SOA Research INSTITUTE

Mortality and Longevity

Aging and Retirement

U.S. Population Mortality Observations

Updated with 2021 Experience

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Updated with 2021 Experience

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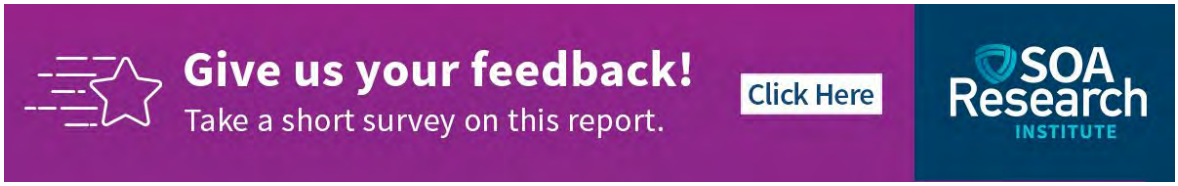

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Section 1: Introduction

The Society of Actuaries has developed this report to provide insights on the historical levels and emerging trends in U.S. population mortality. The most recently released U.S. population mortality experience from calendar year 2021 has been incorporated and added to prior available data to enable analysis of mortality experience over the period 1999-2021. This research is part of its ongoing longevity and mortality research initiatives. The report begins with an Executive Summary, which contains key highlights, followed by analyses of mortality by a number of factors, including sex, age group, cause of death (COD) and socio-economic county grouping. The report is supplemented with a companion online interactive dashboard that allows users to pursue mortality analysis by key attributes.

Section 2: Executive Summary

This report updates prior annual reports on U.S. population mortality with 2021 experience. It takes a novel approach to enable comparisons to pre-COVID mortality by using 2019 as the baseline year instead of a conventional comparison to prior year 2020 mortality. The key measure in the report is a direct comparison of 2021 to 2019 mortality on a non-annualized cumulative basis. The report also analyzes mortality change by year for 2020 and 2021.

2.1 KEY TAKEAWAYS

Relative to pre-pandemic experience:

- Sharply lowered negative mortality improvement for all causes of death with and without COVID
- Circulatory diseases, liver and diabetes very negatively impacted
- Accidents excluding opioids very negatively impacted and opioids saw resumption of extreme mortality increases
- Widened mortality rates by socioeconomic location principally, but not exclusively driven by COVID

2.2 DETAILED HIGHLIGHTS

- Independent of whether COVID was included or removed, 2020-2021 had sharply lower mortality improvement that stands in stark contrast with pre-COVID mortality experience. The overall age-adjusted[1] cumulative mortality improvement rate from 2019-2021 (both sexes) from all causes of death, was -23.0%. This two-year period included the one-year 2020 mortality rate increase of 16.8% that was the historically highest increase of published records[2] dating back to 1900. Mortality increased further in 2021 from 2020 with a one-year -5.3% mortality improvement rate. When COVID deaths were removed, the baseline 2019-2021 cumulative mortality improvement rate was -8.4%. The corresponding one-year mortality improvement rates were -4.9% and -3.3% for the years ending 2020 and 2021, respectively.

- Mortality improvement for some natural causes was extremely lower than pre-pandemic experience. Circulatory diseases of the heart, stroke and hypertension had cumulative 2019-2021 mortality improvement of -7.6%, -11.3% and -20.0%, respectively. As the number one leading cause of death, the further deterioration for heart disease from a historic pre-pandemic pattern that had flattened after earlier positive improvement was notable. Liver and diabetes, which generally had the greatest impact on young working age adults, also saw extreme mortality deterioration from 2019-2021 with cumulative mortality improvement of -17.7% and -27.6%, respectively.

- Other CODs with notable experience included cancer, pulmonary and flu and pneumonia. Cancer had, compared to other CODs, a relatively moderate -0.3% cumulative 2019-2021 mortality improvement, but that result was driven by cancer's first one-year negative mortality improvement during the span of this report of -1.7% in 2021. Pulmonary and flu and pneumonia were the exceptions to all other CODs featured in this report

[1] Age-adjusted rates are calculated assuming the mix of ages in the population stays the same each year. Life expectancy is a composite of mortality rates over a single person's future lifetime. This report focuses on age-adjusted rates (2000 baseline year), as opposed to life expectancy, because actuaries generally require mortality rates, not life expectancies, as an input assumption for their work.

[2] Age-Adjusted Death Rates for Selected Causes, Death Registration States, 1900-32, and United States, 1933-98 https://www.cdc.gov/nchs/nvss/mortality/hist293.htm

as the only CODs with positive cumulative 2019-2021 mortality improvement. Pulmonary had 9.1% and flu and pneumonia had 14.5% mortality improvement during the period.

- The external CODs of accidents excluding opioids, suicide, and assault, each had negative cumulative mortality improvement from 2019-2021. The cumulative 2019-2021 mortality improvement of -18.0% for accidents, excluding opioids was a substantial deterioration from pre-pandemic experience. The suicide 2019-2021 cumulative improvement of -1.1% during the same period was comparatively more moderate. Assaults during the same period had the lowest mortality improvement of -35.5% of the leading causes of death covered in this report.

- The classification of U.S. counties into quintiles based on a socioeconomic index score (SIS) showed gradient separation of mortality by these quintiles. These differences are indicators of whether experience is more or less than average by quintile, both as point in time snapshots and measures of change over time. Generally, mortality rates and mortality improvement rate differences across the quintiles widened abnormally during the pandemic. COVID deaths had a negligible impact in 2020 but, in 2021, about two-thirds of the widening of mortality rates across quintiles was attributable to COVID.

- Opioids saw a resumption of rapidly deteriorating mortality improvement during the pandemic that had moderated somewhat during 2018-2019 from an earlier rapid deterioration. Cumulative mortality improvement over 2019-2021 for opioids, which intersects with a key component of accidental deaths, was -59.5%. Within that two-year period, the opioids one-year -38.0% mortality improvement in 2020 was the most extreme, or lowest, mortality improvement for the full span of this report, with the next most severe mortality improvement of -27.9% in 2016. Although the opioid death rate is much lower compared to other major CODs, it had a large impact on young adults where opioid deaths were 25% of all causes of death for age group 25-34 in 2021. Fentanyl and tramadol opioid death rates were much higher than those from heroin, methadone and natural and semi-synthetic opioids. The 2019-2021 cumulative mortality improvement for fentanyl and tramadol was -91.3%.

- Cumulative mortality improvement in 2019-2021 varied substantially by age group, both with and without COVID, and by sex. Every age group and sex combination, except males less than age one, saw increased mortality over this period, both with and excluding COVID. Mortality was notably more severe for age groups 15-24 and older that all had double digit negative mortality improvement. The lows reached their extreme with COVID for both sexes at age group 35-44 with females at -42.1% and males at -45.2%. Without COVID, the comparable low was at age group 25-34 and was at -24.8% for females and -32.4% for males. Both with and without COVID, they had generally increased mortality improvement by age from their respective lowest age groups. Age group 85+ mortality improvement with COVID was -17.8% and -20.8% for females and males, respectively and, without COVID, was -8.8% and -8.6% for females and males, respectively.

- The overall age-adjusted one-year COVID mortality improvement rate for 2020-2021 (two-year cumulative rate not available) was -22.6%. The difference between sexes (all ages) was relatively small where females had slightly lower improvement rates than males. Females had lower mortality improvement than males in all age groups, except at ages 85+. Mortality improvement rates varied widely by age and, except under age five, generally followed a monotonically increasing pattern by age for both sexes combined and individually. Overall, COVID contributed -14.6% of the total -23.0% 2019-2021 cumulative mortality improvement.

- Female and male mortality patterns for all ages combined were similar, but reflected greater impact of adverse mortality for 2019-2021 cumulative mortality improvement on males than females, both with and without COVID. With COVID, female and male mortality improvement was -21.7% and -23.8%, respectively, and was -8.1% and -8.3%, respectively, without COVID.

- The assignment of the underlying cause of death by certifiers involves judgement within recommended guidelines that were recently updated in 2020 for COVID and published earlier for general application by the CDC in 2003. Readers of this report should be aware that similar circumstances may be viewed differently by individuals and practices may have evolved over time such that consistency of the assignment of the underlying COD could be affected. This is particularly important for this report covering the first year of the COVID pandemic. More information on this with references cited are in Section 9 of this report.

Section 3: Total Population and by Sex

The overall age-adjusted[3] mortality improvement rate for all causes of death and both sexes in 2021 relative to 2019 (not annualized), where pre-COVID 2019 mortality just before the pandemic serves as a baseline in this report, was -23.0%. To distinguish between this measure and references to one-year mortality improvement ending in 2020 and 2021 that are also cited in the report, it is referred to throughout the report as a two-year cumulative mortality improvement measure. This two-year period included one-year 2020 mortality improvement of -16.8% that was the historically lowest mortality improvement of published records[4] dating back to 1900. Mortality improvement increased in the second year of the pandemic with a one-year, -5.3% mortality improvement rate during 2020-2021.

When COVID deaths are removed, the baseline two-year 2019-2021 cumulative mortality improvement rate was -8.4%, which stands in stark contrast to the average annual mortality improvement rates pre-COVID of 1.5% and 0.5% for the ten-year periods ending 2009 and 2019, respectively. Mortality improvement also increased in the second year of the pandemic with COVID removed, but to a smaller extent than inclusive of COVID. The one-year mortality improvement rates were -4.9% and -3.3% for the years ending 2020 and 2021, respectively.

When viewed by sex, cumulative 2019-2021 mortality improvement for all causes of death was lower for males at -23.8% than females at -21.7% but, within the two-year pandemic period, the rank-order of one-year mortality improvement rates switched. Males had lower one-year 2020 mortality improvement and higher one-year mortality improvement in 2021 than females. One-year mortality improvement rates for males and females were -17.9% and -15.3%, respectively, in 2020, and -5.0% and -5.5%, respectively, in 2021. When COVID deaths are removed, the pattern by sex is the same as for all CODs. The cumulative two-year mortality improvement rates for males and females of -8.3% and -8.1%, respectively, were comprised of one-year mortality improvement rates that for males and females were -5.2% and -4.3%, respectively, in 2020, and -2.9% and -3.7%, respectively, in 2021.

Table 1

U.S. POPULATION MORTALITY IMPROVEMENT BY SELECTED PERIODS

All Ages	Average Annual Improvement		Cumulative Improvement	Average Annual Improvement		Cumulative Improvement	Average Annual Improvement	
			With COVID			Without COVID		
	1999-2009	2009-2019	2019-2021	2019-2020	2020-2021	2019-2021	2019-2020	2020-2021
All	1.5%	0.5%	-23.0%	-16.8%	-5.3%	-8.4%	-4.9%	-3.3%
Male	1.8%	0.5%	-23.8%	-17.9%	-5.0%	-8.3%	-5.2%	-2.9%
Female	1.4%	0.5%	-21.7%	-15.3%	-5.5%	-8.1%	-4.3%	-3.7%

[3] Age-adjusted rates are calculated assuming the mix of ages in the population stays the same each year. Life expectancy is a composite of mortality rates over a single person's future lifetime. This report focuses on age-adjusted rates (2000 baseline year), as opposed to life expectancy, because actuaries generally require mortality rates, not life expectancies, as an input assumption for their work.

[4] Age-Adjusted Death Rates for Selected Causes, Death Registration States, 1900-32, and United States, 1933-98 https://www.cdc.gov/nchs/nvss/mortality/hist293.htm

Section 4: Age Group

Table 2 below shows cumulative mortality improvement in 2019-2021 varied substantially by age group, both with and without COVID, and by sex regarding excess COVID mortality. Every age group and sex combination, except males less than age one, saw increased mortality over this period, both with and excluding COVID. With COVID included for ages under 15, mortality improvement ranged between 0.7% for males age less than one and -8.3% for females ages 1-4. All ages 15 and above had substantially lower mortality improvement in a range of -42.1% to -17.8% for females and -45.2% to -18.9% for males. Those improvement rates reached their low at ages 35-44 for both sexes.

When COVID was excluded, all ages 15 and above for both sexes also had increased mortality. The pattern shifted to the lowest improvement at ages 25-34, -24.8% for females and -32.4% for males, with generally increasing mortality improvement at successively higher ages, except ages 85+.

The mortality improvement due to COVID is determined as the difference of the mortality improvement, both with and without COVID, and is shown in the table below as the COVID excess. The COVID excess showed a concave pattern across age groups, with the lowest COVID excess for both sexes at age group 45-54 of -22.2% and -23.5% for females and males, respectively. The difference in the COVID excess between males and females was greatest at the younger ages and lowest at the older ages. Because of the weight of higher mortality rates at the highest ages where males had a lower COVID excess than females, the COVID excess for all ages combined was lower for males, -15.5%, than females, -13.5%.

Table 2

U.S. POPULATION 2019-2021 CUMULATIVE MORTALITY IMPROVEMENT BY AGE AND SEX

	Female			Male			Male-Female COVID Excess
Age Group	With COVID	Excl COVID	COVID Excess	With COVID	Excl COVID	COVID Excess	
< 1	-3.3%	-2.8%	-0.5%	0.7%	1.1%	-0.4%	0.1%
1-4	-8.3%	-6.6%	-1.6%	-6.7%	-5.3%	-1.4%	0.2%
5-14	-5.7%	-3.0%	-2.6%	-7.5%	-5.0%	-2.5%	0.2%
15-24	-28.3%	-21.3%	-6.9%	-27.3%	-23.4%	-3.8%	3.1%
25-34	-37.5%	-24.8%	-12.8%	-41.9%	-32.4%	-9.5%	3.3%
35-44	-42.1%	-22.2%	-19.9%	-45.2%	-27.5%	-17.7%	2.2%
45-54	-32.5%	-10.3%	-22.2%	-36.4%	-12.9%	-23.5%	-1.3%
55-64	-26.6%	-6.9%	-19.8%	-25.7%	-6.5%	-19.2%	0.5%
65-74	-22.4%	-5.2%	-17.1%	-21.2%	-3.8%	-17.3%	-0.2%
75-84	-18.5%	-5.7%	-12.8%	-18.9%	-3.5%	-15.4%	-2.6%
85+	-17.8%	-8.8%	-9.0%	-20.8%	-8.6%	-12.2%	-3.2%
All Ages	**-21.7%**	**-8.1%**	**-13.5%**	**-23.8%**	**-8.3%**	**-15.5%**	**-2.0%**

4.1 MORTALITY ATTRIBUTION BY AGE GROUP

The attribution by age of 2019-2021 cumulative mortality improvement varied across age and by inclusion or exclusion of COVID. Whether COVID was included or excluded, ages under 15 had no contribution to the attribution of mortality improvement. Because all age groups had negative mortality improvement, both with and without COVID, a more negative attribution amount reflects a greater contribution to the total -23.0% and -8.4% mortality improvement with and without COVID, respectively. When COVID was included, the attribution for age groups 15-24 to 85+ decreased monotonically by age group to a maximum impact of a low of -5.5% for ages 85+. Those same ages saw a moderate

decreasing trend with the effects of COVID excluded that reached a low of -2.5% at age group 85+. Because the attribution of mortality improvement for an age group is, in part, determined by its proportion of the mortality for all ages, the older age groups' attribution of mortality change will naturally be magnified relative to other ages. That factor, combined with the older age groups' more adverse COVID experience, produced an attribution of -10.6% or 46.1% of the -23.0% total 2019-2021 cumulative mortality improvement in age groups 75-84 and 85+. When COVID was excluded, those same two age groups' share of the 2019-2020 improvement was -3.8% of the total -8.4% or 45.2% of the total improvement, excluding COVID. Relative improvement of one age group to another also determines age group attributed shares of total change. The very adverse changes with COVID, excluded for ages 15-44, relative to other ages produced -2.2% of the -8.4% total improvement or 26.2% of total improvement. That contrasts with a 14.8% contribution to total improvement with COVID included. Although their age-group mortality improvement was more adverse than older ages, the older ages' higher mortality rates produced a larger share of the attribution of mortality improvement.

Table 3

U.S. POPULATION ATTRIBUTION OF 2019-2021 CUMULATIVE MORTALITY IMPROVEMENT BY AGE

Age Group	Deaths per 100,000		Mortality Improvement		Attribution of Mortality Improvement	
	2021	2021 w/o COVID	2019 to 2021	2019 to 2021 w/o COVID	2019 to 2021	2019 to 2021 w/o COVID
< 1	558.8	556.3	-1.1%	-0.6%	0.0%	0.0%
1-4	25.0	24.6	-7.4%	-5.9%	0.0%	0.0%
5-14	14.3	14.0	-6.8%	-4.2%	0.0%	0.0%
15-24	88.9	85.7	-27.5%	-22.8%	-0.4%	-0.3%
25-34	180.8	167.4	-40.4%	-29.9%	-1.0%	-0.7%
35-44	287.9	251.0	-44.5%	-26.0%	-2.0%	-1.2%
45-54	531.0	440.3	-35.3%	-12.2%	-2.6%	-0.9%
55-64	1,117.1	944.9	-26.5%	-7.0%	-2.9%	-0.8%
65-74	2,151.3	1,846.2	-21.9%	-4.6%	-3.6%	-0.8%
75-84	5,119.4	4,509.7	-18.8%	-4.7%	-5.1%	-1.3%
85+	15,743.3	14,388.9	-19.0%	-8.8%	-5.5%	-2.5%
All Ages	**942.7**	**830.5**	**-23.0%**	**-8.4%**	**-23.0%**	**-8.4%**

* Rounded Age Group attribution values do not sum to Total. The attribution method is described in section 7.

Section 5: Cause of Death

This section covers mortality by the 13 individual causes of death (CODs), including COVID, that were selected from the National Center for Health Statistics' (NCHS) list of rankable causes of death. The remainder of section 5 provides more detailed analysis for 10 CODs: COVID, heart, cancer, Alzheimer's/dementia, diabetes, liver, hypertension, accidents excluding opioids, opioids and suicide.

5.1 CAUSE OF DEATH DISTRIBUTION BY AGE GROUP

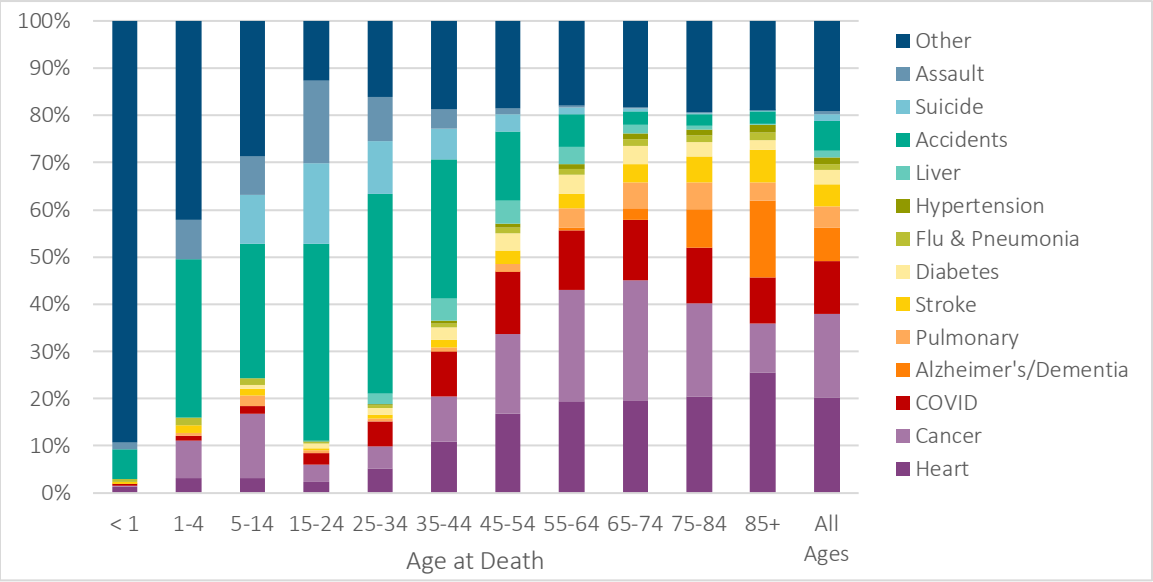
Physiological CODs predominated for older ages and external CODs (assault, suicide, and accidents) predominated for younger ages. Age group 15-24 had the highest proportion, 76.4%, of external CODs in 2020-2021. Accidents were the largest portion of those CODs. Age groups 15-24 and 25-34 had nearly identical portions, 41.7% and 42.2%, respectively, which were higher than all other age groups of accidental deaths.

Heart, cancer, COVID and Alzheimer's/dementia combined predominated within physiological causes for age groups 55-64 and higher. The combined percentage of deaths from those four CODs ranged from 56.3% for age group 55-64 to 61.9% for age group 85+. Within the mix of those four CODs and those age groups, heart and Alzheimer's/dementia had an increasing share of deaths by age. Heart and Alzheimer's/dementia shares were 25.5% and 16.2%, respectively, for ages 85+. COVID shares were relatively flat across the same age groups, except at ages 85+. Shares for age groups from ages 55-84 ranged from 11.9% to 12.8% and peaked for age group 65-74, while ages 85+ had a smaller 9.7% share. Cancer peaked at age group 65-74 with 25.4% of deaths and declined to 10.5% for age group 85+.

The combination of the other physiological CODs shown, stroke, pulmonary, diabetes, flu & pneumonia, liver and hypertension, produced at least 10% of the deaths for age groups 35-44 and higher. The combined percentage of deaths of those six CODs for those age groups ranged from a low of 11.2% for age group 35-44 to 17.7% for age group 75-84. Within that mix of those six CODs for those age groups, stroke, pulmonary, hypertension, and flu & pneumonia generally increased with advancing age, liver decreased with that same age progression, while diabetes had a hump-shaped share progression that peaked at age group 55-64.

Figure 1

COD PROPORTION OF 2020-2021 DEATHS BY AGE GROUP



5.2 MORTALITY ATTRIBUTION BY CAUSE OF DEATH

U.S. population deaths of 3,464,231 in 2021 were the highest in history[5]. Heart disease remained the number one killer and accidents continued to be the highest external[6] COD in 2021. The number of deaths in 2021 for the population by the CODs studied in this report are shown below in descending rank order. The attribution of COVID to the total eclipsed all other CODs and contributed -14.6% to the -23.0% cumulative 2019-2021 mortality improvement rate. Pulmonary and flu & pneumonia were the only CODs that had improved mortality in 2019-2021. Pulmonary continued a recent trend, while flu & pneumonia reflected the very low incidence of it during the COVID pandemic. Taken together, those two CODs produced a 0.8% offset to all other CODs' negative mortality improvement. Except for COVID and the Other COD classification, accidents was the largest contributor to attributed mortality improvement. It's very low -31.3% mortality improvement rate produced a -2.2% contribution to total mortality improvement. While assault is a small proportion of all deaths, it continues to be very prevalent for young adults. It was a top five cause of death for males under age 35 and females under age 25, and it was the number two cause of death for males ages 15-24. Assault mortality improvement for all ages combined was -35.5% in 2019-2021, which contributed -0.3% to total mortality improvement. Heart disease was the next largest impact to mortality improvement after COVID and accidents. Its -7.6% mortality improvement translated into a -1.7% contribution to total mortality improvement. Diabetes, hypertension, liver and stroke all had negative mortality improvement lower than -10%. The range of their mortality improvement rates, -11.3% to -27.6%, produced a combined -1.7% to total mortality improvement.

Table 4

U.S. POPULATION ATTRIBUTION OF 2019-2021 CUMULATIVE MORTALITY IMPROVEMENT BY COD

Cause of Death	2020-2021 Deaths	%	Age-Adjusted 2019-2021 Mortality Improvement	Attribution to All CODs*
Heart Disease	1,392,509	20.3%	-7.6%	-1.7%
Cancer	1,207,563	17.6%	-0.3%	-0.1%
COVID	767,724	11.2%	n/a	-14.6%
Alzheimer's/Dementia	489,660	7.2%	-3.0%	-0.2%
Accidents	425,890	6.2%	-31.3%	-2.2%
Stroke	323,154	4.7%	-11.3%	-0.6%
Pulmonary	294,999	4.3%	9.1%	0.5%
Diabetes	205,482	3.0%	-17.7%	-0.5%
Liver	108,227	1.6%	-27.6%	-0.4%
Flu & Pneumonia	95,461	1.4%	14.5%	0.3%
Suicide	94,162	1.4%	-1.1%	0.0%
Hypertension	84,723	1.2%	-20.0%	-0.2%
Assault	50,607	0.7%	-35.5%	-0.3%
Other	1,307,799	19.1%	-13.6%	-2.9%
All COD	**6,847,960**	**100.0%**	**-23.0%**	**-23.0%**

* The attribution method is described in section 7.

[5] Based on individual years 1933 and later data through 2020 obtained through, HMD. Human Mortality Database. Max Planck Institute for Demographic Research (Germany), University of California, Berkeley (USA), and French Institute for Demographic Studies (France). Available at, www.mortality.org, on 2/1/2023).

[6] See section 7 for definition of external COD.

5.3 COVID

The overall age-adjusted one-year mortality improvement rate for 2020-2021 (both sexes) from COVID was -22.6%. The difference between sexes (all ages) was relatively small where females and males had improvement rates of -22.6% and -21.9%, respectively. Mortality improvement rates varied widely by age and, except under age 5, generally followed a monotonically increasing pattern by age for both sexes combined and individually. With respect to both sexes combined, the mortality improvement rate increases by age brought the rate from a low for age group 5-14 of -184.6% to a near breakeven of -3.4% for age group 75-84 and mortality improvement of 17.7% for ages 85+. That pattern was similar with females and males viewed separately. The small difference of mortality improvement rates between males and females for all ages masks large differences by age. Males had higher mortality improvement than females, except at ages 85+. The degree of that difference varied widely by age in a mountain-like pattern where there was a sharp peak at age group 35-44 of 59.8% and beginning and end points for age groups 5-14 and ages 85+ of 10.5% and -13.3%, respectively.

Table 5

2020-2021 MORTALITY IMPROVEMENT BY AGE AND SEX

Age Group	2020-2021 Mortality Improvement			
	All	Female	Male	Male minus Female
< 1	-172.4%		-100.4%	210.1%
1-4	-189.9%			
5-14	-184.6%	-190.5%	-180.1%	10.5%
15-24	-176.2%	-189.0%	-168.2%	20.8%
25-34	-175.5%	-189.1%	-168.7%	20.5%
35-44	-155.6%	-195.1%	-135.3%	59.8%
45-54	-115.7%	-142.0%	-101.8%	40.3%
55-64	-73.5%	-92.2%	-62.3%	29.9%
65-74	-30.2%	-42.7%	-22.0%	20.7%
75-84	-3.4%	-3.4%	-3.0%	0.4%
85+	17.7%	23.4%	10.0%	-13.3%
All Ages	**-22.6%**	**-22.6%**	**-21.9%**	**0.7%**

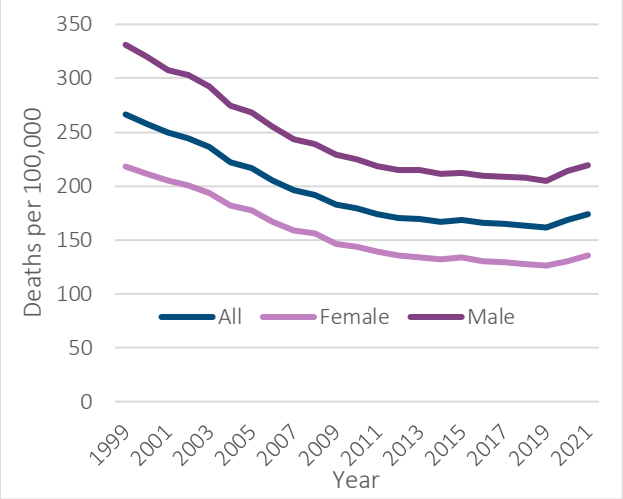
5.4 HEART DISEASE

The cumulative mortality improvement rate over 2019-2021 for heart disease was -7.6%. This broke the long-term trend where average annual mortality improvement was strongest at 3.7% for 1999-2009, and then moderated to 1.2% for 2009-2019. Because heart deaths are highly concentrated in senior ages above age 64, those age groups had the greatest influence in producing the results for all ages combined. Males had higher mortality improvement of -7.2% in 2019-2021 than females at -7.5%. That was a reversal of the long-term trend where female average annual mortality improvement rates were higher than the corresponding rates for males in both prior ten-year periods. The short-term trend implied by the 2019-2021 two-year cumulative mortality improvement and one year 2020-2021 mortality improvement showed that males had higher one-year mortality improvement in 2021 vs. 2020, while females had lower mortality improvement during the same period.

Except for age group 1-4, all ages had negative cumulative mortality improvement during 2019-2021. The degree of that mortality was such that its absolute value exceeded the average annual mortality improvement of both prior ten-year periods for those age groups. The most extreme two-year mortality improvement in 2019-2021 occurred for ages 25-64, which ranged from -9.6% for ages 55-64 to -20.0% for ages 25-34. Although those ages had the lowest two-year mortality improvement rates in 2019-2021, they reversed direction in the second year and posted higher mortality improvement rates in 2021 vs. 2020. Conversely, ages below 15 and age group 85+ all had lower mortality improvement rates in 2020 than 2021. This is particularly relevant for age 85+, which had a 2020 one-year rate of -6.7% and a two-year rate of -7.4%.

Figure 2

2021 HEART HISTORICAL MORTALITY RATES AND MORTALITY IMPROVEMENT BY SELECTED PERIODS



All Ages	Average Annual Improvement		Cumulative Improvement	Average Annual Improvement	
	1999-2009	2009-2019	2019-2021	2019-2020	2020-2021
All	3.7%	1.2%	-7.6%	-4.1%	-3.3%
Male	3.6%	1.1%	-7.2%	-4.6%	-2.5%
Female	3.9%	1.5%	-7.5%	-3.2%	-4.1%
Age Group (includes both sexes)					
< 1	3.5%	3.0%	-4.9%	8.5%	-14.7%
1 - 4	2.3%	1.2%	9.7%	14.6%	-5.6%
5 - 14	2.4%	2.0%	-9.3%	6.2%	-16.4%
15 - 24	1.5%	1.5%	-7.2%	-0.1%	-7.2%
25 - 34	-0.2%	0.2%	-20.0%	-13.7%	-5.6%
35 - 44	1.2%	0.6%	-16.6%	-14.7%	-1.7%
45 - 54	1.5%	0.8%	-11.4%	-11.1%	-0.3%
55 - 64	3.4%	0.0%	-9.6%	-9.7%	0.0%
65 - 74	4.9%	0.8%	-7.1%	-6.5%	-0.6%
75 - 84	4.1%	2.0%	-5.4%	-2.6%	-2.7%
85+	3.3%	1.3%	-7.4%	-0.6%	-6.7%

5.5 CANCER

The cumulative mortality improvement rate over 2019-2021 for cancer was -0.3%. This broke an accelerating long-term trend where average annual improvement was 1.4% for 1999-2009 and 1.7% for 2009-2019. Males had higher mortality improvement of 0.5% in 2019-2021 than females at -1.2%. That was a continuation of the long-term trend where male average annual mortality improvement rates were higher than the corresponding average annual female rates in both prior ten-year periods. The short-term trend showed that both males and females had lower one-year mortality improvement rates in 2021 vs. 2020.

Age group cumulative mortality improvement during 2019-2021 varied by age with no discernable pattern. The 2019-2021 cumulative mortality improvement rates for ages 45-74, that ranged from 2.1% to 5.2%, at least equaled and, in most instances, exceeded their corresponding average annual averages in the two ten-year periods ending in 2009 and 2019. These ages contrasted sharply with ages 75-84 and 85+. Each of those two age groups had negative cumulative mortality improvement in 2019-2021 and had a high impact on the combined rate across all ages over the two-year period. Age 85+ showed the most deterioration with a -9.0% two-year 2019-2021 cumulative mortality improvement rate and one-year 2021 mortality improvement rate of -11.4%.

Figure 3

2021 CANCER HISTORICAL MORTALITY RATES AND MORTALITY IMPROVEMENT BY SELECTED PERIODS

All Ages	Average Annual Improvement		Cumulative Improvement	Average Annual Improvement	
	1999-2009	2009-2019	2019-2021	2019-2020	2020-2021
All	1.4%	1.7%	-0.3%	1.4%	-1.7%
Male	1.8%	2.0%	0.5%	1.5%	-1.0%
Female	1.3%	1.5%	-1.2%	1.3%	-2.5%
Age Group (includes both sexes)					
< 1	-0.3%	2.4%	-0.3%	0.6%	-0.9%
1 - 4	2.3%	1.8%	-2.4%	-9.3%	6.3%
5 - 14	1.2%	1.5%	-0.9%	-2.2%	1.3%
15 - 24	1.7%	1.4%	5.6%	5.6%	0.0%
25 - 34	1.0%	1.4%	-2.1%	0.4%	-2.5%
35 - 44	2.0%	1.6%	-0.5%	0.8%	-1.3%
45 - 54	1.2%	2.6%	5.2%	1.6%	3.7%
55 - 64	2.1%	1.4%	4.1%	1.3%	2.9%
65 - 74	2.1%	2.0%	2.1%	0.8%	1.3%
75 - 84	0.9%	1.9%	-1.1%	1.6%	-2.7%
85+	0.6%	0.8%	-9.0%	2.1%	-11.4%

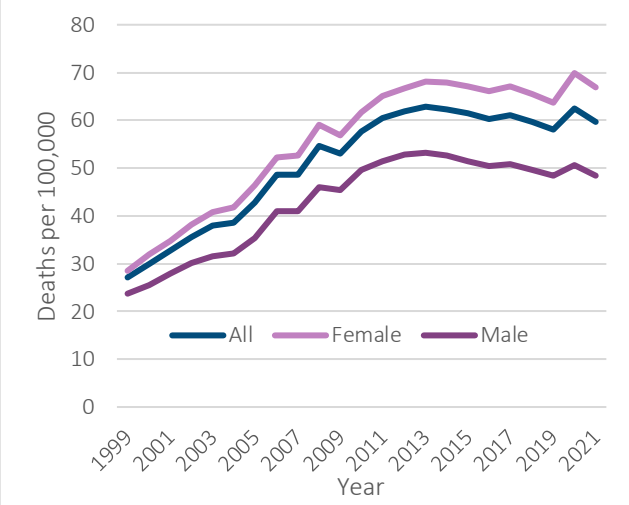
5.6 ALZHEIMER'S/DEMENTIA

The cumulative mortality improvement rate over 2019-2021 for Alzheimer's/dementia was -3.0%. This fell between the average annual rates of mortality improvement of -6.9% for 1999-2009 and -0.9% for 2009-2019. Males had higher mortality improvement, which was flat at 0.0% in 2019-2021 vs. females at -4.8%. That aligned with the long-term trend where male average annual mortality improvement rates were higher than the corresponding average annual female rates in both prior ten-year periods, but with a larger difference. The short-term trend showed that both males and females had lower one-year improvement rates in 2020 vs. 2021. The degree of the reversal was larger for females than males.

Age group cumulative mortality improvement during 2019-2021 varied widely by age, but deaths before age 65 were very low with little overall impact on total mortality. The 2019-2021 cumulative mortality improvement rates for senior ages 65 and higher ranged from -5.6% for age group 65-74 to -1.2% for age group 75-84. Each of the senior age groups 2019-2021 cumulative mortality improvement rate was lower than its average annual 2009-2019 rate and, in the case of ages 65-74, was lower than its average annual 1999-2009 mortality improvement rate. Each of the senior ages had positive one year mortality improvement in 2021. This stands in contrast to the longer term prior ten-year periods ending in 2009 and 2019 where the average annual mortality improvement rate was negative for each age in both periods. There was a large reversal of negative one-year mortality improvement in 2020 to positive mortality improvement in 2021.

Figure 4

2021 ALZHEIMER'S/DEMENTIA HISTORICAL MORTALITY RATES AND MORTALITY IMPROVEMENT BY SELECTED PERIODS



All Ages	Average Annual Improvement		Cumulative Improvement	Average Annual Improvement	
	1999-2009	2009-2019	2019-2021	2019-2020	2020-2021
All	-6.9%	-0.9%	-3.0%	-7.9%	4.5%
Male	-6.7%	-0.7%	0.0%	-4.6%	4.4%
Female	-7.2%	-1.1%	-4.8%	-9.6%	4.4%
Age Group (includes both sexes)					
< 1					
1 - 4					
5 - 14					
15 - 24					
25 - 34					
35 - 44		5.2%	-15.2%		
45 - 54	-8.6%	1.2%	9.6%	7.9%	1.8%
55 - 64	-5.6%	-2.1%	-2.3%	-6.7%	4.1%
65 - 74	-5.1%	-1.3%	-5.6%	-13.6%	7.0%
75 - 84	-6.7%	-0.4%	-1.2%	-8.3%	6.5%
85+	-7.2%	-1.1%	-3.6%	-7.2%	3.4%

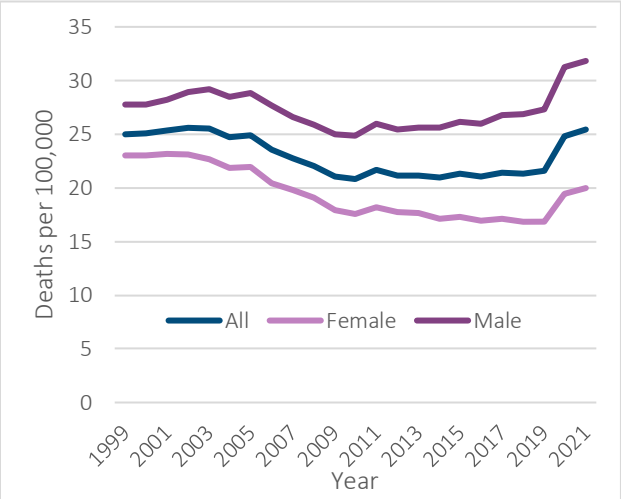
5.7 DIABETES

The cumulative mortality improvement rate over 2019-2021 for diabetes was -17.7%. This was substantially lower than the average annual rates of mortality improvement of 1.7% for 1999-2009 and -0.3% for 2009-2019. Males had slightly higher cumulative mortality improvement at -16.4% in 2019-2021 than females at -18.8%. That contrasted to the long-term trend where female average annual mortality improvement rates were higher than the corresponding average annual male rates in both prior ten-year periods. The short-term trend showed that both males and females had lower one-year mortality improvement rates in 2020 vs. 2021. The degree of the reversal was only slightly higher for females than males.

Each age group had negative 2019-2021 cumulative mortality improvement in this two-year period that was substantially less than the average annual mortality improvement rates in the two ten-year periods ending in 2009 and 2019. The most extreme negative mortality improvement in this two-year period occurred for the youngest ages that had the lowest death rates. Although variable within the trend, two-year cumulative mortality improvement generally increased with age. Focusing on ages 45 and higher, the two-year mortality improvement rate ranged from -20.2% for ages 45-54 to -13.3% for ages 65-74. Each of the age groups 45-54 and older saw higher mortality improvement rates in 2021 vs. 2020.

Figure 5

2021 DIABETES HISTORICAL MORTALITY RATES AND MORTALITY IMPROVEMENT BY SELECTED PERIODS



All Ages	Average Annual Improvement		Cumulative Improvement	Average Annual Improvement	
	1999-2009	2009-2019	2019-2021	2019-2020	2020-2021
All	1.7%	-0.3%	-17.7%	-14.9%	-2.4%
Male	1.1%	-0.9%	-16.4%	-14.2%	-2.0%
Female	2.5%	0.6%	-18.8%	-15.5%	-2.8%
Age Group (includes both sexes)					
< 1					
1 - 4					
5 - 14	1.0%	1.1%	-81.3%	-115.4%	15.8%
15 - 24	0.4%	-4.2%	-37.8%	-26.2%	-9.2%
25 - 34	-0.2%	-2.7%	-46.3%	-31.3%	-11.4%
35 - 44	-0.5%	-1.7%	-27.6%	-28.9%	1.0%
45 - 54	0.1%	-2.0%	-20.2%	-20.4%	0.1%
55 - 64	1.7%	-1.3%	-19.0%	-16.2%	-2.4%
65 - 74	2.7%	-0.5%	-13.3%	-14.1%	0.7%
75 - 84	2.0%	0.5%	-15.4%	-11.3%	-3.7%
85+	1.1%	0.8%	-19.4%	-13.0%	-5.6%

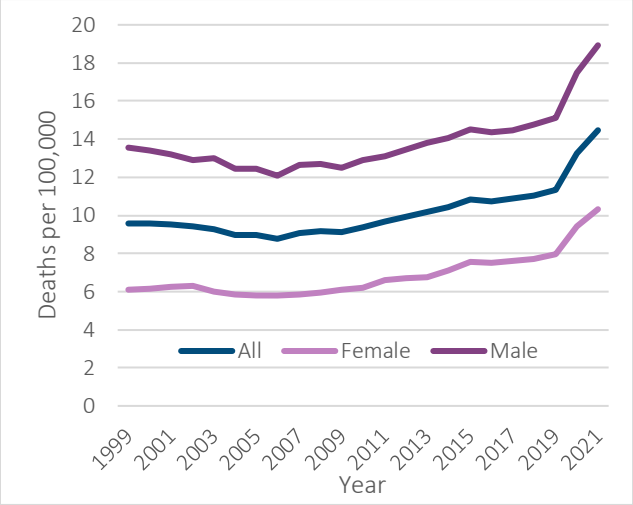
5.8 LIVER

The cumulative mortality improvement rate over 2019-2021 for liver was -27.6%. This was substantially lower than the average annual rates of mortality improvement of 0.4% for 1999-2009 and -2.2% for 2009-2019. Males had less adverse mortality improvement at -25.4% in 2019-2021 than females at -29.8%. That aligned with the long-term trend where male average annual mortality improvement rates were higher than the corresponding average annual female rates in both prior ten-year periods. The short-term trend showed that both males and females had lower one-year mortality improvement rates in 2020 vs. 2021. The degree of the reversal was slightly higher for females than males.

Each age group had negative 2019-2021 cumulative mortality improvement in this two-year period that was substantially less than the average annual improvement rates in the two ten-year periods ending in 2009 and 2019. The most extreme negative cumulative mortality improvement in this two-year period occurred for the youngest ages that had much lower death rates. These mortality improvement rates generally increased with age with a low of -77.1% for age group 15-24 to a high of -13.0% for age group 75-84. Except for ages 85+, each of the other age groups saw higher mortality improvement, albeit with negative rates, in 2021 vs. 2020. The change of mortality improvement in 2021 vs. 2020 decreased by age. Ages 85+ saw lower mortality improvement in 2021 vs. 2020 where its -15.0% one-year 2021 mortality improvement rate comprised most of its -17.0% 2019-2021 cumulative two-year mortality improvement.

Figure 6

2021 LIVER HISTORICAL MORTALITY RATES AND MORTALITY IMPROVEMENT BY SELECTED PERIODS



All Ages	Average Annual Improvement		Cumulative Improvement	Average Annual Improvement	
	1999-2009	2009-2019	2019-2021	2019-2020	2020-2021
All	0.4%	-2.2%	-27.6%	-16.9%	-9.1%
Male	0.8%	-1.9%	-25.4%	-15.9%	-8.2%
Female	0.0%	-2.7%	-29.8%	-18.7%	-9.4%
Age Group (includes both sexes)					
< 1					
1 - 4					
5 - 14					
15 - 24	2.4%	-3.9%	-77.1%	-42.9%	-24.0%
25 - 34	-1.1%	-7.9%	-66.5%	-46.3%	-13.8%
35 - 44	2.0%	-3.2%	-63.8%	-42.9%	-14.7%
45 - 54	-0.7%	-0.6%	-30.3%	-18.8%	-9.6%
55 - 64	-0.9%	-2.7%	-21.8%	-12.4%	-8.3%
65 - 74	1.9%	-2.7%	-16.2%	-10.5%	-5.1%
75 - 84	1.6%	-1.7%	-13.0%	-7.1%	-5.5%
85+	0.9%	-2.3%	-17.0%	-1.7%	-15.0%

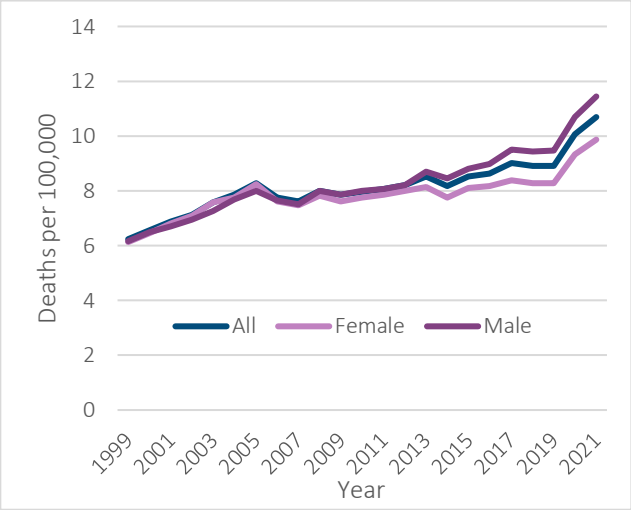
5.9 HYPERTENSION

The cumulative mortality improvement rate over 2019-2021 for hypertension was -20.0%. This was substantially lower than the average annual rates of mortality improvement of -2.3% for 1999-2009 and -1.3% for 2009-2019. Males had more adverse two-year mortality improvement of -20.7% in 2019-2021 than females at -19.3%. That aligned with the long-term trend where male average annual mortality improvement rates were lower than the corresponding average annual female rates in both prior ten-year periods. The short-term trend showed that both males and females had lower one-year improvement rates in 2020 vs. 2021. The degree of higher mortality improvement in 2021 than 2020 was slightly higher for females than males.

Each age group 25-34 and older had negative 2019-2021 cumulative mortality that was substantially less than the average annual mortality improvement rates in the two ten-year periods ending in 2009 and 2019. The most extreme negative cumulative mortality improvement in this two-year period occurred for the youngest ages shown that have much lower death rates. Focusing on age groups 55-64 and older that have over 93% of the combined 2020 and 2021 hypertension deaths, the two-year cumulative mortality improvement rates generally increased by age with a low of -24.2% for age group 55-64 to a high of -16.4% for age group 75-84. Each of these age groups saw higher mortality improvement, albeit with negative rates, in 2021 vs. 2020, but the change of one-year mortality improvement in 2021 vs. 2020 decreased with increasing age from age group 55-64 to age group 85+.

Figure 7

2021 HYPERTENSION HISTORICAL MORTALITY RATES AND MORTALITY IMPROVEMENT BY SELECTED PERIODS



All Ages	Average Annual Improvement		Cumulative Improvement	Average Annual Improvement	
	1999-2009	2009-2019	2019-2021	2019-2020	2020-2021
All	-2.3%	-1.3%	-20.0%	-13.1%	-6.1%
Male	-2.4%	-1.9%	-20.7%	-12.8%	-7.0%
Female	-2.2%	-0.8%	-19.3%	-13.0%	-5.6%
Age Group (includes both sexes)					
< 1					
1 - 4					
5 - 14					
15 - 24					-3.1%
25 - 34	-4.2%	0.7%	-38.1%	-18.9%	-16.2%
35 - 44	-4.2%	-1.3%	-29.3%	-14.8%	-12.6%
45 - 54	-3.6%	-1.6%	-32.9%	-24.8%	-6.5%
55 - 64	-2.5%	-3.3%	-24.2%	-20.4%	-3.1%
65 - 74	-0.7%	-2.5%	-18.9%	-14.1%	-4.2%
75 - 84	-1.6%	-0.6%	-16.4%	-11.0%	-4.9%
85+	-3.2%	-0.9%	-19.3%	-10.2%	-8.2%

5.10 ACCIDENTS EXCLUDING OPIOIDS

The cumulative mortality improvement rate over 2019-2021 for accidents excluding opioids was -18.0%. This continued the trend of negative mortality improvement prior to the pandemic but was much more extreme than the average annual mortality improvement over 2009-2019 of -0.9%. Accidents excluding opioids had negative one-year mortality improvement that was more adverse in 2021, at -10.3%, than it was in 2020, at -7.0%. Motor vehicle accidents (MVA) and falls are the largest portion of this COD's deaths. During the 2019-2021 period, they had cumulative two-year mortality improvement rates of -19.8% and -16.8%, respectively. The 2021 one-year mortality improvement of MVAs at -10.2% in 2021 was more adverse than in 2020 at -8.7%. The 2021 one-year MVA mortality improvement was the most adverse of any year during the span of this report and was more adverse than the next lowest pre-COVID -6.5% MVA 2016 mortality improvement rate[7]. Males had slightly lower two-year cumulative mortality improvement of -17.7% in 2019-2021 than females at -17.1%, but within the two-year period, males had lower one-year mortality improvement in 2020 than females and higher mortality improvement than females in 2021. During the one-year period ending 2021, male and female mortality improvement decreased from 2020 one-year mortality improvement rates by 2.0% and 5.8%, respectively.

For accidents excluding opioids, age group cumulative mortality improvement during 2019-2021 varied by age in a wave-like pattern and every age group with available data[8] had negative cumulative mortality improvement over this two-year period. The two-year cumulative improvement rates for age groups 1-4 and 85+ were similar at -16.2% and -18.1%, respectively. Within the range of those two age groups, the two-year cumulative mortality improvement rate undulated to a low of -27.1% for age group 25-34 and a high of -9.6% for age group 75-84. Within the two-year period, one-year mortality improvement rates had a seesaw-type pattern in both 2020 and 2021. Taken together, the progression revealed a convex or hump-shaped pattern by age of the change in one-year mortality improvement for 2020 vs. 2021. Although all age group one-year 2021 mortality improvement rates were negative, their change from 2020 to 2021 was positive for age groups from 15-24 through 45-54 and had a negative change for all other age groups. The maximum change of the one-year mortality improvement rates from 2021 vs. 2020 was 10.9% for age group 15-24 and the minimum corresponding change was -14.6% for age group 85+.

Figure 8

2021 ACCIDENTS EXCL OPIOIDS HISTORICAL MORTALITY RATES AND MORTALITY IMPROVEMENT BY SELECTED PERIODS

All Ages	Average Annual Improvement		Cumulative Improvement	Average Annual Improvement	
	1999-2009	2009-2019	2019-2021	2019-2020	2020-2021
All	0.4%	-0.9%	-18.0%	-7.0%	-10.3%
Male	0.5%	-0.9%	-17.7%	-7.5%	-9.5%
Female	0.1%	-0.9%	-17.1%	-5.3%	-11.2%
Age Group (includes both sexes)					
< 1					
1 - 4			-16.2%	-1.3%	-14.7%
5 - 14		1.3%	-12.2%	-3.2%	-8.8%
15 - 24	3.4%	2.2%	-16.9%	-13.7%	-2.8%
25 - 34	0.5%	-0.3%	-27.1%	-16.3%	-9.3%
35 - 44	0.6%	-1.1%	-25.6%	-13.3%	-10.9%
45 - 54	-1.9%	-0.4%	-17.8%	-9.8%	-7.3%
55 - 64	-0.5%	-3.0%	-17.8%	-8.3%	-8.7%
65 - 74	0.8%	-1.9%	-12.7%	-2.1%	-10.4%
75 - 84	-0.3%	-1.1%	-9.6%	1.9%	-11.8%
85+		-2.0%	-18.1%	-1.6%	-16.2%

[7] https://wonder.cdc.gov/Deaths-by-Underlying-Cause.html

[8] Accidents excluding opioids are derived by subtracting accidents with opioids from accidents. Because accidents excluding opioids are suppressed by WONDER for some ages with low death counts, accidents excluding opioids cannot be calculated for those ages.

5.11 OPIOIDS

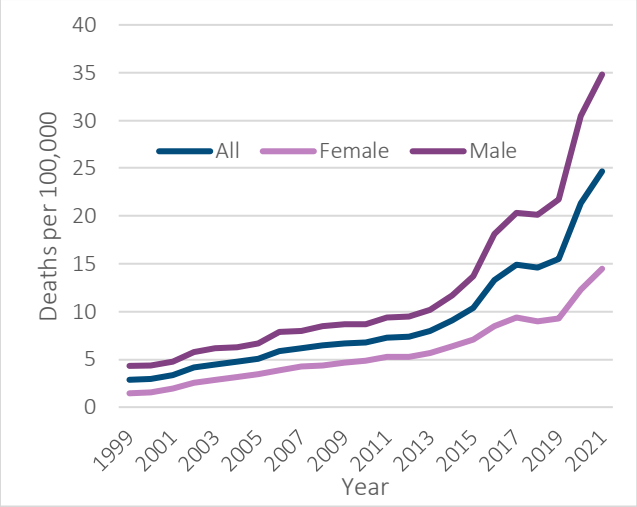
The cumulative mortality improvement rate over 2019-2021 for opioids, which intersects a key component of accident deaths, was -59.5%. This was a radical deterioration of mortality improvement that moderated in 2018-2019 from earlier high deterioration during 2014-2017. The extreme one-year 2020 mortality improvement of -38.0% was the lowest one-year mortality improvement during the span of this study and was followed by -15.6% one-year mortality improvement in 2021. Males had slightly lower cumulative mortality improvement of -60.5% in 2019-2021 than females at -55.7%, but within the two-year period, males had lower one-year mortality improvement in 2020 than females and higher improvement than females in 2021. Female annual mortality improvement increased from -32.4% in 2020 to -17.7% in 2021 and male mortality improvement increased from -40.3% in 2020 to -14.4% in 2021.

Age group cumulative mortality improvement during 2019-2021 varied in a step-like pattern where succeeding age groups generally had higher, although all negative, mortality improvement rates. The youngest ages had the lowest mortality improvement rates substantially below -100% that stepped up to a plateau from ages 15-24 to 65-74, where mortality improvement rates were in a range from -67.9% to -53.9%, and then increased again to -16.0% and -25.9% for age groups 75-84 and ages 85+, respectively. There was a generally decreasing pattern by age of the change from 2020 to 2021 of one-year mortality improvement rates for age-groups 5-14 and higher. Although all those age groups had negative one-year mortality improvement ending in 2021, age groups 5-14 through 55-64 had positive 2021 vs. 2020 changes, while age groups 65-74 and higher had negative changes during the same period. Age groups 5-14 and 55-64 had mortality improvement rates that changed by 80.9 and 7.0 percentage points, respectively, while age groups 65-74 and 85+ had mortality improvement rates that changed by -4.5 and -15.5 percentage points, respectively. The lowest change in the 2020 to 2021 improvement rate was -31.7 percentage points in age group 75-84.

The online Tableau "Opioid Deaths by Opioid Type and County Quintile Group" dashboard (included as companion information to this study) provides perspective on the source of overdose types across the span of this report. In recent years, tramadol and fentanyl experienced a -91.3% cumulative mortality improvement rate over 2019-2021. The cumulative mortality improvement rate was comprised of negative mortality improvement that lessened in degree, going from one-year mortality improvement of -55.6% in 2020 to -22.9% in 2021. Heroin, methadone and natural and semi-synthetic opioids had 2019-2021 cumulative mortality improvement of 36.7%, -32.5% and -13.2%, respectively. Heroin, methadone and natural and semi-synthetic opioids also saw higher mortality improvement rates in 2021 than 2020. The 2020 and 2021 mortality improvement rates for heroin were 6.5% and 32.3%, respectively; methadone were -30.9% and -1.3%, respectively; and natural and semi-synthetic opioids were -13.7%, and 0.4%, respectively. Because opioid death rates for heroin, methadone and natural and semi-synthetic opioids are much lower than tramadol and fentanyl overdoses, they have less impact on the total opioid death statistics.

Figure 9

2021 OPIOIDS DEATHS PROFILE AND MORTALITY IMPROVEMENT BY SELECTED PERIODS



All Ages	Average Annual Improvement		Cumulative Improvement	Average Annual Improvement	
	1999-2009	2009-2019	2019-2021	2019-2020	2020-2021
All	-8.7%	-8.9%	-59.5%	-38.0%	-15.6%
Male	-7.2%	-9.6%	-60.5%	-40.3%	-14.4%
Female	-12.3%	-7.2%	-55.7%	-32.4%	-17.7%
Age Group (includes both sexes)					
< 1					-87.7%
1 - 4		-4.0%	-175.9%	-50.9%	-82.9%
5 - 14		-2.6%	-128.1%	-96.8%	-15.9%
15 - 24	-12.3%	-5.5%	-67.9%	-61.2%	-4.1%
25 - 34	-10.0%	-10.5%	-53.9%	-36.7%	-12.6%
35 - 44	-4.7%	-10.2%	-63.0%	-40.6%	-16.0%
45 - 54	-9.5%	-6.2%	-56.5%	-34.0%	-16.7%
55 - 64	-16.8%	-10.4%	-62.6%	-31.1%	-24.1%
65 - 74	-13.8%	-12.7%	-61.8%	-25.0%	-29.5%
75 - 84	-7.4%	-6.3%	-16.0%	7.0%	-24.7%
85+		-3.1%	-25.9%	-4.7%	-20.2%

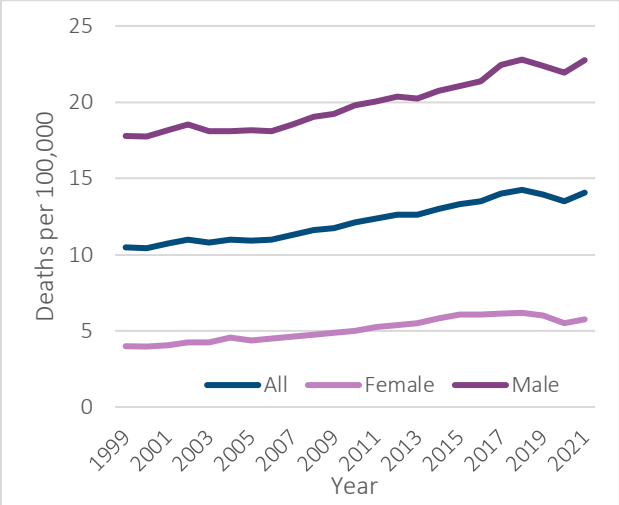
5.12 SUICIDE

The cumulative mortality improvement rate over 2019-2021 for suicide was -1.1%. Although negative, that mortality improvement rate, uncharacteristic of most CODs, was higher than the long-term average annual mortality improvement of -1.2% for 1999-2009 and -1.7% for 2009-2019. Males had notably lower two-year cumulative mortality improvement of -1.8% in 2019-2021 than females at 4.6%. That continued the long-term trend where male average annual mortality improvement rates were lower than the corresponding average annual female rates in both prior ten-year periods, but during those two years of the pandemic, that gap was much wider. The short-term trend showed that both males and females had lower one-year mortality improvement rates in 2021 vs. 2020 and that they were positive one-year mortality improvements in 2020 that swung to negative in 2021.

Age group cumulative mortality improvement during 2019-2021 varied by age with no discernable pattern. Age groups spanning ages 5-34 and 75 and above had negative 2019-2021 cumulative mortality improvement. It ranged from -11.3% for ages 85+ to 0.3% for age group 35-44. Age groups spanning ages 45-74 had positive mortality improvement during that time, ranging from 1.2% for age group 65-74 to 12.5% for age group 55-64. All age groups 15-24 and higher had negative one-year mortality improvement in 2021, ranging from -7.3% to -0.5% for age groups 85+ and 55-64, respectively. Age group 5-14 was the only one with positive mortality improvement of 0.8% during that same period.

Figure 10

2021 SUICIDE DEATHS PROFILE AND MORTALITY IMPROVEMENT BY SELECTED PERIODS



All Ages	Average Annual Improvement		Cumulative Improvement	Average Annual Improvement	
	1999-2009	2009-2019	2019-2021	2019-2020	2020-2021
All	-1.2%	-1.7%	-1.1%	3.0%	-4.2%
Male	-0.8%	-1.5%	-1.8%	1.9%	-3.7%
Female	-2.0%	-2.1%	4.6%	8.0%	-3.6%
Age Group (includes both sexes)					
< 1					
1 - 4					
5 - 14	-0.8%	-7.5%	-9.2%	-10.1%	0.8%
15 - 24	0.1%	-3.4%	-8.6%	-2.1%	-6.4%
25 - 34	-0.3%	-3.0%	-11.0%	-4.6%	-6.1%
35 - 44	-1.2%	-1.2%	-0.3%	3.9%	-4.4%
45 - 54	-3.3%	-0.2%	7.2%	8.4%	-1.3%
55 - 64	-3.0%	-1.7%	12.5%	13.0%	-0.5%
65 - 74	-0.2%	-1.2%	1.2%	6.3%	-5.5%
75 - 84	1.3%	-1.6%	-4.9%	1.1%	-6.1%
85+	1.6%	-2.1%	-11.3%	-3.7%	-7.3%

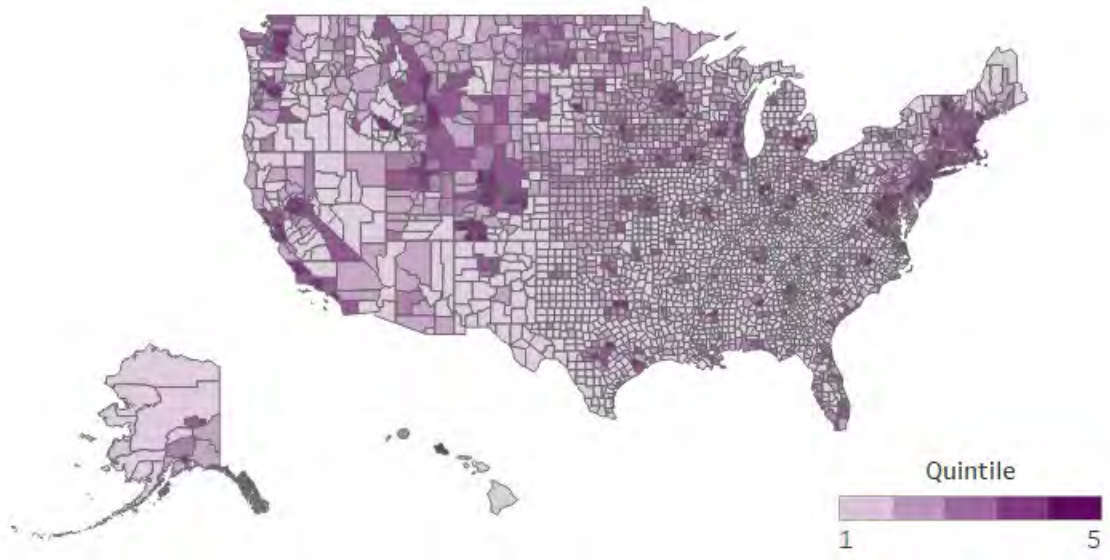
Section 6: Socioeconomic Quintile County Groups

The section provides analysis of experience by socioeconomic status. A Socioeconomic Index Score (SIS)[9] was computed for each county. The counties were then grouped into quintiles with each quintile holding 20% of the total U.S. population. Mortality rates were then calculated for each county quintile grouping as described further in section 8. Quintile group 1 contains the counties with the lowest Socioeconomic Index Score and quintile group 5 contains the counties with the highest Socioeconomic Index Score. The Socioeconomic Index Score used for the groupings in this report takes county-wide variables of education, occupation, employment, income, and housing price and quality into account.

Mortality was analyzed over the entire U.S. population (All Counties) and compared to mortality in the socioeconomic quintile county groups. The map below shows the counties. Generally, quintile groups 1 and 2 are geographically large, but widely dispersed, rural areas. Quintile groups 4 and 5 are mostly, but not exclusively, geographically small metropolitan areas. For example, in addition to major metropolitan areas, quintile 4 regions can be seen in less populated New England areas, the oil patch of North Dakota, and the eastern front of the Sierras in California. Quintile group 3 does not show a distinct urban or rural pattern, but is more geographically prevalent west of the Mississippi River than east of it.

Figure 11

U.S. COUNTIES BY SOCIOECONOMIC QUINTILE GROUP



Generally, with few exceptions, mortality rates by county grouping follow a rank-order of the lowest mortality for quintile group 5 and highest mortality for quintile group 1. There is a corresponding rank-order pattern for mortality improvement, which is generally highest for quintile group 5 and lowest for quintile group 1. Important differences occur in the range of mortality improvement by quintile as it changes over time and by the range of quintile mortality rates to

[9] Society of Actuaries. Mortality by Socioeconomic Category in the United States. https://www.soa.org/resources/research-reports/2020/us-mort-rate-socioeconomic/. November 2020.

all quintiles by COD. These differences are important indicators of whether experience is more or less than average by quintile, both as point in time snapshots and measures of change over time.

The range of mortality rates for all causes of death by quintile relative to all quintiles expressed as a percentage widened during 2020 and 2021. The high to low range of these percentages for all causes of death widened from 37.0% in 2019 to 48.6% in 2021. The 11.6% increase of the range was due to a 6.0% increase in quintile 1 and a 5.6% decrease in quintile 5. The corresponding ranges in 2020 and 2021 for all causes excluding COVID also increased, but to a lesser degree than for all causes of death, from 2020 to 2021 going from 40.2% to 43.1%, but the range for COVID for the same period was higher than excluding COVID, which jumped substantially in 2021 to 89.5% from 42.2% in 2020. The increase of the quintile percentage index range from 2020 to 2021 was 8.2% for all causes of death and 2.9% excluding COVID. This implies that the large COVID quintile range in 2021 was a large driver that contributed 5.3% of the total 8.2%, or proportionally 65%, of the change in the 2021 quintile range for all causes of death.

Table 6

2019-2021 U.S. POPULATION COUNTY QUINTILE DEATH RATES AS A PERCENTAGE OF ALL QUINTILES

Quintile	All Causes			All Causes Excluding COVID		COVID	
	2019	2020	2021	2020	2021	2020	2021
1 – Lowest SIS	120.3%	122.6%	126.3%	121.9%	123.5%	128.8%	146.7%
2	105.4%	104.7%	108.1%	105.6%	106.7%	96.6%	118.6%
3	100.7%	100.8%	100.3%	101.2%	100.7%	98.2%	97.1%
4	91.8%	91.4%	90.2%	91.4%	90.9%	91.0%	84.5%
5 – Highest SIS	83.3%	82.2%	77.7%	81.7%	80.4%	86.6%	57.2%
High-Low	**37.0%**	**40.4%**	**48.6%**	**40.2%**	**43.1%**	**42.2%**	**89.5%**

As shown in Table 7, mortality improvement rates for all causes of death widened substantially by quintile during the pandemic relative to earlier periods. This widening occurred for both two-year cumulative mortality improvement ending 2021 and one-year improvement from 2020-2021, whether COVID was included or excluded. The range of the mortality improvement rates without COVID substantially exceeded the pre-pandemic ranges, which were narrowing during the two ten-year periods ending 2009 and 2019. The widened range by quintile of COVID experience discussed earlier is evident in the wider range in the with COVID results than the without COVID results during the pandemic period.

Table 7

U.S. POPULATION COUNTY QUINTILE MORTALITY IMPROVEMENT BY SELECTED PERIODS

Quintile	Average Annual Improvement		Cumulative 2021 Improvement			
			With COVID		Without COVID	
	1999-2009	2009-2019	Since 2019	Since 2020	Since 2019	Since 2020
1 – Lowest SIS	1.1%	0.2%	-29.1%	-8.5%	-11.3%	-4.7%
2	1.4%	0.3%	-26.2%	-8.8%	-9.9%	-4.4%
3	1.6%	0.4%	-22.5%	-4.7%	-8.5%	-2.9%
4	1.7%	0.6%	-20.8%	-3.9%	-7.4%	-2.8%
5 – Highest SIS	2.1%	0.7%	-14.7%	0.5%	-4.7%	-1.8%
All	1.5%	0.5%	-23.0%	-5.3%	-8.4%	-3.3%
High-Low	**1.0%**	**0.6%**	**14.4%**	**9.2%**	**6.6%**	**3.0%**

Quintile mortality rates as a percentage of the national death rate showed notable variation by COD in 2021. The range of those values, which is equal to the highest percentage minus the lowest percentage varied by COD. Table 8 shows the five highest and lowest ranges of the CODs featured in this report and as a baseline the range for all causes of death. Two natural CODs, Alzheimer's/dementia and cancer, had the lowest and next lowest range of 16% and 27%, respectively, which implies that socioeconomic location has less of an effect for those two CODs than it does for all causes of death. And, although opioids have experienced high mortality rates, their impact was also distributed more evenly across quintile locations where their range was 33% compared to the 49% range for all causes of death. Assault and COVID had the highest quintile ranges. Assault quintile mortality rates to national percentages spanned a range of 91% where the quintile 1 mortality rate was 268% of the quintile 5 mortality rate. COVID had a range of 90% and a quintile 1 rate that was 256% of the quintile 5 rate. As discussed earlier, the wide range of COVID mortality rates played a large part in widening the quintile range of all causes of death in the same time period.

Table 8

2021 U.S. POPULATION COUNTY QUINTILE DEATH RATES AS A PERCENTAGE OF ALL QUINTILES BY SELECTED COD

Cause of Death	Quintile High minus Low	Quintile				
		1 Lowest SIS	2	3	4	5 Highest SIS
Alzheimer's/Dementia	16%	109%	101%	99%	97%	93%
Cancer	27%	115%	105%	100%	94%	88%
Stroke	29%	115%	107%	100%	94%	86%
Opioids	33%	113%	103%	112%	95%	81%
Hypertension	39%	123%	103%	94%	98%	84%
All Causes	**49%**	**126%**	**108%**	**100%**	**90%**	**78%**
Accidents excluding Opioids	67%	136%	113%	103%	86%	69%
Diabetes	72%	139%	112%	97%	88%	67%
Pulmonary	84%	147%	112%	96%	84%	63%
COVID	90%	147%	119%	97%	85%	57%
Assault	91%	145%	117%	121%	76%	54%

Section 7: Additional Supporting Material

The remaining content of the report is online in three interactive dashboards, which can be found on the same webpage where the pdf of this report is located. In the dashboards, the 13 listed CODs are also shown on a combined basis by physiological and external causes, plus an option to see All CODs without COVID. Given the continued interest in opioid-related deaths, opioids are shown as a COD, as are the accidents excluding opioids analysis, and they are shown in an exhibit of deaths by opioid type for all ages and sexes. The COD variation of interest can be viewed in the first two dashboards by using a drop-down box at the top right of the data board. The "U.S. Population Mortality by Sex" dashboard includes a graph of age-adjusted death rates from 1999-2021 by sex and both sexes combined, and a related table with corresponding average annual mortality improvement rates. The table shows experience by sex for all ages combined and by combined sex for age groups[10]. The 2021 average annual mortality improvement rates are shown over the 1999 to 2009 and the 2009 to 2019 time periods, along with cumulative improvement from 2019 to 2021 and from 2020 to 2021. The drop-down box below the COD choice enables the by sex analysis to be filtered by a selected county quintile group. The "U.S. Population Mortality by County Socioeconomic Quintile Group" dashboard is like the "U.S. Population Mortality by Sex" dashboard, except that the graph shows county variation rather than sex variation with a drop-down box choice to filter by a selected sex. The third dashboard, "Opioid Deaths by Opioid Type and County Quintile Group," shows the exhibit of opioid deaths by opioid type with variation by county quintile group for all ages and sexes combined. All data supporting this report and the dashboards are included in an appendix in the form of an Excel file that can be found on the same webpage where this report and these dashboards are located.

[10] The accidents excluding opioids COD variation does not contain any experience by age group for the county income groups other than 'All Counties.'

Section 8: Methodology

The source of the mortality rates found in this report was the Centers for Disease Control and Prevention's (CDC) Wide-ranging Online Data for Epidemiologic Research (WONDER) database, released in January 2023[11].

To analyze mortality by socioeconomic status, a Socioeconomic Index Score[12] was computed for each county. The counties were then grouped into quintiles with each quintile holding 20% of the total U.S. population. Counties in each of the quintile county groups were entered into WONDER and mortality rates for the group were retrieved. Quintile group 1 contains the counties with the lowest Socioeconomic Index Score, or the lowest socioeconomic status, and quintile group 5 contains the counties with the highest Socioeconomic Index Score, or the highest socioeconomic status. The county groups were held constant over the 1999-2021 period and based on total U.S. data from 2008-2012. Any reference to "All Counties" refers to the entire U.S. population or all U.S. counties.

The mortality rates from WONDER are based on annual death data and, generally, mid-year populations. For any mortality rate calculation, deaths for age x are equal to calendar year deaths between ages x and x+1 and the populations are estimates from the U.S. Census Bureau. See the CDC WONDER 'Dataset Documentation' for more information[13].

Age group mortality rates in this report are derived using calendar-year deaths and population from WONDER with rates per 100,000 rounded to six decimal places. All subsequent calculations for mortality improvement and age-adjusted mortality rates use these rounded rates.

Mortality improvement rates in this report are expressed in geometric average annual and cumulative rates of improvement. They are derived as follows for age x over an n year period ending in calendar year CY.

Average annual rate of improvement:

$$1 - \left(\frac{q_x^{CY}}{q_x^{CY-n}} \right)^{\left(\frac{1}{n}\right)}$$

Cumulative rate of improvement:

$$1 - \left(\frac{q_x^{CY}}{q_x^{CY-n}} \right)$$

[11] Centers for Disease Control and Prevention, National Center for Health Statistics. CDC WONDER Online Database, released in 2023. Underlying Cause of Death data are from 1999-2020 Underlying Cause of Death by Bridged-Race Categories database and 2018-2021 Underlying Cause of Death by Single-Race Categories database, https://wonder.cdc.gov/Deaths-by-Underlying-Cause.html. Multiple Cause of Death data are from 1999-2020 Current Final Multiple Cause of Death by Bridged-Race Categories database and 2018-2021 Current Final Multiple Cause of Death by Single Race Categories database, https://wonder.cdc.gov/mcd.html. Data was compiled from bridged-race categories for 1999-2020 and single-race categories for 2021. Data queries were cross checked by comparing 2018-2020 of the bridged-race to 2018-2020 of the single-race data. Data was accessed on various dates January 2023.

[12] Society of Actuaries. Mortality by Socioeconomic Category in the United States. https://www.soa.org/resources/research-reports/2020/us-mort-rate-socioeconomic/. November 2020.

[13] Source: https://wonder.cdc.gov/wonder/help/ucd.html#

All mortality rates shown in this report, other than those shown for ten-year age groups, are age-adjusted rates based on the CDC's 2000 U.S. Standard Population. This is a change from prior reports that used the non-standard population in 2010, which was chosen for those reports because 2010 was more central to the mid-point of the years evaluated. That option was eliminated with this year's data release. The 2000 standard population was chosen based on year 2000 being the closest of the options available to the range of years evaluated in this report. To achieve consistent comparisons across sex, all age-adjusted rates were determined using the 2000 combined female and male age group distribution. Age-adjusted mortality rates and improvement in this report are based on age only with no demographic adjustments for mixes of sex or race.

Age-adjusted rates in this report are calculated as follows using 2000 as the base year and rounded to six decimal places.

$$\sum_{n=1}^{11} Pct_{Age_n} * q_{Age_n}$$

Where:

Age_n = Age group *n* (11 age groups)

Pct_{Age_n} = % of age group *n* 2000 Population

q_{Age_n} = Calendar year crude q_x for age group *n*

Attributions of 2019-2021 cumulative mortality improvement by ages and CODs shown in section 4 are determined as follows:

Age Group Attribution

Age group n attribution to all ages improvement is:

$$\frac{Pct_{Age_1} * q_{Age_1}}{\sum_{n=1}^{11} Pct_{Age_n} * q_{Age_n}} * Improvement_{Age_1}$$

Where:

Age_n = Age group *n* (11 age groups)

Pct_{Age_n} = % of age group *n* 2000 Population

q_{Age_n} = 2019 Crude q_x for age group *n*

$Improvement_{Age_n}$ = Age group *n* 2021 cumulative mortality improvement rate from 2019

q_{Age_n} and $Improvement_{Age_n}$ are based on crude rates per 100,000 lives rounded to one decimal place, which is consistent with age-adjustment calculation methodology[14].

[14] Source: https://wonder.cdc.gov/wonder/help/ucd.html#

COD Attribution

COD is simpler because COD mortality improvement is already expressed on an age-adjusted basis. Unrounded values are used.

COD_n, attribution to all causes mortality improvement is:

$$\frac{q^{COD_n}}{q^{COD_{All}}} * Improvement_{COD_n}$$

Where:

q^{COD_n} = 2019 COD_n age-adjusted mortality rate

$q^{COD_{All}}$ = 2019 age-adjusted mortality rate for all causes of mortality

$Improvement_{COD_n}$ = COD_n 2021 cumulative mortality improvement rate from 2019

To meet the CDC's privacy data use requirements, calculated annual improvement values are not shown for age groups where the number of deaths for that age group was less than ten in any one year.

The NCHS's rankable causes of death are a subset of its "113 Selected Causes of Death." The selected 13 causes of death covered in the report are, with four exceptions, the top five rankable causes of death in 2021 for each of the ten-year age and sex groups available in WONDER. Because of limited interest, two of the top five rankable CODs that were present up to age 14 were excluded[15], while flu & pneumonia and hypertension, which were not in the top five rankable causes, were included due to interest in those CODs. Below is a table of the 13 selected causes of death covered in this report and their International Classification of Diseases, Tenth Revision[16] (ICD-10) 113 Code and Cause List as they appear in WONDER.

Report Cause of Death	ICD-10 113 Code	ICD-10 113 Cause List (with ICD-10 codes)
Physiological:		
Alzheimer's/Dementia[17]	GR113-052	#Alzheimer's disease (G30)
Cancer	GR113-019	#Malignant neoplasms (C00-C97)
COVID	GR113-137	COVID-19 (U07.1)
Diabetes	GR113-046	#Diabetes mellitus (E10-E14)
Flu/Pneumonia	GR113-076	#Influenza and pneumonia (J09-J18)
Heart	GR113-054	#Diseases of heart (I00-I09, I11, I13, I20-I51)
Hypertension	GR113-069	#Essential hypertension and hypertensive renal disease (I10, I12, I15)
Liver	GR113-093	#Chronic liver disease and cirrhosis (K70, K73-K74)
Pulmonary	GR113-082	#Chronic lower respiratory diseases (J40-J47)
Stroke	GR113-070	#Cerebrovascular diseases (I60-I69)
External:		
Accidents	GR113-112	#Accidents (unintentional injuries) (V01-X59, Y85-Y86)
Assault	GR113-127	#Assault (homicide) (*U01-*U02, X85-Y09, Y87.1)
Suicide	GR113-124	#Intentional self-harm (suicide) (*U03, X60-X84, Y87.0)

[15] GR113-108 - Certain conditions originating in the perinatal period (P00-P96), present at age less than one and GR113-109 - Congenital malformations, deformations and chromosomal abnormalities (Q00-Q99), present up to age 14.

[16] World Health Organization https://icd.who.int/browse10/2016/en

[17] Dementia is not one of the NCHS's rankable causes of death but has been included with the review of Alzheimer's. The ICD-10 codes for Dementia are (F01, F03)

For opioid deaths by opioid type, the method to identify drug overdose deaths involving opioids was taken from the Increases in Drug Overdose Deaths in the United States, 1999–2018[18]. These deaths were identified by the ICD-10 underlying cause-of-death codes X40–44 (unintentional), X60–64 (suicide), X85 (homicide), or Y10–Y14 (undetermined intent) in combination with any one of the following multiple cause-of-death codes: T40.0 (opium); heroin (T40.1); natural/semisynthetic opioids (T40.2); methadone (T40.3); synthetic opioids other than methadone (T40.4); or other and unspecified narcotics (T40.6).

Appendices with the following data and information can be found in an accompanying Excel file.

A. Age-Adjusted Death Rates used to produce graphs, tables, and observations in this report.
B. Age Group Rates used to produce tables and observations in this report.
C. Age-Adjusted Rates by Opioid Type used to produce tables and observations in this report.
D. Links to sample CDC WONDER queries[19] used to pull values for the 'All' and 'Opioid' CODs analyses.
E. Listings of the counties in each of the five socioeconomic county groups.

[18] Hedegaard H, Miniño AM, Warner M. Drug overdose deaths in the United States, 1999–2018. NCHS Data Brief, no 356. Hyattsville, MD: National Center for Health Statistics. 2020.
[19] The SOA is not responsible if these links do not continue to work and will not update them if they break.

Section 9: Reliance and Limitations

Data to calculate mortality rates in this report were drawn from the Centers for Disease Control and Prevention (CDC) Wide-ranging Online Data for Epidemiologic Research (WONDER) database. There are limited instances where the mortality rates, associated mortality improvement, or comparative results between the quintile county groups and All Counties are not shown. This is because death counts of less than ten for sub-national data are suppressed by WONDER.

Data provided through WONDER is subject to restricted use for health statistical reporting and analysis. This research confines itself to those parameters. While the data may be useful for application in specific purposes, no assessment has been made concerning the applicability of this experience to other such purposes.

Opioid deaths overlap with the accident, assault, and suicide deaths analyzed in this report. The opioid deaths have a meaningful impact on the accident results and, therefore, have been removed from the accident deaths in a separate COD analysis shown as accident excluding opioids. The impact of opioid deaths in the assault and suicide analyses was deemed to be immaterial and, therefore, not included in this report.

This report does not attempt to comment on changes or improvements in the process to record cause of death codes over the report horizon and their potential impact on observations noted in this report. For example, possible limitations regarding the accuracy or completeness of the assignment of COD could affect the determination of the accidents excluding opioids COD in this report. Some of the deaths associated with the increases in 2016-2021 that were not identified as opioid-related to determine the accidents excluding opioid deaths could, in fact, be opioid-related. Insights regarding the mortality reporting process with a focus on COVID were provided by Robert Anderson, Chief of Mortality Statistics at NCHS, in a 2021 podcast[20]. The CDC provided guidance to certifiers on COVID mortality reporting in 2020[21] as an update to the general concepts published in 2003[22]. Potential changes in recording processes should be considered if utilizing the information provided in this report.

[20] Death Certificate Data & COVID-19: Interview with Robert Anderson, Part One (cdc.gov)

[21] https://www.cdc.gov/nchs/data/nvss/vsrg/vsrg03-508.pdf

[22] https://www.cdc.gov/nchs/data/misc/hb_cod.pdf

Section 10: Acknowledgments

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