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.

Excess mortality in the United States in the 21st century
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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. 1A 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 | 2000 | 2000 with 2017 age–sex distribution | 2017 | Years of life lost (in 1,000s) |
|-------------|------|--------------------------------------|------|-------------------------------|
| Total       | 226,165 | 297,922                             | 400,732 | 6,318                         |
| 0           | 9,653  | 9,900                                | 9,634  | 736                           |
| 1–14        | 3,282  | 3,361                                | 4,010  | 229                           |
| 15–24       | 10,344 | 11,575                               | 20,441 | 581                           |
| 25–34       | 11,398 | 12,763                               | 40,116 | 915                           |
| 35–44       | 24,056 | 21,543                               | 42,072 | 915                           |
| 45–54       | 32,637 | 37,785                               | 67,044 | 968                           |
| 55–64       | 51,508 | 90,382                               | 115,589| 1,108                         |
| 65–74       | 65,126 | 100,817                              | 118,613| 970                           |
| 75–84       | 32,663 | 35,856                               | 81,002 | 319                           |
| 85+         | –14,501| –26,060                              | –97,788| –48                           |

Source: HMD (12). Note that numbers might not add due to rounding.
Data Availability. The data are publicly available on the Human Mortality Database (https://mortality.org/cgi-bin/hmd/hmd_download.php) and a Stata do-file for the analysis has been deposited at https://yanavierboom.weebly.com/replication-materials.html.

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1. E. M. Crimmins, S. H. Preston, B. Cohen, Eds., Explaining Divergent Levels of Longevity in High-Income Countries (National Academies Press, 2011).
2. National Research Council and Institute of Medicine, U.S. Health in International Perspective: Shorter Lives, Poorer Health (National Academies Press, 2013).
3. J. Y. Ho, S. H. Preston, US mortality in an international context: Age variations. Popul. Dev. Rev. 36, 749–773 (2010).
4. A. Palloni, J. A. Yonker, Is the US old-age mortality advantage vanishing? Popul. Dev. Rev. 42, 465–489 (2016).
5. A. Chen, E. Oster, H. Williams, Why is infant mortality higher in the US than in Europe? Am. Econ. J. Econ. Policy 8, 89–124 (2016).
6. J. Y. Ho, Mortality under age 50 accounts for much of the fact that US life expectancy lags that of other high-income countries. Health Aff. (Millwood) 32, 459–467 (2013).
7. A. Case, A. Deaton, Rising morbidity and mortality in midlife among white non-Hispanic Americans in the 21st century. Proc. Natl. Acad. Sci. U.S.A. 112, 15078–15083 (2015).
8. A. Case, A. Deaton, Deaths of Despair and the Future of Capitalism (Princeton University Press, 2020).
9. K. G. Manton, J. W. Vaupel, Survival after the age of 80 in the United States, Sweden, France, England, and Japan. N. Engl. J. Med. 333, 1232–1235 (1995).
10. Centers for Disease Control and Prevention, COVID-19 death data and resources: Daily updates of totals by week and state. https://www.cdc.gov/nchs/nvss/vsrr/covid19/index.htm. Accessed 20 February 2021.
11. J. R. Goldstein, R. D. Lee, Demographic perspectives on the mortality of COVID-19 and other epidemics. Proc. Natl. Acad. Sci. U.S.A. 117, 22035–22041 (2020).
12. University of California, Berkeley and Max Planck Institute for Demographic Research, The Human Mortality Database. www.mortality.org or www.humanmortality.de. Accessed 10 October 2020.