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Years of life lost associated with COVID-19 deaths in the USA during the first year of the pandemic

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ABSTRACT

Background Years of Life Lost (YLLs) measure the shortfall in life expectancy due to a medical condition and have been used in multiple contexts. Previously it was estimated that there were 1.2 million YLLs associated with coronavirus disease 2019 (COVID-19) deaths in the USA through 11 July 2020. The aim of this study is to update YLL estimates for the first full year of the pandemic.

Methods We employed data regarding COVID-19 deaths in the USA through 31 January 2021 by jurisdiction, gender and age group. We used actuarial life expectancy tables by gender and age to estimate YLLs.

Results We estimated roughly 3.9 million YLLs due to COVID-19 deaths, which correspond to roughly 9.2 YLLs per death. We observed a large range across states in YLLs per 10 000 capita, with New York City at 298 and Vermont at 12. Nationally, the YLLs per 10 000 capita were greater for males than females (136.3 versus 102.3), but there was significant variation in the differences across states.

Conclusions Our estimates provide further insight into the mortality effects of COVID-19. The observed differences across states and genders demonstrate the need for disaggregated analyses of the pandemic's effects.

Keywords infectious disease, mortality

Introduction

Years of life lost (YLLs) estimate at the population level the number of years that decedents would have lived but for a cause of death. It thus provides insight into the age of those who died and results in higher values when there are a greater number of deaths and/or deaths are more concentrated among the young. The measure has been used to describe all-cause mortality,[1] as well as for specific causes including noncommunicable diseases,[2–5] drug misuse[6,7] and suicides.[8,9] YLLs have been used to characterize deaths due to coronavirus disease 2019 (COVID-19), both in multinational[10–12] and single-country[13,14] analyses.

This short report updates a previous study by the authors of the USA[15] which estimated 1.2 million YLLs associated with COVID-19 deaths through 11 July 2020. The number of YLLs per death was estimated at roughly 9.3 per death, while the top three jurisdictions in terms of total YLLs were New York City, New Jersey and New York (excluding New York City). This study updates the estimates through the roughly first year of the pandemic, both overall and by jurisdictions and gender.

Methods

Data

The data and methods employed follow those used in Quast *et al*.[15] Data regarding COVID-19 deaths were again obtained

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from the dataset 'Provisional COVID-19 Death Counts by Sex, Age and State' published by the National Center for Health Statistics in the US Centers for Disease Control and Prevention (CDC).[16] The data reflect the period 1 January 2020 through 31 January 2021 and were obtained on 3 February 2021. We use the term jurisdiction rather than state to refer the geographic entities as the CDC data included observations for the non-state areas New York City and Washington, D.C. For confidentiality reasons, the number of deaths was suppressed in the dataset for a given jurisdiction/gender/age group if the value ranged from one to nine. Out of 192 545 female deaths, 377 did not include information regarding age. The corresponding values for male deaths were 228, 825 and 326. Further, eight deaths had a value of 'Unknown' for gender. The suppressed deaths and deaths for which gender was unknown were excluded from the analysis.

Life expectancies by age and gender were obtained from actuarial life tables published by the US Social Security Administration.[17] The most recent year available was 2017. Appendix Table A1 reports the mapping of age groups used in the COVID-19 deaths data to ages for which the life expectancy was used. The table also reports the approximated life expectancy reported for the specified age.

'Annual State Resident Population Estimates' published by the US Census Bureau was the source of our state-level population data.[18] The data were as of 1 July 2019 and were obtained by gender. Following the COVID-19 deaths data, we estimated the population of New York City and the remainder of New York state separately. We obtained the population of New York City and the percentage of population by gender as of 1 July 2019 from 'QuickFacts: New York City, New York' published by the US Census Bureau.[19]

Our sample consisted of 52 jurisdictions: 49 states, New York state excluding New York City, New York City and Washington, D.C.

Statistical Analysis

We approximated the age of death for each age group based on the single-age values reported in Appendix Table A1. For each death, we assigned a life expectancy for that gender-age cohort. We obtained population-level YLL estimates by summing the life expectancies for the deaths in the relevant population. Per-capita YLLs were calculated per 10 000 residents for the respective jurisdiction-gender population.

A significant aspect of COVID-19 deaths in calculating YLLs is that many of those who died of the disease had significant pre-existing medical conditions. Such deaths could be considered as displaced mortality in that these individuals on average would likely not reach the full life expectancy reported in actuarial tables. In their forecast model of COVID-19 deaths in the UK based on data from Italy, Hanlon *et al*.[14] estimated that the greater pre-existing morbidity of those who died of COVID-19 reduced the estimated YLLs per COVID-19 death from 14 to 13 for men and 12 to 11 for women.[15] In our analysis we conservatively reduced the expected life expectancy by 25% to reflect the typically greater morbidity of COVID-19 decedents.

Results

Table 1 reports by jurisdiction the number of deaths and YLLs, both the actual values and those measured per 10 000 capita, ranked in decreasing order by YLLs per 10 000 capita. The roughly 420 000 COVID-19 deaths in the USA during the first year of the pandemic translate to nearly 3.9 million YLLs. This corresponds to approximately 120 YLLs per 10 000 capita and 9.2 YLLs per death. New York City has, by far, the highest YLLs per 10 000 capita, at nearly twice the level of the next highest jurisdiction (New Jersey) and nearly 25 times greater than the lowest value (Vermont). California has the highest number of YLLs and represents nearly 11% of the national total, but has only the 31st highest value on a per 10 000 capita basis. Washington, DC has the highest average YLLs per death, indicating a relatively younger age distribution of COVID deaths.

Figure 1 details YLLs per 10 000 capita by jurisdiction and gender. In every jurisdiction, the male value is greater than the female value, which is consistent with YLLs per 10 000 capita for males being roughly a third greater than for females at the national level (136.3 versus 102.3). However, the divergence between the two genders varies considerably by state. In New York City, the male value was nearly 75% greater than the female value, while in Mississippi the male value was only 7% greater. The extent of the differences between the male and female values does not appear to be related to the total YLLs per capita in the state. For instance, New York City and Mississippi represent the first and third highest jurisdictions in terms of total YLLs per capita, yet the differences between the male and female values for the two jurisdictions vary substantially. At the other end of the spectrum, Vermont and Hawaii have the lowest and second-lowest total YLLs per 10 000 capita, yet in Vermont the YLLs per 10 000 capita by gender are relatively equal, while in Hawaii the male value is roughly twice the female value. Likewise, no patterns emerge regarding the gender differences in YLLs per 10 000 capita and geographic location or population size.

Table 1 Number of deaths and YLLs by jurisdiction

Jurisdiction	Number of deaths		YLLs		YLLs per death
	Number	Per 10 000 capita	Number	Per 10 000 capita	
Total	420 682	13.0	3861 965	119.0	9.2
New York City	23 722	28.5	248 490	298.1	10.5
New Jersey	19 058	21.7	177 126	201.7	9.3
Mississippi	5592	19.0	57 627	196.0	10.3
District of Columbia	1046	15.0	11 746	168.7	11.2
Arizona	11 497	16.0	121 050	168.2	10.5
Louisiana	7428	16.2	74 444	162.2	10.0
Alabama	7794	16.1	77 869	160.7	10.0
New Mexico	2960	14.3	32 630	157.3	11.0
South Dakota	1750	20.1	13 457	154.2	7.7
North Dakota	1533	20.4	11 434	152.1	7.5
New York (excl NYC)	19 221	17.6	161 435	148.2	8.4
Nevada	4208	13.8	44 611	146.5	10.6
Arkansas	4718	15.8	42 380	142.2	9.0
Texas	37 250	13.0	405 786	141.8	10.9
Rhode Island	2003	19.1	14 281	136.2	7.1
Tennessee	9391	13.9	89 341	132.4	9.5
Illinois	18 385	14.7	165,371	132.0	9.0
Pennsylvania	21 231	16.8	163 267	128.9	7.7
Connecticut	5815	16.5	43 769	124.0	7.5
Iowa	5054	16.2	37 862	121.5	7.5
Oklahoma	5116	13.1	47 104	120.5	9.2
Michigan	13 070	13.2	116 195	117.6	8.9
Massachusetts	11 258	16.5	80 040	117.3	7.1
Indiana	9692	14.6	77 742	116.9	8.0
Maryland	7634	12.8	69 552	116.4	9.1
Kansas	4041	14.0	32 696	113.6	8.1
Georgia	11 575	11.0	118 553	113.0	10.2
Missouri	8163	13.5	67 080	110.6	8.2
Montana	1341	12.7	11 565	109.4	8.6
Ohio	15 923	13.8	125 780	108.9	7.9
California	41 003	10.5	418 974	107.3	10.2
Florida	24 821	11.7	225 341	106.0	9.1
Nebraska	2432	12.7	19 909	104.3	8.2
South Carolina	5510	10.8	51 840	101.8	9.4
Kentucky	4925	11.2	41 493	94.0	8.4
Wisconsin	6768	11.8	52 573	91.3	7.8
West Virginia	1835	10.3	14 892	83.9	8.1
Delaware	995	10.3	8020	83.3	8.1
Minnesota	6275	11.3	45 469	81.6	7.2
Colorado	5368	9.4	45 037	79.1	8.4
Virginia	7200	8.5	61 059	72.4	8.5
Idaho	1634	9.3	12 698	71.9	7.8
Wyoming	502	8.8	4098	71.6	8.2
Utah	1749	5.5	16 954	53.7	9.7
New Hampshire	1046	7.8	6573	48.8	6.3
Washington	4,009	5.3	33 927	45.1	8.5

Continued

Table 1 Continued

Jurisdiction	Number of deaths		YLLs		YLLs per death
	Number	Per 10 000 capita	Number	Per 10 000 capita	
North Carolina	4073	3.9	38 584	37.2	9.5
Oregon	1720	4.1	14 131	33.9	8.2
Maine	627	4.7	4115	30.9	6.6
Alaska	225	3.1	1931	26.8	8.6
Hawaii	358	2.6	3320	23.7	9.3
Vermont	138	2.2	744	12.0	5.4

Conclusions/Discussion

The main findings

Over the first year of the pandemic in the USA, COVID-19 deaths were associated with roughly 3.9 million YLLs. On average, roughly 9.2 years of life were lost per death. We observed dramatic differences across jurisdictions in YLLs per capita. YLLs per capita were greater for females than males, but the extent of the difference varied significantly across jurisdictions.

What is already known on this topic

Existing studies have found that YLLs associated with COVID-19 deaths in the USA are higher than in most other countries. Per-capita US YLLs were found to be roughly 13% greater than in Italy and nearly six times larger than the German value.[10] An analysis of USA, UK, Canada, Norway and Israel estimated that the U.S. and U.K. YLLs per capita values were the highest among the group and roughly equal.[11] However, a study of 30 countries with relatively high COVID-19 incidence found that the USA had only the eighth highest YLLs per capita.[12]

The current study updates a previous analysis by the authors of YLLs in the USA through 11 July 2020.[15] The prior analysis estimated 1.2 million YLLs associated with COVID-19 deaths nationally. The YLLs in New York City represented roughly one-sixth of the national total. The remaining top four jurisdictions in terms of YLLs were New Jersey, New York (excluding New York City), California and Illinois. In all states the YLLs per 10 000 capita were greater for males than females.

What this study adds

This study updates earlier YLL estimates to include a period of dramatic COVID-19 mortality in the USA. The number of YLLs estimated in this study is greater by over a factor of three than the number through July 2020. Further, we observed substantial changes in the rankings by jurisdiction relative to our earlier study. While New York City had the highest number of YLLs per 10 000 capita, California replaced New York City as the jurisdiction with the highest total YLLs. Texas and Florida replaced New Jersey and New York (excluding New York City) in the top five states in total YLLs. In terms of YLLs per 10 000 capita, Mississippi went from the 14th highest jurisdiction to third. However, the average YLLs per death was largely unchanged from the estimate in the earlier study. The current study included a period of dramatic increase in the number of cases in the USA. The national 7-day moving average increased from 35 370 on 10 September 2020 to a peak of 248 709 on 8 January 2021.[20]

Our analysis also highlights significant variation in the mortality effects of COVID-19. The dramatic variation in YLLs per 10 000 capita across states highlights differences across geographic regions. We also found substantial heterogeneity in the levels of YLLs per 10 000 capita by gender across states. This finding suggests that differences in the effects of COVID-19 by gender should be investigated at a more local level rather than nationally.

Limitations

This study shares several limitations with our previous analyis.[15] We relied on national life expectancy estimates as jurisdiction-level data were not available. Further, our life expectancy estimates are conditional upon an individual reaching the specified age. We had to employ a rough approximation for the pre-existing reduced expected life expectancy of those who died from COVID-19. While our use of a 25% reduction is conservative, especially in light of earlier estimates,[15] a more precise estimate based on U.S. data would provide greater clarity. Our analysis does not attempt to adjust for quality of life as has been done elsewhere.[11]

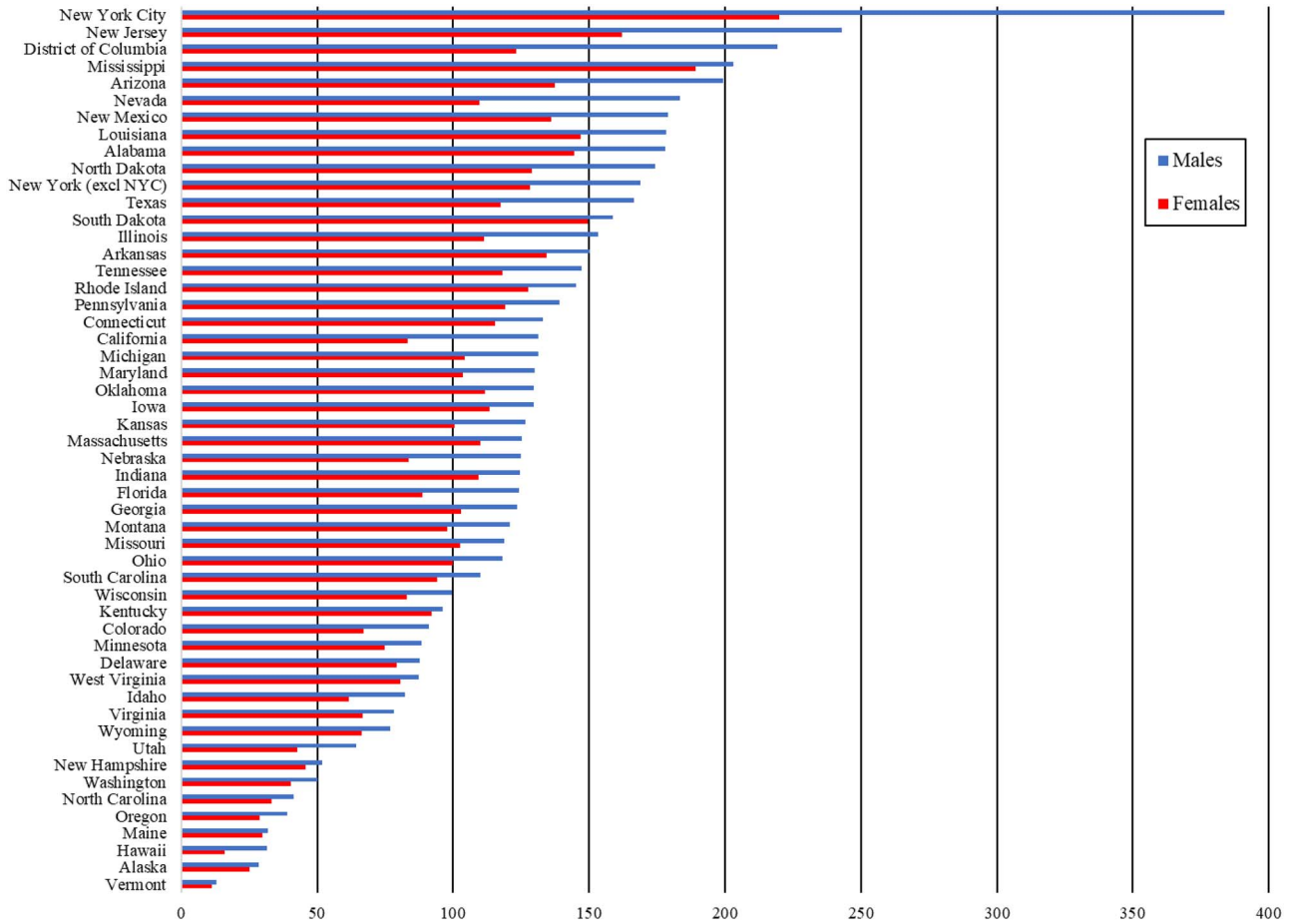

Fig. 1 YLLs per 10 000 capita by state and gender.

The COVID-19 deaths data were provisional and thus incomplete. Estimates based on complete data would result in higher aggregate values, but given our large sample period the differences would likely be relatively minor. There are also concerns as to the accuracy of determinations of deaths caused by COVID-19.[21] Any undercounting or overcounting of COVID-19 deaths would directly affect our YLLs estimates.

Conclusions

Our estimates of nearly 3.9 million YLLs and 9.2 YLLs per death in the first year of the pandemic in the USA provide another perspective on the striking mortality inflicted by COVID-19. Our analysis also details the substantial variation in mortality effects by state. Further, our gender analysis indicates significant heterogeneity across states. Our findings suggest that attempts to understand the mortality impact of COVID-19 should investigate subnational regions and subpopulations.

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