

**Beyond Deaths per Capita:  
Comparative CoViD-19 Mortality Indicators**

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## **Beyond Deaths per Capita: Comparative CoViD-19 Mortality Indicators**

### **Abstract**

*Background:* CoViD-19 deaths per capita are often used to compare the progression of the disease across populations. This article discusses alternative comparative measures based on well-established practices in demography.

*Methods:* Using extant estimates, we calculate CoViD-19 death rates for 263 countries, territories, provinces in China and US states. We indirectly standardize 250 of these rates using population age-and-sex distributions. Using extant projections and life tables, we calculate reductions in 2020 life expectancy at birth for 108 countries and states.

*Results:* To date, New York has the highest of the 263 CoViD-19 death rates, exceeding the state's 2017 Crude Death Rate for the period between March 14 and May 20. Relative to the US, standardization lowers European rates but increases South American rates. When both can be calculated, indirectly and directly standardized rates are very close. Reductions over one year in 2020 life expectancy at birth are projected in 3 countries and 7 states, even exceeding 2 years in New York.

*Conclusions:* Our results validate indirect standardization as a valuable alternative, especially for small areas where age-and-sex CoViD-19 data might be unavailable or unreliable. Uncertainty about CoViD-19 trajectories remains substantial, but current projections seem more likely to under- than to over-estimate the eventual impact of CoViD-19 on the annual life expectancy at birth. For the US, they suggest that by October 1 that impact would reach twice the impact of HIV infections or opioid overdoses, reducing the 2020 life expectancy to its lowest level since 2008.

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## Beyond Deaths per Capita

### *Background*

As of June 1<sup>st</sup>, deaths from the novel coronavirus disease 2019 (CoViD-19) had been reported in 186 of the 235 countries and territories of the United Nations system (UN). As with previous pandemics,<sup>1</sup> the disease progression can be more reliably tracked with death than with case counts. Cumulative CoViD-19 death counts at a given time depend on the determination of the cause of death, delays in reporting deaths to central reporting agencies—different for deaths at home, in hospitals and other institutions—and delays in verification, consolidation and publication at reporting agencies. Differences across locations in each of these processes affect the comparability of the mortality estimates, but the comparability of case estimates is affected to a much greater extent, in particular, by differences in testing practices.<sup>2</sup> CoViD-19 mortality indicators are also more pertinent for assessing public-health measures that were intended less to reduce the eventual number of cases than to “flatten the curve” so that the need for emergency hospitalizations would remain below local hospital capacity.

For comparative purposes, however, several cumulative death counts are affected by several demographic characteristics such as, most obviously, population size. Correspondingly, a deaths per capita ratio represents the first rather than the only adjustment that can be taken towards more meaningful CoViD-19 mortality comparisons. Following well-established practices in demography,<sup>3</sup> this article presents additional indicators that can be derived with additional demographic data. The corresponding measures are discussed using results for the 186 UN countries and territories with at least one death by June 1<sup>st</sup>. To illustrate the issue of scale as well, the measures are also calculated for each of the U.S. states and 26 provinces in China—thus for a total of 263 populations.

## Methods and Data

We first calculate an occurrence/exposure *rate*, the period Crude CoViD-19 Death Rate (*CCDR*):

$$CCDR[t_1, t] = \frac{D^C[t_1, t]}{N(t_m) \cdot (t - t_1)}$$

where  $t_1$  is an initial time,  $D^C[t_1, t]$  a cumulative CoViD-19 deaths count at time  $t$ , and  $N(t_m)$  an estimate of the total population size at time  $t_m$  between time  $t_1$  and time  $t$ . The difference between this period rate and the deaths per capita ratio can easily be missed when the deaths count in the numerator, identical for both, is an annual number of deaths. In that case, the number of person-years in the denominator of the occurrence/exposure rate can indeed be approximated by population size at some point during the year. However, the two are no longer directly comparable, and the metric of the ratio difficult to interpret, when the death counts correspond to periods of different durations. On the contrary, the *CCDR* is expressed in deaths per person-year and remains directly comparable to the annual Crude Death Rate (*CDR*) available for most populations. For the 186 UN countries and territories, we first calculate the *CCDR* for the period starting on the day of the first death in the population, which was obtained from World Health Organization (WHO) daily situation reports,<sup>4</sup> and ending on June 12. The estimated deaths count on that day was obtained from Johns Hopkins University's Center for Systems Science and Engineering (CSSE)<sup>5</sup> and total population size was obtained from the UN.<sup>6</sup> (Additional sources used for the provinces of China and US states are referenced in the Technical Appendix.) Using projections from the University of Washington's Institute for Health Metrics and Evaluation (IHME),<sup>7</sup> we also calculate a *CCDR* for the period ending on August 4 for 55 countries and on October 1 for the U.S.A. and each of the US states.

When death rates vary by age and sex, which has been clearly established for CoViD-19 mortality,<sup>8</sup> this period rate should be adjusted to take into account different age and sex

population compositions. Direct age-and-sex standardization requires data on CoViD-19 deaths by age and sex, which are unavailable or unreliable for a majority of UN countries and territories and for many sub-national populations. An alternative approach, known as indirect standardization, borrows an age-and-sex pattern of mortality from a well-documented population so that only the age-and-sex composition of the other populations is required. Based on this approach, we calculate the Comparative CoViD-19 Mortality Ratio (*CCMR*):

$$CCMR[t_1, t] = \frac{D^c[t_1, t]}{\sum_j \sum_i {}^{US}M_{ij}^c \cdot N_{ij}(t_m)}$$

where  ${}^{US}M_{ij}^c$  is the CoViD-19 death rate specific to age group  $i$  and sex  $j$  in the U.S.A. and  $N_{ij}(t_m)$  is the size of the age group  $i$  for sex  $j$  in the population of interest. The reference age-and-sex death rates were obtained from the Centers for Disease Control and Prevention (CDC) weekly-updated distribution of CoViD-19 deaths by age and sex in the U.S.A.,<sup>9</sup> selected because this is to date the largest number of CoViD-19 deaths distributed by age and sex. Unavailable only for the 13 countries/territories whose population size is less than 90,000, population age-and-sex distributions were taken from the UN data.

Multiplying a population *CCMR* by the US *CCDR* yields an Indirectly age-and-sex Standardized CoViD-19 Death Rate (*ISCDR*) for that population, with the US age-and-sex population distribution as the standard:

$$ISCDR[t_1, t] = \sum_j \sum_i ({}^{US}M_{ij}^c \cdot CCMR[t_1, t]) \cdot {}^{US}N_{ij}(t_m)$$

*CCMR* and *ISCDR* are again calculated both for CSSE current estimates (250 populations) and IHME August-4 or October-1 projections (107 populations). For countries and states for which a breakdown of CoViD-19 deaths is available,<sup>10</sup> the *ISCDR* can be compared to a Directly age-and-

sex Standardized CoViD-19 Death Rate (*DSCDR*) with the US age-and-sex population distribution as the standard.

Last, life expectancy at birth provides a summary indicator of mortality in a population in a more intuitive metric (years) than these rates. A standard demographic technique allows to estimate the impact *eliminating* a cause of death would have on life expectancy at birth. When a prior period life table (i.e., not factoring CoViD-19 mortality) is available, applying this technique backward allows to translate a cumulative CoViD-19 deaths forecast for the same period into a CoViD-19-induced *reduction* in male and female life expectancies at birth. Although they are not extended to the end of the year, the IHME projections were used as projections of the cumulative number of CoViD-19 deaths in 2020 to derive new male and female life expectancies at birth in these 107 populations. These calculations required a previous projection of the male and female year-2020 life tables in these populations. For countries, these were again derived from UN data, by interpolation between the 2015-20 estimates and 2020-25 projections. For US states, the tables were extrapolated from CDC data for years up to 2016. Additional details on the calculation of these various indicators are described in the online supplementary materials of this article.

### *Results*

Values of these indicators are calculated weekly from updates of the CCSE, IHME and CDC data and shared on a Github repository.<sup>11</sup> To illustrate their properties, we briefly describe these indicators based on the June-12 updates of the CCSE, IHME and CDC data. (Full results for that week, ranked on *CCDR* values, are also available in the online supplementary materials of this article). Across countries with a population size of 90,000 or more, Belgium has the highest current-period *CCDR* value (3.42 per thousand), followed by 7 other European countries and the

U.S.A. (1.23 per thousand). New York (6.29 per thousand) and 4 other US states have higher current-period *CCDR* value than Belgium. The main motivation for the *CCDR* is not to compare CoViD-19 mortality across populations, however, but rather to compare CoViD-19 and overall mortality. As shown in Figure 1 for New York, the period *CCDR* has peaked but remained above the state's most recent annual *CDR* (7.83 per thousand in 2017)<sup>12</sup> until May 20. Ignoring seasonality and temporal trends in overall mortality, this indicates roughly equivalent mortality from CoViD-19 and from all other causes combined between March 14 (first death) and May 20 in the state.

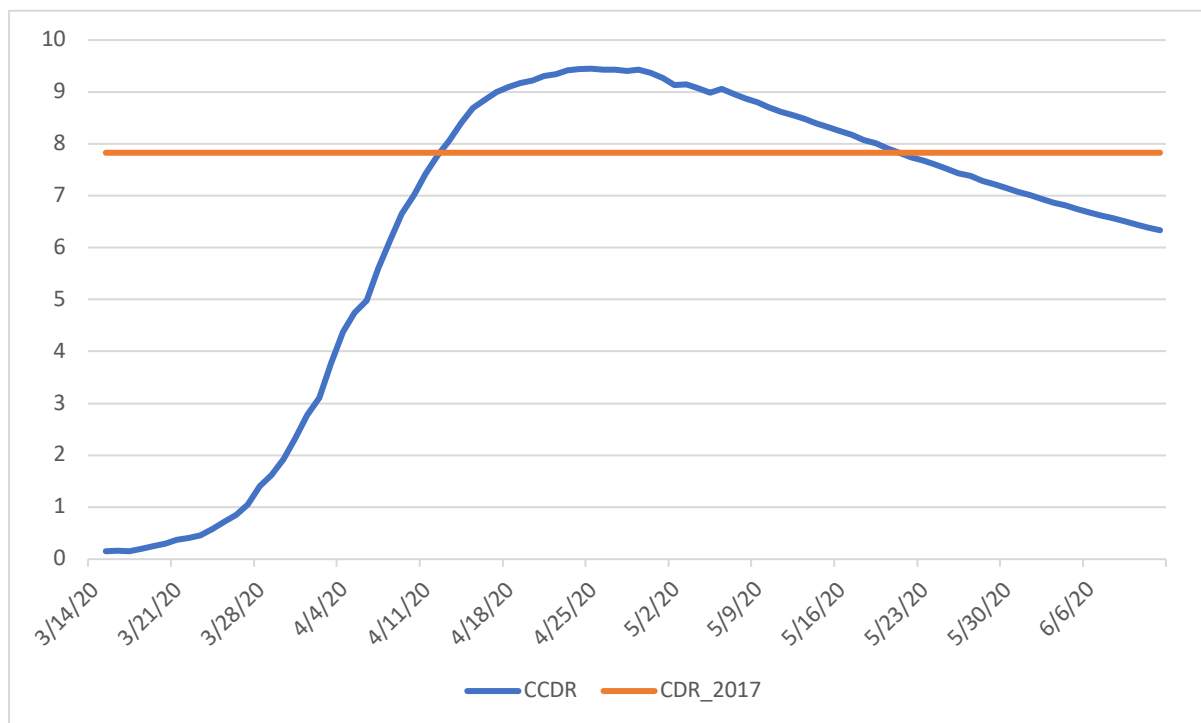


Figure 1: Estimated value of the period *CCDR*, New York (in deaths per 1,000 person-years, period starting on March 14 and ending on day shown on the horizontal axis)

The effects of indirect age-standardization are illustrated in Figure 2, comparing current-period *CCDR* and *ISCDR* values for populations of 10 million or more with the largest *CCDR* (.8 or more). By construction, the US *CCMR* equals 1 and the *CCDR* and *ISCDR* are the same. For



the 7 European countries, the standardized *ISCDR* is lower than the unstandardized *CCDR*.

France, Italy and the Netherlands, for instance, have higher unstandardized but lower standardized rates than the U.S.A. On the contrary, standardization leads to substantially higher rates in the 3 South American countries, more than doubling in Ecuador for instance (from .87 to 1.80 per thousand).

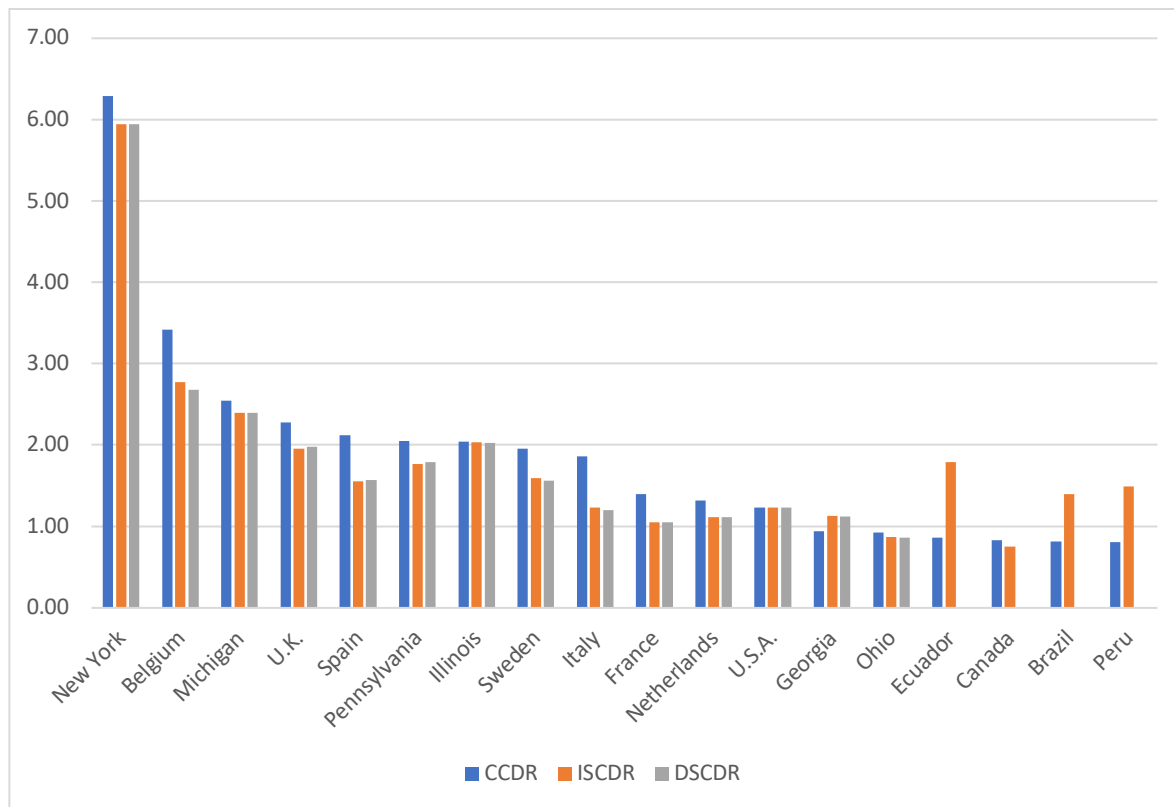


Figure 2: Estimated value of the *CCDR*, *ISCDR* and *DSCDR* (in deaths per 1,000 person-years), by country and state with an estimated *CCDR* of .8 or more and population size over 10 million)

For the 7 European countries and 6 states, Figure 2 also compares the indirectly and directly standardized rates. For each of these populations, the values are very close, confirming that indirect standardization is a good alternative to direct standardization when CoViD-19 deaths are not available by age and sex.

As for the future mortality impact, 2020 life expectancies at birth are expected to be lower than previously projected by more than a year in 3 South American countries and 7 US states, exceeding 2.0 years in New York (Figure 3). Figures are not directly comparable for states and countries though, since the IHME projections for the latter are not extended beyond August 4 at this writing.

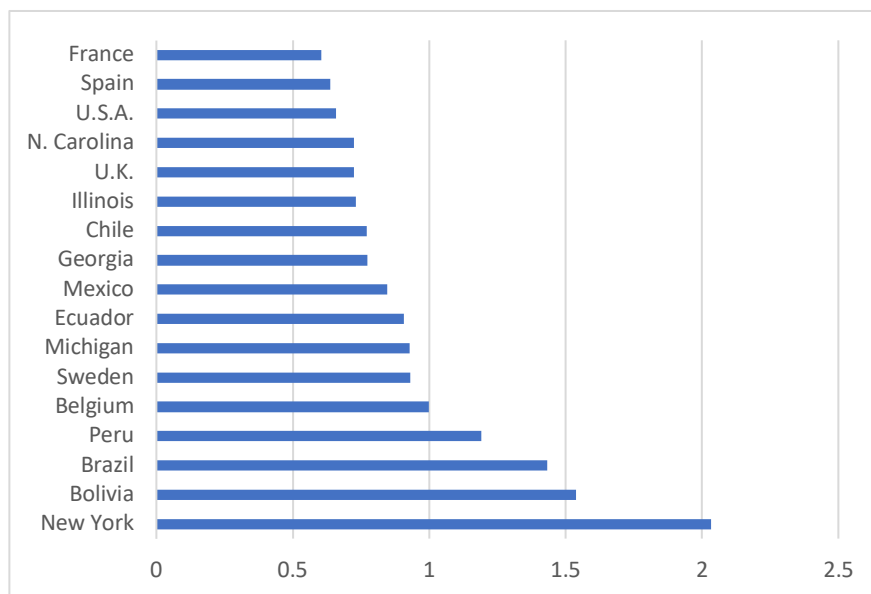


Figure 3: Estimated reduction in life expectancy at birth for year 2020, both sexes (in years), by country and state with an estimated reduction of .6 or more and population size over 10 million

Life expectancy reductions allow to put the mortality impact of CoViD-19 in perspective. The US .66 reduction, for instance, would induce a larger single-year decline in life expectancy at birth than during each of the last two public health crises in the U.S.A.: a decline from 75.8 in 1992 to 75.5 years in 1993 (HIV/AIDS-related mortality) and from 78.9 years in 2014 and 78.6 years in 2017 (opioid-overdose-related mortality).<sup>13</sup> As illustrated in Figure 4, it would more than eliminate any longevity gain the country could have made over a 12 years period (2009-2020).

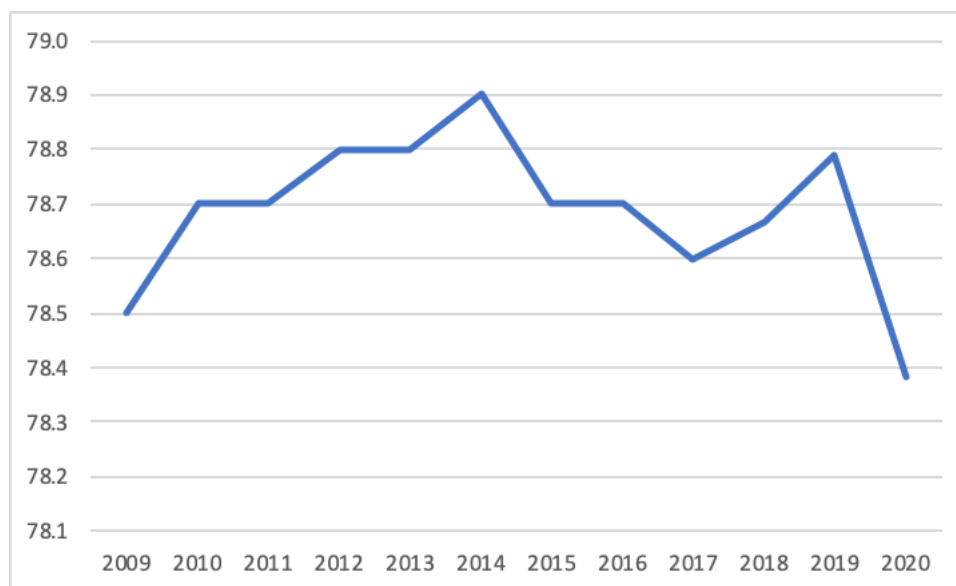


Figure 4: Estimated life expectancy at birth, U.S. population, both sexes, by year

Sources. 2009-1017: CDC, 2017-2020: UN and authors' calculations (see technical appendix)

### *Discussion*

The results above illustrate the properties of different comparative indicators of CoViD-19 mortality. For comparisons across populations, the *ISCDR*, and *CCMR* on which it builds, control for 3 important determinants of cumulative CoViD-19 deaths in a population: the length of the period over which these deaths are cumulated, the size of the population, and its age-and-sex composition. With respect to the age-and-sex composition, comparisons with directly standardized rates show that the *ISCDR* performs very well.

Caveats are in order with respect to the other two components. First, both the unstandardized and standardized rates are period indicators that increase and decrease as waves of the pandemic develop. Contrary to the death per capita ratio, which can only increase over time, the period rates begin to decline when the daily number of additional deaths drops below its average for the period. This property of the period rates accurately reflects for CoViD-19 mortality a temporal dimension that can often be neglected for overall mortality. This also

implies, however, that comparing *ISCDR* values across populations at too different durations of exposure to CoViD-19 would not be meaningful. As shown in Figure 1, this is more problematic early in the diffusion of the epidemic.

Second, with respect to population size, comparing *ISCDR* values in the U.S.A. and across the different states illustrates how comparisons may differ depending on the scale at which they are performed. Across countries, Belgium may have the highest *ISCDR* value, but that value is lower than in 4 US states with population ranging from 3.6 to 19.8 million, and more comparable to Belgium (11.6 million) than the whole U.S.A. To illustrate the properties of these indicators, we only estimated them at the sub-national level for provinces in China and US states. We prioritized these two countries both because of their size and within-country differences in CoViD-19 mortality: New York *ISCDR* is nearly 5 times the US average, Hubei's is more than 23 times the average for China. Even though their within-country differences do not appear as strong at the moment, disaggregation below the national level would clearly be more useful for other large countries like India or Brazil, or for other countries with a high concentration of CoViD-19 mortality. With a population size similar to Belgium, for instance, Lombardy has a ratio of CoViD-19 deaths per capita nearly 3 times the Italian average, suggesting an *ISCDR* value around 3.55 for the province (assuming the same population composition as Italy, result not shown). This would place Lombardy above Belgium and only below New York, 3 other states and DC. Further disaggregation may even prove more informative depending on the type analysis. In this respect, the *ISCDR* may be particularly useful for smaller areas for which data on CoViD-19 deaths by age and sex may not be available or reliable due to small sample size.

Substantial uncertainties remain as regards the direct and indirect mortality impact of the pandemic. With respect to the impact to date, the main factors of uncertainty are (1) the degree to which CoViD-19 has been properly identified and reported as the cause of death and (2) the “downstream” effects of the pandemic and mitigating policies on mortality from other causes. CDC data on excess deaths<sup>14</sup> shows that for the 8-week period ending on May 16, the number of deaths in the U.S.A. exceeded expectations based on past trends by over 107,000 at a time when the country’s cumulative CoViD-19 deaths count stood at 86,000. All else equal, life-expectancy reductions would be larger than estimated here, regardless of whether CoViD-19 deaths are under-reported or mortality from other causes has also increased, because reductions are estimated on the assumption that mortality from other causes remains unchanged.

Obviously, there are even greater uncertainties about the cumulative impact for the year 2020. The CDC currently tracks no less than 15 forecasting models.<sup>15</sup> Our choice of the IHME projections among those to illustrate the properties of the different indicators was not based on a quality assessment, which would be beyond our expertise. The IHME projections have a broader international coverage and longer time horizon than most other models. Comparisons with other models when populations and horizons overlap do not show the IHME projections as particularly alarmist. Adding that the current projections do not include any “second wave” of CoViD-19 deaths, the eventual impact on life expectancy at birth in 2020 appears more likely to be higher than lower than calculated at this time.

To be sure, the rapidly evolving data and understanding of CoViD-19 mortality will likely continue to require frequent updates and flexibility. Calculations presented here can easily be customized for different periods, different geographical scales, or to accommodate uncertainty across different sources of estimates and forecast.

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