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Original Paper

Twenty-Year Observational Study Shows Rising Alcohol-Attributable Death Profiles in the U.S. and Delaware

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Abstract

The U.S. alcohol-attributable mortality burden makes it the third-leading cause of preventable deaths. This 1999-2018 observational study used the Tenth Revision of the International Classification of Diseases codes and the alcohol-related disease impact (ARDI) causes of death records to track alcohol's mortality burden. The Centers for Disease Control and Prevention keeps Wide-Ranging Online Data for Epidemiologic Research (WONDER) death certificates for the U.S. community. Evidence indicates that the U.S. ARDI mortality rates progressively trended upward (53.73%). Men were three times as likely as women to die, but female mortality rate changes (90.03%) advanced more rapidly than males. The study also revealed that the changes in alcohol-related death rate percentages for middle-age groups increased faster. In contrast, the African American/Black (AA/B) community's age-adjusted mortality rate change patterns first declined and then increased. The alcohol-attributable mortality rate (1999 to 2018) difference for AA/B was -6.35%.

Delaware's population is around one million, and about 23% is African American/Black. The subgroup analysis for Delaware's population was robust and showed alcohol-attributable mortality rates above national averages. This trend was apparent for both gender and race.

In conclusion, for both the U.S. and Delaware, alcohol use disorder is a risk factor for mortality, especially for males.

Keywords

alcohol, alcohol-related, alcohol-attributable, mortality rate, age-adjusted, US, Delaware, ICD-10, CDC, WONDER

1. Introduction

National Institutes of Health (NIH), National Institute of General Medical Sciences (NIGMS)-IDeA Networks of Biomedical Research Excellence (INBRE), National Science Foundation (NSF)-Established Program to Stimulate Competitive Research (EPSCoR), and State of Delaware (DE) funding, provided a far greater share of financial assistance (D'Souza, Wentzien et al., 2019; Neff & D'Souza, 2019) towards the institutionalization of the Wesley College STEM UR-CATS (Undergraduate Research Center for Analytics, Talent and Success). The Wesley College STEM UR-CATS provides financial aid (research assistant and internship stipends) to individual undergraduates in specific data science research projects. The research students data-mine the Centers for Disease Control and Prevention (CDC) Wide-Ranging Online Data for Epidemiologic Research (WONDER) records (CDC, 2017; Friede et al., 1993). Typically in such discovery projects, students uncover ways to cross-reference and probe the WONDER's menu-driven files to look for associations between incidences of chronic health conditions and mortality (D'Souza, Wentzien et al., 2017; D'Souza, Li, Gannon et al., 2019).

Under the Wesley College STEM UR-CATS umbrella and within course-embedded research projects (Neff & D'Souza, 2019), students use publicly available, interactable, and searchable databases. For their research projects, students probe the databases' annual records for population, demographic, housing, social, and economic characteristics for all U.S. states, as well as for the State of Delaware (D'Souza et al., 2018; D'Souza, Kashmar et al., 2015; D'Souza, Li, & Wentzien, 2019; D'Souza, Wentzien et al., 2019; D'Souza, Wentzien, Bautista et al., 2017; D'Souza, Li, Gannon et al. 2019; Neff & D'Souza, 2019). Furthermore, undergraduates completed epidemiologic methods in study design, data analysis, and statistical interpretations for the adverse human health effects observed from persistent health complications arising from obesity, diabetes, cardiovascular diseases, and cancer (D'Souza et al., 2018; D'Souza, Kashmar et al., 2015; D'Souza, Li, Gannon et al., 2019; D'Souza, Li, & Wentzien, 2019; D'Souza, Walls et al., 2015; D'Souza, Wentzien et al., 2017; D'Souza, Wentzien et al., 2019). Results reveal that the listed chronic conditions do (indeed) impact all segments of the U.S. population and that the African American/Black (AA/B) population has been disproportionately affected. Also, project data showed that the AA/B community invariably experienced higher age-adjusted mortality rate averages correlated to low socioeconomic status and lack of adequate healthcare (D'Souza et al., 2018; D'Souza, Kashmar et al., 2015; D'Souza, Li, Gannon et al., 2019).

Delaware's population is close to one million, about 0.33% of the U.S. total (U.S. Census Bureau, 2020). Delaware is diverse, and its race and demographic composition differ from the U.S. general population (U.S. Census Bureau, 2020). Wesley's correlation studies between explanatory and response variables show Delaware to have a much higher mortality rate when obesity is a contributory factor on the death certificate (D'Souza et al., 2018; D'Souza, Li & Wentzien, 2019; D'Souza, Wentzien, Bautista et al., 2017; D'Souza, Wentzien, Bautista et al., 2019). Still, its death rates for diabetes, cardiovascular disease, and cancer closely follow the declining national trends (D'Souza et al., 2018; D'Souza, Kashmar et al. 2015; D'Souza, Li, Gannon et al., 2019; D'Souza, Li, & Wentzien, 2019; D'Souza, Wentzien, Bautista et al., 2019; D'Souza, Wentzien et al., 2017).

All U.S. death records for alcohol-related disease impacts (ARDI) are public and can be accessed through the national CDC WONDER repository (Case & Deaton, 2017; CDC, 2012; Mokdad et al., 2018). Alcohol dependence is found to be a U.S. public health challenge, as substantial increases are observed in the associations of alcohol-induced mortality (Rehm et al., 2013; Spillane et al., 2020). Chronic alcohol use and its addiction effects on health, social outcomes, and mortality at both the U.S. individual and population levels are well documented (Norström & Skog, 2001; White et al., 2020).

For improving the surveillance of alcohol mortality statistics, this project utilized the alcohol-related disease impact (ARDI) codes (CDC, 2012) from the International Classification of Diseases, 10th Revision (ICD-10) (Saunders, 2017) (Table 1). To understand changes in mortality rate trends and to interpret public health problems, the projects' data analytics methods included the abstraction, compilation, and analysis of CDC WONDER's alcohol-induced mortality surveillance (1999-2018) data (Case & Deaton, 2017; CDC, 2012; CDC, 2017; Friede et al., 1993; Mokdad et al., 2018; Saunders, 2017).

2. Methods

We obtained this study's data from the Centers for Disease Control and Prevention (CDC), Wide-ranging Online Data for Epidemiologic Research (CDC, 2017). CDC collects and compiles the data from the death certificates reported from all 50 states and the District of Columbia. The CDC calculates age-adjusted mortality rates and confidence interval limits to permit comparisons between demographic groups over time (CDC, 2017; Friede et al.,1993). We downloaded the data into an M.S. Excel dataset utilizing the query menu-driven access tools and line graphs generated using the SAS software.

CDC WONDER provides a menu-driven system made available to public health professionals and the public. It provides access to a wide array of public health information, including mortality rates, age-adjusted mortality rates, and 95% confidence interval limits by several demographic factors such as race and gender. The age-adjusted rates were determined using the year 2000 population distributions as the reference population (Hoyert & Anderson, 1998). The effect of a change in mortality rates due to a change in the age distribution of a population is minimized using the age-adjusted rates, thereby permitting a more effective analysis of mortality rates over time (Anderson & Rosenberg, 2001;

Anderson & Arias, 2003). Mortality rates and age-adjusted mortality rates for alcohol attributed deaths according to alcohol-related impact (ARDI) ICD-10 codes between 1999 and 2018 were obtained and analyzed.

The CDC's alcohol-related disease impact (ARDI) online application uses more ICD-10 codes for alcohol-attributable deaths than the database category "Alcohol-Induced Causes" under the CDC WONDER database. Even though some of the codings are for fetal deaths, we selected age-groups older than 15 years to exclude fetal deaths from the final calculation when searching the database. There were similarities between the ARDI codes and the "Alcohol-Induced Causes" category under the database. For the inclusion category under mortality, we selected as the single underlying cause, "all causes of death." For multiple causes of death, we selected all the ICD-10 codes under Table 1.

Table 1. The ICD-10 Codes for Chronic and Acute Conditions According to the Alcohol-related Disease Impact (ARDI) Application Reports from the CDC

Chronic Causes (100% Attributable)	**ICD-10**
Alcoholic psychosis	F10.3-F10.9
Alcohol abuse	F10.0, F10.1
Alcohol dependence syndrome	F10.2
Alcohol polyneuropathy	G62.1
Degeneration of the nervous system due to alcohol	G31.2
Alcoholic myopathy	G72.1
Alcohol cardiomyopathy	I42.6
Alcoholic gastritis	K29.2
Alcoholic liver disease	K70-K70.4, K70.9
Fetal alcohol syndrome	Q86.0
Fetus and newborn affected by maternal use of alcohol	P04.3, O35.4
Alcohol-induced chronic pancreatitis	K86.0
Acute Causes (100% Attributable)	
Alcohol poisoning	X45, Y15, T51.0, T51.1, T51.9
Suicide by and exposure to alcohol	X65
Excessive blood level of alcohol	R78.0

The CDC WONDER data was used to construct line graphs comparing alcohol-related deaths between Delaware and the U.S. by gender, race, and age. Confidence interval limits for the age-adjusted mortality rates were used to create line graphs to analyze differences between the U.S. and Delaware (DE). Although all available records from the death certificates were used to construct the age-adjusted mortality rates, confidence interval limits were calculated because of the error resulting from inaccurate or inconsistent reporting on death certificates. Line graphs displaying the age-adjusted mortality rates between 1999 and 2018 were constructed to compare the Delaware and U.S. rates by gender and race. Mortality rates between 1999 and 2018 were constructed to compare the Delaware and U.S. rates by age.

3. Results and Discussion

The alcohol-related disease impact (ARDI) mortality is the third leading preventable cause of U.S. death (Norström & Skog, 2001; Rehm et al., 2013; Spillane et al., 2020; White et al., 2020). During the 1998-2018 time-period, the ARDI death ratio of the Cumulative Sum of Alcohol-Related Deaths/Total Population for the U.S. was 1,016,445/4,872,789,837 (0.00021), and for Delaware, it was 3,724/14,228,378 (0.00026). The near equivalent 1999-2018 ARDI mortality record ratios where alcohol is listed as an influential factor on the death certificate, suggests the existence of highly connected time-related ARDI mortality rate similarities between diverse Delawareans and the U.S. national residents.

The 1999 and 2018 individual ARDI age-adjusted mortality rates for the U.S. and the State of Delaware (DE) at 95% confidence intervals (CI) are presented in Table 2. The twenty years of study (Figure 1) show that the national ARDI age-adjusted mortality rates steadily trended higher and accelerated to 53.73% in 2018. For Delaware, the ARDI age-adjusted mortality rate trend line (Figure 1) shows that the underlying relationship is not linear, and its final mortality rate increased by 15.87%.

Table 2. The 1999 and 2018 U.S. and Delaware (DE) Populations Alcohol-related Disease Impact (ARDI) Age-adjusted Mortality Rates and Corresponding 95% CI Values

Year		Gender	Rate	95% CI
1999	US	Female	6.72	[6.57, 6.87]
		Male	27.81	[27.49, 28.14]
	Delaware	Female	8.95	[5.99, 12.85]
		Male	39.99	[32.96, 47.68]
2018	US	Female	12.77	[12.58, 12.96]
		Male	39.23	[38.89, 39.56]
	Delaware	Female	15.88	[12.12, 20.44]
		Male	40.50	[34.09, 46.91]

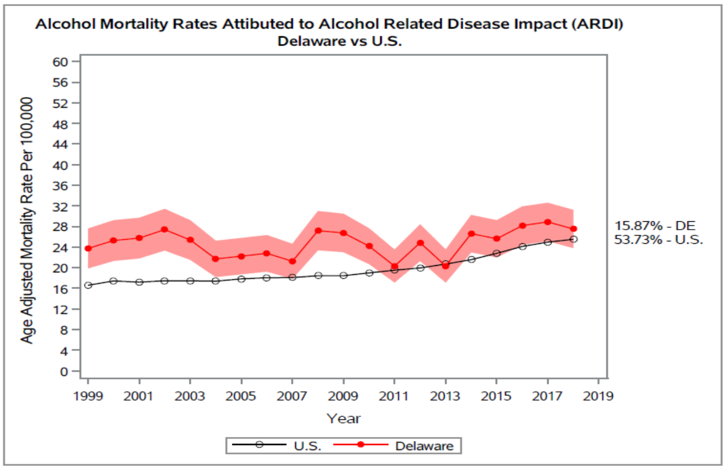

Figure 1. Twenty-year (1999-2018) Trends for the U.S. and Delaware's Alcohol-attributable Age-adjusted Mortality Rates

Also exhibited in Figure 1 are the 95% CI bands for Delaware's ARDI age-adjusted mortality rates that generally trended higher than the national mortality rate averages but saw periodic annual overlays. Close ascending patterns were also observed in prior comparison studies of Delaware's obesity-related mortality rates with their corresponding national obesity-related mortality rate averages (D'Souza et al., 2018; D'Souza, Kashmar et al., 2015; D'Souza, Li, & Wentzien, 2019; D'Souza, Wentzien et al., 2017). The 1999 and 2018 U.S. and DE gender-based ARDI age-adjusted mortality rates and their corresponding 95% CI values are shown in Table 3. Illustrated in Figure 2 are the similar gender-based, twenty-year (1999-2018), age-adjusted ARDI mortality rate trends.

For US females, the 1999-2018 Cumulative Sum of Alcohol-Related Deaths/Total Population was 241,517/2,500,958,378 (0.000097), and the calculated mortality rate ratio for US males was 774,928/2,371,831,459 (0.00033). Parallel gender calculations for Delaware resulted in higher gender mortality rate ratio calculations with 855/7,415,777 (0.00012) for females, and a complementary higher number for Delaware males 2,869/6,812,601 (0.00042).

Table 3. The 1999 and 2018 U.S. and DE Gender-based Alcohol-related Disease Impact (ARDI) Age-adjusted Mortality Rates and Their Corresponding 95% CI Values

Year		Rate	95% CI
1999	US	16.60	[16.43, 16.77]
	Delaware	23.75	[19.89, 27.61]
2018	US	25.52	[25.33, 25.71]
	Delaware	27.52	[23.81, 31.22]

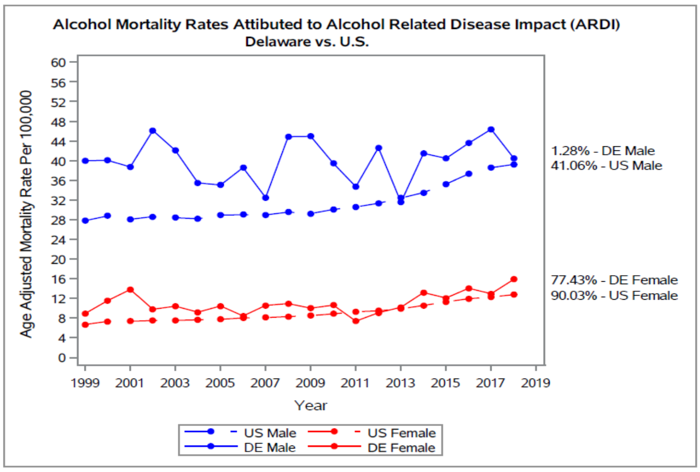

Figure 2. Twenty-year (1999-2018) Trends for the U.S. and Delaware's Gender-based Alcohol-attributable Age-Adjusted Mortality Rates

When the computed gender-based population mortality rate ratio values that were obtained from death certificate data that listed alcohol as a contributory and/or induced cause of death are coupled with the 1999-2018 ARDI age-adjusted mortality rate information provided in Table 3 and Figure 2, they demonstrate increasing numbers of alcohol-related deaths for both males and females in Delaware and the general US population. Except for 2013 and 2018, Delaware males had greater age-adjusted ARDI mortality rates than national averages.

For men, both in Delaware and in the U.S., the observed number of 1999-2018 alcohol-related deaths was more than three times greater than the related alcohol-related death ratio observed in women. Also, Figure 2 gender-based patterns for men show that throughout the 1999-2018 time-period, the age-adjusted alcohol-induced mortality rates trended at enormously higher rates than those observed for women. However, the absolute change between the 1999 and 2018 national average for alcohol-induced mortality related rates was very much higher amongst women, as demonstrated by the 2018 percentage rise of 90.03% for U.S. females compared to a 41.06% increase for U.S. males. On the other hand, for the State of Delaware, the same 1999 and 2018 female rate changes were considerably lower but still unmistakable and corresponded to an alcohol-induced mortality rate increase of 77.43% for women and a minor 1.28% increase for Delawarean men.

Reflecting on the negative consequences of previously studied chronic condition-related mortality on African-American/Blacks (AA/B) in the U.S. and Delaware (D'Souza et al., 2018; D'Souza, Kashmar et al., 2015; D'Souza, Li, Gannon et al., 2019; D'Souza, Li, & Wentzien, 2019; D'Souza, Walls et al., 2015; D'Souza, Wentzien et al., 2017; D'Souza, Wentzien et al., 2019), we first analyzed the (1999-2018) Cumulative Sum of Alcohol-Related Deaths/Total Population for both Whites and AA/B. For US Whites, this ratio was, 860,507/3,928,531,479 (0.00022) and for AA/B, it was 115,113/623,882,576 (0.00018). Proportionally for Delaware, the corresponding ARDI age-adjusted death ratios were higher for both Whites and AA/B at 3,007/10,703,061 (0.00028) and 691/2,962,447 (0.00023), respectively.

Due to low numbers of 1999-2018 deaths in the other racial/ethnic categories, Table 4 only lists ARDI age-adjusted mortality rates for Whites and African-American/Black (AA/B) and their 95% CI values. Figure 3 graphs illustrate the age-adjusted alcohol-attributable mortality rates for Whites and AA/B in the U.S. and Delaware.

The Figure 3 race-based data for the U.S. and Delaware bare the fact that the AA/B individuals had substantially higher 1999 ARDI age-adjusted mortality rates whose gradient veered noticeably downwards and then in 2013, rose upwards. As a result, the 1999 to 2018 ARDI age-adjusted mortality rate differences for Whites in the U.S. and Delaware were very positive, at 70.68% and 20.34%, respectively. Comparatively, for the U.S. and Delaware AA/B population, the alcohol-attributable death rates ended in 2018 at -6.35% and -20.34%, respectively.

Table 4. The 1999 and 2018 U.S. and DE Race-based Alcohol-related Disease Impact (ARDI) Age-adjusted Mortality Rates and Corresponding 95% CI Values

Year		Race	Rate	95% CI
1999	US	White	15.79	[15.60, 15.97]
		AA/B	24.09	[23.44, 24.74]
	Delaware	White	23.89	[19.57, 28.21]
		AA/B	29.21	[19.08, 42.80]
2018	US	White	26.95	[26.73, 36.64]
		AA/B	22.56	[22.07, 23.06]
	Delaware	White	30.90	[26.16, 35.64]
		AA/B	23.27	[16.77, 31.45]

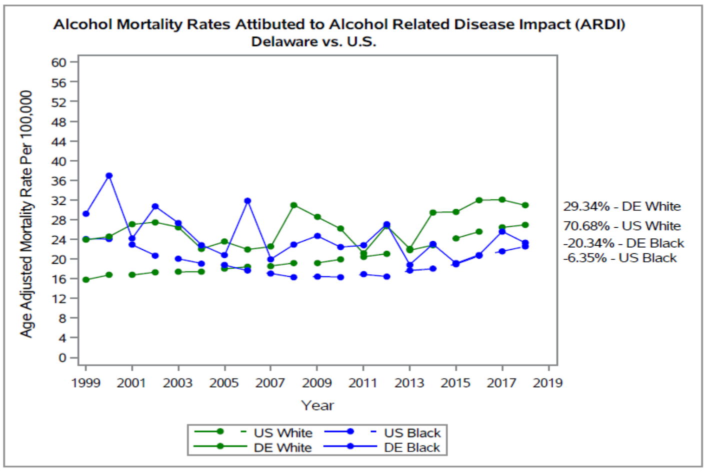

Figure 3. Twenty-year (1999-2018) Trends for the U.S. and Delaware's Race-based Alcohol-attributable Age-adjusted Mortality Rates

Due to lower available ARDI death record numbers for the age-groups, 35-44, 44-54, 55-64, and 65-74, crude mortality rates were utilized for both the U.S. and Delaware residents. For each listed age-group, Table 5 contains the 1999 and 2018 age-group-based alcohol-related disease impact (ARDI) crude mortality rates and their corresponding 95% CI values for the U.S. and Delaware. The twenty-year (1999-2018) crude-adjusted mortality rate trends for the U.S. are shown in Figure 4, and likewise, the Delaware graphs are in Figure 5.

The US populations 1999-2018 Cumulative Sum of Alcohol-Related Deaths/Total Population for the 35-44, 45-54, 55-64, and 65-74 age-groups were; 137,682/847,491,952 (0.00016), 288,756/846,335,185 (0.00034), 290,268/681,572,633 (0.00043), and 148,951/446,425,510 (0.00033). For Delaware, the analogous calculations were; 609/ 2,377,719 (0.00026), 1,076/2,459,699 (0.00044), 911/2,089,504 (0.00044), and 507/1,485,147 (0.00034).

Table 5. The 1999 and 2018 Age-group Based Alcohol-related Disease Impact (ARDI) Crude Mortality Rates and Their Corresponding 95% CI Values for the U.S. and Delaware

Year		Age Group	Rate	95% CI
1999	US	35-44	15.13	[14.77,15.48]
		44-54	26.64	[26.11, 27.17]
		55-64	31.67	[30.96, 32.39]
		65-74	30.85	[30.05, 31.65]
	Delaware	35-44	29.96	[21.20, 41.12]
		44-54	33.72	[23.35, 47.12]
		55-64	35.77	[23.15, 52.81]
		65-74	30.25	[17.62, 48.44]
2018	US	35-44	20.58	[20.14, 21.02]
		44-54	39.52	[38.91, 40.12]
		55-64	59.22	[58.49, 59.95]
		65-74	44.99	[44.24, 45.75]
	Delaware	35-44	35.88	[25.64, 48.86]
		44-54	44.90	[33.83, 58.45]
		55-64	47.92	[36.98, 61.08]
		65-74	51.76	[39.10, 67.21]

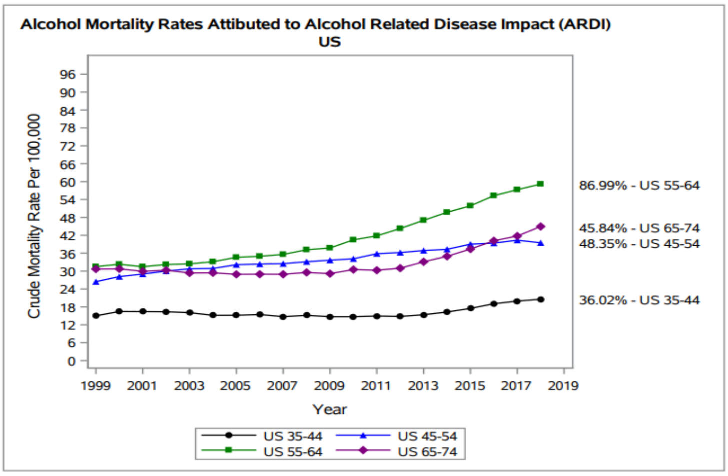

Figure 4. The Twenty-year (1999-2018) U.S. Age-based Alcohol-attributable Crude-adjusted Mortality Rates due to Excessive Alcohol Use for the Age-groups 35-44, 45-54, 55-64, and 65-74

The calculated US 1999-2018 cumulative alcohol-related mortality ratio and Figure 4 age-groups twenty-year trends show that the overall crude-mortality rates increased for all age groups. Rates of alcohol-induced deaths for persons aged 55-64 years rose from 31.67 per 100,000 population in 1998 to 59.22 in 2018. The alcohol-specific deaths by age group data clearly show that for deaths registered in 2018, the highest alcohol-specific death rate was among those U.S. residents aged 55 to 64 years (86.99%).

Similarly, the calculated cumulative alcohol-related mortality (1999-2018) ratios for Delaware shown above, in conjunction with Figure 4 data, clearly display increases in the crude-mortality rates for all listed age-groups. Still, its upper middle-age (65-74) residents had the highest (1999 to 2018) increase (71.11%).

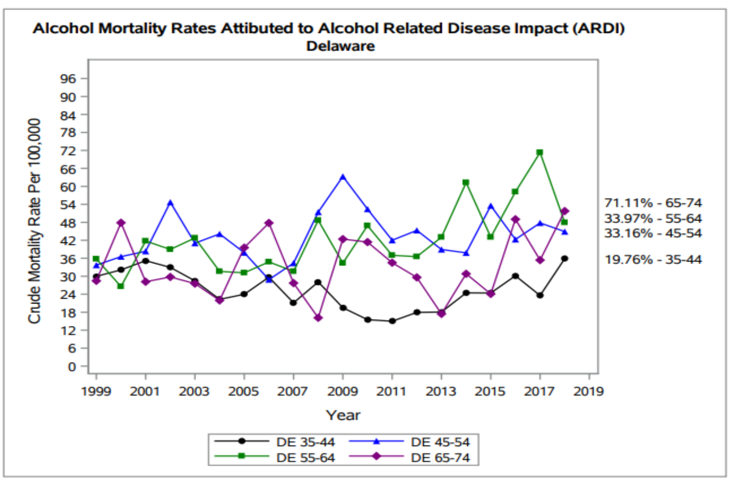

Figure 5. The Twenty-year (1999-2018) Delaware Age-based Alcohol-attributable Crude Mortality Rates for the Age-groups 35-44, 45-54, 55-64, and 65-74

The State of Delaware is divided into three counties: New Castle, Kent, and Sussex (U.S. Census Bureau, 2020). The educational attainment and socioeconomic data show that the two southern Delaware counties, Kent County and Sussex County, have areas of "high need," and this has been correlated to poor health outcomes (D'Souza, Kashmar et al., 2015; D'Souza, Wentzien et al., 2017; U.S. Census Bureau, 2020).

Prior obesity-related mortality data analyses (D'Souza, Kashmar et al., 2015; D'Souza, Li, Gannon et al., 2019; D'Souza, Wentzien et al., 2017) showed that Kent County experienced the most massive mortality rate increases (66.0%), followed by New Castle County (47.4%), and Sussex County (25.2%). No significant Pearson correlations were found between the county mortality rates and per-capita income levels, except for Sussex County, which was very close to a 5% threshold (p = .0513).

The Figure 6 Delaware County trends for the alcohol-attributable crude mortality rates feature large 1999 to 2018 crude mortality rate changes of 48.19% for Kent County and 42.39% for Sussex County. The Kent and Sussex County percentages are much lower than the comparable 1999 to 2018 crude mortality rate change of 72.09% for the U.S. national average. They are in line with the general epidemiological patterns for the prevalence rates for alcohol use (Norström & Skog, 2001; Rehm et al., 2013; Spillane et al., 2020; White et al., 2020) and previous Delaware obesity-related mortality statistics (D'Souza, Kashmar et al., 2015; D'Souza, Li, Gannon et al., 2019; D'Souza, Wentzien et al., 2017).

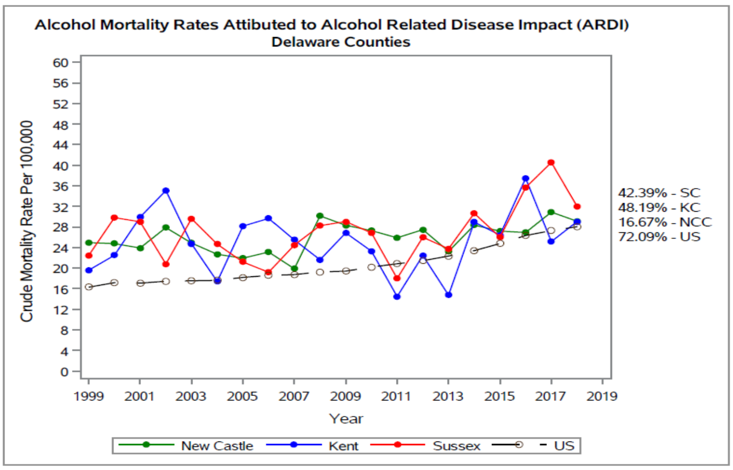

Figure 6. The Twenty-year (1999-2018) U.S. and Delaware County (New Castle County, Kent County, and Sussex County) Alcohol-attributable Crude Mortality Rates

4. Conclusions

The alcohol-related disease impact application was useful in tracking the estimates of alcohol-attributable deaths in the U.S. and Delaware. In the twenty-year (1999-2018) period, deaths registered show that there were 1,016,445 US deaths and 3,724 Delaware deaths known to be a consequence of alcohol. Overall, the U.S. alcohol-attributable mortality rates increased by 53.73%, and they increased by 15.87% in Delaware. The death rates were highest among the middle-age groups, and the male mortality rates are more than triple than those observed in females. Considering the 1999 to 2018 population and race distributions, the percentages in alcohol-attributable deaths in the African American/Black population was found to be negative. The input provided by this project is useful for developing educational strategies aimed at reducing alcohol consumption.

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