Excess mortality in the United States in the 21st century

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We use three indexes to identify how age-specific mortality rates in the United States compare to those in a composite of five large European countries since 2000. First, we examine the ratio of age-specific death rates in the United States to those in Europe. These show a sharp deterioration in the US position since 2000. Applying European age-specific death rates in 2017 to the US population, we then show that adverse mortality conditions in the United States resulted in 400,700 excess deaths that year. Finally, we show that these excess deaths entailed a loss of 13.0 My of life. In 2017, excess deaths and years of life lost in the United States represent a larger annual loss of life than that associated with the COVID-19 epidemic in 2020.

mortality | age-specific death rates | international comparisons

It is widely recognized that the United States has fallen behind other wealthy countries in measures of mortality. This phenomenon was highlighted in two volumes by the National Research Council, the first concentrating on ages 50+ y (1) and the second on all ages (2). Related research has explicitly examined the pattern of US adult mortality deficits by age (3, 4). Other studies have focused on comparatively high US mortality in specific age intervals: infancy (5), ages below 50 y (6), and ages 45 to 54 y (7, 8). One exception to the poor performance of the United States is that for several decades it has had lower death rates at ages 80+ y than most other wealthy countries (3, 4, 9).

In this paper, we use data from the Human Mortality Database (HMD) to create three indexes designed for making 21st-century age-specific comparisons of US and European mortality. To represent European mortality conditions, we create a composite of the five largest European countries, whose combined population size is very similar to that of the United States: Germany, England and Wales, France, Italy, and Spain. We use size as a selection criterion for two reasons: The comparisons of death rates should have relatively low variability, and the exceptional combinations of factors affecting mortality in small populations (e.g., climate, diet, social history, and healthcare delivery) may provide unrealistic expectations for larger and more diverse populations. Our comparisons extend from 2000 to 2017, the latest year for which data are available for all six countries.

Results

Fig. 1A shows the ratio of US death rates to the mean of death rates in the five European countries (the "European standard"), by age, in 2000, 2010, and 2017. Both series refer to the mean of male and female death rates. All results in Fig. 1 pertain to single years of age. Mortality in the United States is consistently higher (a ratio above 1) at all ages below age 80 y, with mortality at ages 20 to 60 y performing progressively worse throughout the period. The relative increase in US mortality at ages 20 to 34 y is particularly sharp, such that US 30-y-olds in 2017 were more than three times as likely to die as their European counterparts. On the other hand, in 2017 the United States had lower death rates at all ages above age 85 y; the US advantage at the very high ages has increased since 2000.

Fig. 1B shows the age pattern of excess deaths, deaths that would not have occurred if the United States had the age- and sex-specific death rates of the European standard. The age pattern of excess deaths differs from the ratios of Fig. 1A because it is a function of the difference in death rates (rather than the ratio) and the size of the population at risk. The peak at age 30 y in Fig. 1A is not sustained in Fig. 1B because few people die in this age interval. Instead, excess deaths are heavily concentrated at ages 55 to 84 y.

Table 1 shows that a total of 400,732 excess deaths occurred in the United States in 2017, representing 14.2% of all deaths in the United States in 2017. Above age 85 y, the United States has 97,788 fewer deaths than if subject to the European standard; these deaths represent 11.1% of the actual number of deaths recorded at ages 85+ y. The US advantage above age 85 y means that there were 498,520 (= 400,732 + 97,788) excess deaths below age 85 y, representing 25.8% of total deaths below age 85 y in the United States. Excess deaths in infancy numbered 9,634 in 2017, representing 2.4% of all excess deaths. Male excess deaths number 202,815 and female, 197,917.

Fig. 1C presents estimates of years of life lost (YLL) as a result of higher US mortality. YLL weights the number of excess deaths at a particular age by US life expectancy at that age. Since life expectancy is higher at younger than at older ages, weighting by life expectancy shifts values in this panel to the left. The United States lost 13.02 My of life to excess mortality in 2017 (Table 1). The US advantage at 85+ y is not particularly consequential in this calculation because individuals "saved" by lower mortality rates in the United States are expected to live few additional years. High US mortality in the working ages 25 to 64 y accounts for 64.9% of the years of life lost. Another 5.8% of lost life years is contributed by high infant mortality in the United States. Males in 2017 lost 7.09 My of life to excess mortality, compared to 5.93 My for females.

Trends in excess deaths and YLL are best gauged by controlling the effects of changes in the age/sex distribution (Table 1). If the excess age-specific death rates of 2000 were applied to the 2017 US age/sex distribution, there would have been 297,922 excess deaths. Compared to the actual number of 400,732 in 2017, the number of excess deaths increased by 34.5% by virtue of worsening relative mortality in the United States. A comparable calculation for YLL shows that the actual value of 13.02 million in 2017 represents an increase of 64.9% over the value of 7.90 million based on comparative death rates 17 y earlier. The percentage increase in YLL is greater than that in
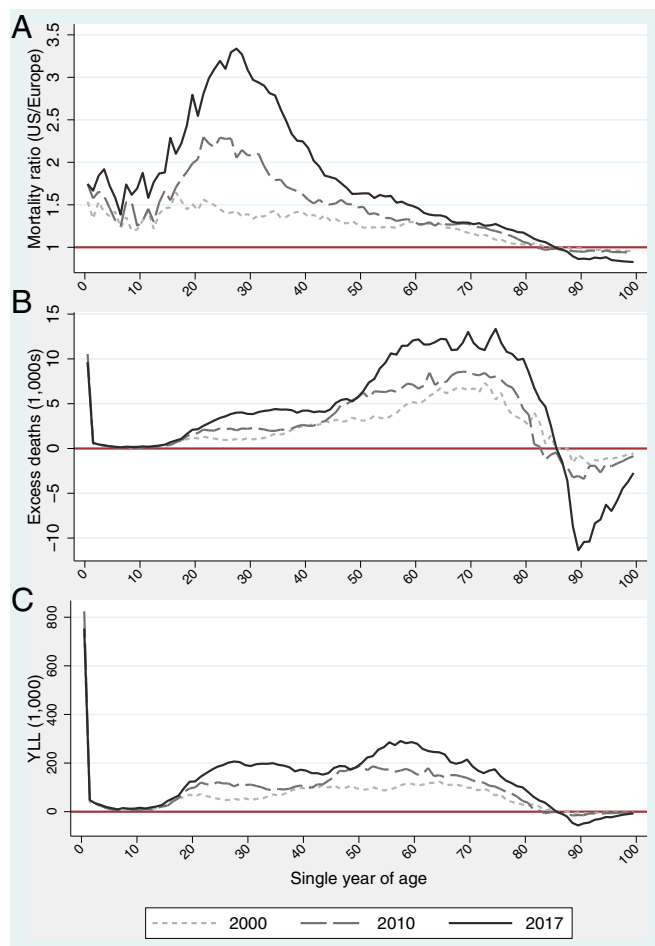
Fig. 1. Age-specific comparisons of US and European mortality: 2000, 2010, 2017. Source: HMD (12). (*A*) Ratio of US age-specific death rate to European standard. (*B*) Change in US death count if US had European age-specific death rates. (*C*) Years of life lost based on US life expectancies and US/European comparisons of age-specific death rates.

excess deaths because the age distribution of excess deaths has grown younger over the period.

Discussion

Because it has captured a great deal of national attention, the number of deaths from the COVID-19 epidemic in 2020 forms a

timely basis of comparison. On 20 February 2021, the Centers for Disease Control and Prevention reported that 376,504 deaths ascribed to COVID-19 had occurred in the United States in calendar year 2020 (10). That figure is similar to but below the estimated total number of excess deaths of 401,000 in the United States in 2017 (Table 1).

The comparison is more striking when years of life lost is the measure used. Goldstein and Lee (11) estimate that the mean loss of life years for a person dying from COVID-19 in the United States is 11.7 y. Multiplying 377,000 decedents by 11.7 y lost per decedent gives a total of 4.41 My of life lost to COVID-19 in 2020, only a third of the 13.02 million life years lost to excess mortality in the United States in 2017 (Table 1). The reason that the comparison is so much sharper for YLL than for excess deaths is that COVID-19 deaths in 2020 occurred at much older ages, on average, than the excess deaths of 2017.

Materials and Methods

All data come from the HMD (12). We use life tables in single calendar years and single years of age as well as population and death counts for the United States. Calculations are made by single year of age below age 110 y. Above age 110 y, results pertain to the open-ended age interval 110+ y. Death rates in the European standard are the simple arithmetic mean of death rates in the five European countries.

The ratios in Fig. 1*A* are based upon the mean of male and female death rates at a particular age. We show the ratio of US death rates to the simple mean of death rates across the five European standard countries by calendar year.

We estimate the number of US deaths that would not have occurred at age x, year t if the United States had the set of age-specific death rates of the European standard, ED(x,t), as

$$ED(x,t) = DU(x,t) - NU(x,t) * ME(x,t),$$

where DU(x,t) = number of deaths recorded at age x, year t in the United States; NU(x,t) = number of people alive in the United States at age x on July 1, year t; and ME(x,t) = death rate at age x, year t, in the European standard. These calculations are made separately for each sex and then summed for the total United States.

We calculate years of life lost to the US mortality disadvantage at age x, year t, or YLL(x,t), as

$$YLL(x,t) = ED(x,t) * e(x,t),$$

where e(x,t) is the US life expectancy at age x, year t in the period life table in the HMD. Since x refers to age at last birthday, it is necessary to take the average of life expectancy at exact age x and exact age $x + 1$ to estimate e(x,t). These calculations are also made separately for each sex and then summed for the total United States. Using period life expectancies in the United States produces conservative estimates of YLL compared to using cohort life expectancies (11) or European life expectancies.

For expanded details on the methods used, refer to *SI Appendix*. All code for replicating this paper's analyses are publicly available (see *SI Appendix*).

Table 1. Excess deaths and years of life lost by age group for years 2000 and 2017

Age group, y	Excess deaths			Years of life lost (in 1,000s)		
	2000	2000 with 2017 age–sex distribution	2017	2000	2000 with 2017 age–sex distribution	2017
0	9,653	9,900	9,634	736	755	754
1–14	3,282	3,361	4,010	229	235	286
15–24	10,344	11,575	20,441	581	649	1,170
25–34	11,398	12,763	40,116	539	606	1,973
35–44	24,056	21,543	42,072	915	820	1,700
45–54	32,637	37,785	67,044	968	1,111	2,081
55–64	51,508	90,382	115,589	1,108	1,933	2,695
65–74	65,126	100,817	118,613	970	1,523	1,910
75–84	32,663	35,856	81,002	319	350	844
85+	−14,501	−26,060	−97,788	−48	−85	−390
Total	226,165	297,922	400,732	6,318	7,897	13,023

Source: HMD (12). Note that numbers might not add due to rounding.

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