper and Parikh, 2018). Drug overdoses, which played a prominent role in the increased mortality among NH Whites between 1999 and 2017, only recently began to increase for Hispanics and NH Blacks (Alexander et al., 2018; Woolf et al., 2018). Evidence suggests that alcohol consumption and binge drinking are increasing more among NH Blacks and Hispanics than among NH Whites (Grucza et al., 2018). Whether these increases in consumption will contribute to a further escalation in alcohol-related deaths in these groups is unknown.

In 2017, death certificates captured 10,596 deaths due to overdoses on a combination of alcohol and other drugs and another 2,358 deaths from overdoses on alcohol alone. Alcohol causes respiratory depression on its own, and the risk of acute respiratory failure increases when alcohol is combined with other drugs that suppress respiration, such as opioids and benzodiazepines (Kircher et al., 1985; Krumpe et al., 1984; Ren et al., 2012). Alcohol plays a prominent role in overdoses on other drugs, contributing to roughly 21% of deaths involving heroin, 17% of deaths involving hydrocodone, and 22% of deaths involving diazepam (Warner et al., 2016). A recent study highlights the dangers of combining alcohol with opioids. A dose of 20 mg of oxycodone given to healthy subjects reduced ventilation by 28%. Giving subjects enough alcohol IV to produce a BAC of 0.10% reduced ventilation by another 19% and caused an increase in apneic events. A synergistic effect between opioids and alcohol on ventilation was especially pronounced in a group of older subjects aged 66 to 77 compared to subjects aged 21 to 28 (van der Schrier et al., 2017). The fact that a moderately intoxicating dose of alcohol significantly increased the respiratory depression produced by a medicinal dose of oxycodone suggests that any alcohol consumption could contribute to fatal overdoses involving opioids. The CDC recently created the State Unintentional Drug Overdose Reporting System to provide comprehensive data on fatal drug overdoses and associated risk factors (O'Donnell et al., 2017). This surveillance system should greatly advance our understanding of the role of alcohol in fatal drug overdoses by collecting data on decedents' BACs from toxicology reports and information on the concurrent use of alcohol and drugs from death scene investigations.

Limitations

For the present study, we utilized data contained in death certificates to examine trends in alcohol-related mortality.

While physicians, medical examiners, and coroners completing death certificates are encouraged to list alcohol if they have reason to believe it contributed (NCHS, 2003), evidence suggests that alcohol commonly is omitted from death certificates. Studies spanning several decades have documented the underreporting of alcohol involvement on death certificates (Hanzlick, 1988; Kircher et al., 1985; Nashold and Naor, 1981; Nelson et al., 1993; Petersson et al., 1982; Pollock et al., 1987; Romelsjö et al., 1993). Nearly 40 years ago, Nashold and Naor (1981) examined death certificates and available medical records to assess the extent to which death certificates captured the involvement of alcohol in traffic fatalities in Wisconsin across a 3-year period between 1975 and 1977. The authors concluded, "Clearly, the impact of alcohol as a cause of death is grossly underestimated as far as motor vehicle drivers and pedestrians are concerned. Out of every ten such fatalities in which relevant evidence of alcohol involvement was documented, the death certificate mentioned this fact for only one." It appears that underreporting of alcohol involvement in traffic fatalities has not improved in the years since. A recent study comparing data from death certificates to data in the Fatality Analysis Reporting System (FARS), a national database maintained by the National Highway Traffic Safety Administration that contains details of deaths from all fatal motor vehicle traffic crashes across the United States, estimated that death certificates captured only about 18% of driver deaths and 16% of all crash deaths in which the decedent had a BAC $\geq$ 0.08% (Castle et al., 2014). An updated analysis showed that the reporting practice has not been improved since the publication of the study (data not shown).

The large discrepancy between the number of death certificates noting alcohol involvement in fatal crashes and the number noted in the FARS database is a strong indication of the need to improve our surveillance of alcohol-related mortality. Similar underreporting might occur with deaths from other alcohol-related injuries and chronic ailments. As mentioned previously, alcohol was listed as a contributing factor in only 1.8% of death certificates for fatalities from falls among people aged 65+ in 2017 even though the CDC estimates 32% of fatalities from falls in the United States probably involve alcohol (CDC, 2013, 2018). If the CDC is correct, nearly 9,500 additional people aged 65+ died from alcohol-related falls than suggested by death certificates in 2017. In general, it seems reasonable to expect that the overall magnitude of alcohol-related deaths in the United States is far greater than the number reflected in death certificates alone. Hopefully, greater awareness of the roles that alcohol plays in mortality and the extent to which the contribution of alcohol to deaths is underreported will contribute to better recording practices.

CONCLUSIONS

Using death certificates to examine patterns in alcohol-related mortality between 1999 and 2017, we found the number of alcohol-related deaths doubled and the age-adjusted death rate increased by half. Rates were highest for males and females in the age range 45–74. Deaths related to acute alcohol consumption increased more for people 55–64, but deaths related to chronic alcohol use increased most for people aged 25–34. Women experienced a larger increase in alcohol-related deaths than men. Across racial and ethnic groups, the biggest increases in rates occurred among NH Whites and there were initial declines followed by increases for Hispanic males and NH Black males and females. By the end of the study period, rates were increasing for all racial and ethnic groups. Given evidence that death certificates often do not reflect the contribution of alcohol, the magnitude of alcohol-related mortality in the United States is likely much higher than suggested from death certificates alone.

CONFLICT OF INTEREST

None.

DISCLAIMERS

The views and opinions expressed in this report are those of the authors and should not be construed to represent the views of the Federal government.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Grouping of ICD-10 Codes for Underlying Cause.

Table S2. Number of Alcohol-Related Deaths: United States, 1999 to 2017.

Table S3. Age-Adjusted or Age-Specific Rate of Alcohol-Related Deaths: United States, 1999 to 2017.

Table S4. Trends in Age-Adjusted or Age-Specific Rates of Alcohol-Related Deaths: United States, 1999 to 2017.

Table S5. Underlying Cause of Alcohol-Related Deaths: United States, 1999 and 2017.