RESEARCH LETTER

COVID-19 and Excess All-Cause Mortality in the US and 18 Comparison Countries

The US has experienced more deaths from coronavirus disease 2019 (COVID-19) than any other country and has one of the highest cumulative per capita death rates.[1,2] An unanswered question is to what extent high US mortality was driven by the early surge of cases prior to improvements in prevention and patient management vs a poor longer-term response.[3] We compared US COVID-19 deaths and excess all-cause mortality in 2020 (vs 2015-2019) to that of 18 countries with diverse COVID-19 responses.

Supplemental content

Methods | We compared the US with Organisation for Economic Co-operation and Development countries with populations exceeding 5 million and greater than $25 000 per capita gross domestic product. For each country, we calculated the COVID-19 per capita mortality rate and grouped countries by mortality: (1) low (COVID-19 deaths, <5/100 000), (2) moderate (5-25/100 000), and (3) high (>25/100 000).[1] We used Poisson regression for comparisons across countries.

We calculated the difference in COVID-19 deaths between each country and the US through September 19, 2020 (week 38) under 3 scenarios: if the US had a comparable per capita COVID-19 mortality rate to each country from the start of the pandemic (February 13) or if the US mortality rate became comparable to other countries beginning May 10 or June 7, to allow lag time for policy interventions.[3] (See the Supplement for formulas.)

We also considered all-cause mortality per capita for countries with publicly available data through July 25, 2020 (week 30). This measure is robust to country-level differences in COVID-19 death coding and captures indirect pandemic effects. We estimated excess all-cause mortality (the difference between mean 2020 deaths and deaths in corresponding weeks of 2015-2019) for each country and the US,

Table 1. COVID-19 Mortality in the US Compared With That of Other Countries[a]

Country	Date COVID-19 cases surpassed 1 per million	COVID-19 deaths per 100 000			Excess US COVID-19 deaths (% of reported deaths)		
		Since the start of the pandemic	Since May 10, 2020	Since June 7, 2020	Since the start of the pandemic	Since May 10, 2020	Since June 7, 2020
Low mortality (COVID-19 deaths, <5/100 000)							
South Korea	2/20/20	0.7	0.2	0.2	196 161 (99)	120 625 (61)	88 771 (45)
Japan	2/23/20	1.2	0.7	0.5	194 711 (98)	119 090 (60)	87 939 (44)
Australia	3/1/20	3.3	2.9	2.9	187 661 (94)	111 747 (56)	79 849 (40)
Moderate mortality (COVID-19 deaths, 5-25/100 000)							
Norway	2/29/20	5.0	1.0	0.5	182 099 (92)	118 074 (59)	87 655 (44)
Finland	3/2/20	6.1	1.4	0.3	178 373 (90)	116 698 (59)	88 432 (45)
Austria	3/1/20	8.6	1.7	1.0	170 247 (86)	115 874 (58)	86 066 (43)
Denmark	3/4/20	10.9	2.1	0.8	162 600 (82)	114 438 (58)	86 669 (44)
Germany	3/1/20	11.3	2.4	0.9	161 393 (81)	113 422 (57)	86 521 (44)
Israel	3/2/20	14.0	11.2	10.6	152 393 (77)	84 676 (43)	54 529 (27)
Switzerland	2/29/20	20.6	2.8	1.2	130 654 (66)	112 205 (57)	85 402 (43)
Canada	3/6/20	24.6	12.4	4.0	117 622 (59)	80 631 (41)	76 235 (38)
High mortality (COVID-19 deaths, >25/100 000)							
The Netherlands	3/3/20	36.2	5.2	1.5	79 318 (40)	104 177 (52)	84 514 (43)
France	3/1/20	46.6	7.5	3.2	45 142 (23)	96 763 (49)	78 947 (40)
Sweden	2/29/20	57.4	23.5	10.3	9581 (5)	44 210 (22)	55 607 (28)
Italy	2/23/20	59.1	9.1	3.1	4136 (2)	91 604 (46)	79 120 (40)
United Kingdom	3/3/20	62.6	16.3	5.0	−7459 (−4)	67 927 (34)	73 103 (37)
Spain	2/29/20	65.0	8.6	4.6	−15 204 (−8)	93 247 (47)	74 163 (37)
Belgium	3/2/20	86.8	12.4	4.2	−87 057 (−44)	80 475 (41)	75 572 (38)
United States	3/7/20	60.3	36.9	27.2			

[a] Data on coronavirus disease 2019 (COVID-19) deaths are from February 13, 2020, through September 19, 2020 (n = 198 589 US deaths). In columns 4-6, due to large sample sizes, all mortality rates are statistically significantly different from the corresponding US mortality rates (*P* < .001). Scenarios in the last 3 columns assume that compared with the country in a given row, (A) the US had a comparable cumulative mortality rate; (B) the US mortality rate was unchanged until May 10 (n = 77 180 deaths), when it became comparable to the other country's death rate; and (C) the US mortality rate was unchanged until June 7 (n = 109 143 deaths), when it became comparable to the other country's death rate.

Table 2. Excess All-Cause Mortality in the US Compared With That in Other Countries[a]

Country	Excess all-cause mortality per 100 000: Since the start of the pandemic	Since May 10, 2020	Since June 7, 2020	Excess US deaths from all causes (% of reported deaths): Since the start of the pandemic	Since May 10, 2020	Since June 7, 2020
Moderate mortality (COVID-19 deaths, 5-25/100 000)						
Norway	−2.6	−4.3	−2.1	235 610 (100)	102 598 (44)	63 952 (27)
Denmark	5.1	1.9	1.8	218 664 (93)	96 375 (41)	57 910 (25)
Israel	8	7.5	5.4	209 376 (89)	77 932 (33)	46 091 (20)
Germany	10.0	1.4	−0.2	202 547 (86)	97 905 (42)	63 952 (27)
Canada	13.3	−3.7	−7.6	192 009 (81)	102 598 (44)	63 952 (27)
Switzerland	17.0	−3.6	−2.7	179 545 (76)	102 598 (44)	63 952 (27)
Austria	17.1	3.2	1.4	179 208 (76)	92 042 (39)	59 375 (25)
Finland	19.1	8.7	5.4	172 706 (73)	74 116 (31)	46 264 (20)
High mortality (COVID-19 deaths, >25/100 000)						
Sweden	50.8	14.9	3.7	68 540 (29)	53 429 (23)	51 864 (22)
France	51.5	5.9	2.6	66 167 (28)	83 301 (35)	55 512 (24)
The Netherlands	55.1	0.1	−0.7	54 282 (23)	102 157 (43)	63 952 (27)
Belgium	67.8	−4.6	−6.4	12 638 (5)	102 598 (44)	63 952 (27)
United Kingdom	94.5	13.7	−1.2	−75 196 (−32)	57 659 (24)	63 952 (27)
Spain	102.2	2.1	1.8	−100 768 (−43)	95 784 (41)	57 948 (25)
United States	71.6	31.2	19.4			

[a] Data on deaths are through July 25, 2020 (week 30, n = 235 610 excess US deaths compared with 145 546 reported COVID-19 deaths). Countries lacking publicly available all-cause mortality data through this time are omitted. Excess deaths were estimated by week, compared with 2015-2019, beginning when a country surpassed 1 COVID-19 case per million population. In columns 3-5, due to large sample sizes, all mortality rates are statistically significantly different from the corresponding US mortality rates ($P < .001$). Scenarios in the last 3 columns assume that compared with the country in a given row: (A) the US had a comparable cumulative mortality rate; (B) the US excess all-cause mortality rate was unchanged until May 10 (week 20, n = 133 012 deaths), when it became comparable to the other country's death rate; and (C) the US excess all-cause mortality rate was unchanged until June 7 (week 24, n = 171 659 deaths), when it became comparable to the other country's death rate. Totals are truncated to avoid exceeding US estimated deaths. Due to reporting lags, these data include less follow-up time than Table 1, which in some cases produces lower cumulative death rates.

compared rates across countries using Poisson regression with country and week fixed effects (Supplement), and estimated the difference in excess all-cause mortality between each country and the US as described above. We used R software (version 4.0.2) for all analyses.

Results | On September 19, 2020, the US reported a total of 198 589 COVID-19 deaths (60.3/100 000), higher than countries with low and moderate COVID-19 mortality but comparable with high-mortality countries (**Table 1**). For instance, Australia (low mortality) had 3.3 deaths per 100 000 and Canada (moderate mortality) had 24.6 per 100 000. Conversely, Italy had 59.1 COVID-19 deaths per 100 000; Belgium had 86.8 per 100 000. If the US death rates were comparable to Australia, the US would have had 187 661 fewer COVID-19 deaths (94% of reported deaths), and if comparable with Canada, 117 622 fewer deaths (59%).

While the US had a lower COVID-19 mortality rate than high-mortality countries during the early spring, after May 10, all 6 high-mortality countries had fewer deaths per 100 000 than the US. For instance, between May 10 and September 19, 2020, Italy's death rate was 9.1/100 000 while the US's rate was 36.9/100 000. If the US had comparable death rates with most high-mortality countries beginning May 10, it would have had 44 210 to 104 177 fewer deaths (22%-52%) (Table 1). If the US had comparable death rates beginning June 7, it would have had 28% to 43% fewer reported deaths (as a percentage overall).

In the 14 countries with all-cause mortality data, the patterns found for COVID-19–specific deaths were similar for excess all-cause mortality (**Table 2**). In countries with moderate COVID-19 mortality, excess all-cause mortality remained negligible throughout the pandemic. In countries with high COVID-19 mortality, excess all-cause mortality reached as high as 102.1/100 000 in Spain, while in the US it was 71.6/100 000. However, since May 10 and June 7, excess all-cause mortality was higher in the US than in all high-mortality countries (Table 2).

Discussion | Compared with other countries, the US experienced high COVID-19–associated mortality and excess all-cause mortality into September 2020. After the first peak in early spring, US death rates from COVID-19 and from all causes remained higher than even countries with high COVID-19 mortality. This may have been a result of several factors, including weak public health infrastructure and a decentralized, inconsistent US response to the pandemic.[4,5]

Limitations of this analysis include differences in mortality risk: the US population is younger but has more comorbidities compared with the other countries.[6] In addition, since late August death rates have increased in several countries, and how mortality will compare with the US throughout fall remains unknown.

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Concept and design; acquisition, analysis, or interpretation of data; and drafting of the manuscript: Both authors.
Critical revision of the manuscript for important intellectual content: Emanuel.
Statistical analysis: Bilinski.
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Additional Information: Data and code are publicly available on GitHub.

1. COVID-19 data. European Centre for Disease Prevention and Control. Accessed September 25, 2020. https://www.ecdc.europa.eu/en/covid-19/data

2. Viglione G. How many people has the coronavirus killed? *Nature*. 2020;585(7823):22-24. doi:10.1038/d41586-020-02497-w

3. Lyu W, Wehby GL. Shelter-in-place orders reduced COVID-19 Mortality and reduced the rate of growth in hospitalizations: study examine effects of shelter-in-places orders on daily growth rates of COVID-19 deaths and hospitalizations using event study models. *Health Aff (Millwood)*. 2020;39(9):1615-1623. doi:10.1377/hlthaff.2020.00719

4. Verity R, Okell LC, Dorigatti I, et al. Estimates of the severity of coronavirus disease 2019: a model-based analysis. *Lancet Infect Dis*. 2020;20(6):669-677. doi:10.1016/S1473-3099(20)30243-7

5. Maani N, Galea S. COVID-19 and underinvestment in the public health infrastructure of the United States. *Milbank Q*. 2020;98(2):250-259. doi:10.1111/1468-0009.12463

6. Chaudhry R, Dranitsaris G, Mubashir T, Bartoszko J, Riazi S. A country level analysis measuring the impact of government actions, country preparedness and socioeconomic factors on COVID-19 mortality and related health outcomes. *EClinicalMedicine*. 2020;25:100464. doi:10.1016/j.eclinm.2020.100464

Pediatric Magnet Ingestions After Federal Rule Changes, 2009-2019

Magnet ingestions among children have become a serious health risk after the 2009 introduction of high-powered, rare-earth magnets, commercially sold as small (3- to 6-mm) recreational objects.[1,2] These neodymium magnets are 5 to 10 times more powerful than traditional ferrite magnets and are sold as sets for entertainment and toys (eg, Bucky Balls building sets, jewelry kits, spinning toys).[3] Ingestion of multiple magnets, or a magnet with a metal object, can result in bowel obstruction, perforation, and death when magnets attach through bowel walls.[4] After reports of pediatric injuries and deaths related to ingested neodymium magnets, the Consumer Product Safety Commission (CPSC) initiated campaigns to limit sales in 2012 with voluntary recalls and safety standards.[5] Other CPSC efforts included awareness campaigns, legislative advocacy, and lawsuits.[1] In October 2014, the CPSC published its final rule, Safety Standard for Magnet Sets, prohibiting sales of these small high-powered magnet sets.[3] In November 2016, this rule was legally remanded by the US Court of Appeals 10th Circuit after being challenged by Zen Magnets LLC, resulting in a resurgence of these magnets on the market.[6] This study examined trends in US emergency department (ED) visits for pediatric magnet ingestions over the period of the changes in federal regulations.

Methods | Data from the National Electronic Injury Surveillance System (NEISS), a national sample of US injury-related ED visits, were obtained for January 1, 2009, through December 31, 2019. Magnet ingestions were identified for children aged 17 years or younger with NEISS diagnosis codes of ingested object (41) or aspirated object (42). Only narratives with the key word *magnet* were included. We used US Census data, NEISS sample weights, and clusters to calculate age-specific weighted rates of ED visits for ingestions per 100 000 persons of the population. An interrupted time-series analysis using linear regression modeling examined trends during 3 periods: (1) 2009-2012, before CPSC involvement; (2) 2013-2016, during the CPSC federal rule (including increasing CPSC regulations); and (3) 2017-2019, after the CPSC rule was vacated. Mean ED visit rates for each period and slope changes between periods were calculated. Analysis of variance was used to compare demographics. A 2-sided $P < .05$ was considered significant. Data were analyzed with SAS version 9.3 (SAS Institute Inc) using SURVEYFREQ, SURVEYREG, and SURVEYLOGISTIC, and R for regression analyses (2020; R Foundation). This study was deemed exempt by the Partners Healthcare Institutional Review Board.

Results | A total of 36 701 ED visits were identified for ingested or aspirated objects; 1421 met criteria for magnet

Supplemental Online Content

Bilinski AJ, Emanuel EJ. COVID-19 and excess all-cause mortality in the us and 18 comparison countries. *JAMA*. doi:10.1001/jama.2020.20717

Calculations in Tables 1 and 2

eTable. Data sources for all-cause mortality

This supplemental material has been provided by the authors to give readers additional information about their work.

SUPPLEMENTAL INFORMATION

COVID-19 and All-Cause Mortality in the US and 18 Comparison Countries

Alyssa Bilinski · Ezekiel Emanuel[1],[2]

CALCULATIONS IN TABLES 1 AND 2

Difference in deaths

Let r_i be the death rate of interest (reported COVID-19 deaths or excess all cause mortality) per 100,000 in country i, and d be US deaths over the period of study. Let p be the US 2019 population, $p = 329,064,917$ according to the European Centre for Disease Prevention and Control. We estimate difference in deaths:

$$d - (r_i/100,000) * p \tag{1}$$

Difference in deaths if comparable after some time point

Letting r_{iT} be the death rate per 100,000 in country i between time T and the end of the period of study and d_T be US deaths by time T, we estimate potential difference in deaths since time T:

$$d - (d_T + (r_{iT}/100,000) * p) \tag{2}$$

REGRESSIONS

Table 1

Let d_i be the number of deaths in country i over some time period, and p_i be its population. Assume we have countries $j = 1, ..., n$ and $\mathbf{C}$ be a $(n-1) \times 1$ vector of country indicator variables with the US omitted as reference category. We assume that $d_i \sim Pois(\lambda_i)$ and

$$\mathbb{E}\left[log(\lambda_i)\right] = \beta_0 + \boldsymbol{\beta}\mathbf{C} + log(p_i), \tag{3}$$

where $\boldsymbol{\beta}$ is $1 \times n - 1$ and β_j compares the death rate in country j to the US.

Table 2

Let $d_{i,w,y}$ be the number of deaths in country i at week w in year y, and p_i be its population. Assume we have countries $j = 1, ..., n$ and $\mathbf{C}$ be an $(n-1) \times 1$ vector of country indicator variables with the US omitted as reference category, $\mathbf{W}$ be a $(W-1) \times 1$ vector of week indicator variables, and $\mathbb{I}_{2020}$ be equal to 1 if the year is 2020 and 0 otherwise. We assume that $d_{i,w,y} \sim Pois(\lambda_{i,w,y})$ and

$$\mathbb{E}\left[log(\lambda_{i,w,y})\right] = \beta_0 + \boldsymbol{\beta}\mathbf{C} + \boldsymbol{\gamma}\mathbf{W} + \delta\mathbb{I}_{2020} + \boldsymbol{\alpha}\mathbf{C}\mathbb{I}_{2020} + log(p_i), \tag{4}$$

where $\boldsymbol{\alpha}$ is $1 \times n - 1$ and α_j compares excess 2020 mortality in country j to in the US.[3]

DATA SOURCES

We accessed data on **COVID-19 deaths** from the **European Centre for Disease Prevention and Control COVID-19 database** (link, accessed through R library sars2pack). We accessed **all-cause mortality data** from country-specific sources (Table S1). We also referenced *The Economist* (link) and *The New York Times* (link) excess death GitHubs and associated coverage.

[1]Contact: zemanuel@upenn.edu

[2]Data and code are available on GitHub (link).

[3]For estimation strategies, see Weinberger DM, Chen J, Cohen T, et al. Estimation of Excess Deaths Associated With the COVID-19 Pandemic in the United States, March to May 2020. JAMA Intern Med. Published online July 1, 2020. doi:10.1001/jamainternmed.2020.3391.

Country	Source	File	Included	Week format[4]	Notes	Link
Australia	Australian Bureau of Statistics	Provisional Mortality Statistics	No		Data only available through May 2020	link
Austria	Statistics Austria	Age-specific death rates in Austria (excl. deaths abroad) by calendar week	Yes	Sunday-Saturday		link
Belgium	Statbel	Number of deaths per day, sex, age, region, province, district	Yes	Daily data, aggregated by week (Monday-Sunday)		link
Canada	StatCan	Adjusted number of deaths, expected number of deaths and estimates of excess mortality, by week	Yes	Monday-Sunday		link
Denmark	Statistics Denmark	DODC2: Deaths per week (experimental statistics) by region, sex and age	Yes	Sunday-Saturday		link
Finland	Statistics Finland	12ng – Deaths by week according to sex, age and region (Rapid estimate), 1990W01-2020W37*	Yes	Sunday-Saturday		link
France	Insée	Téléchargement des fichiers des décès quotidiens	Yes	Daily data, aggregated by week (Monday-Sunday)	Economist GitHub used for all-cause mortality 2015-17	link, link
Germany	DeStatis	Sterbefälle - Fallzahlen nach Tagen, Wochen, Monaten, Altersgruppen und Bundesländern für Deutschland 2016 - 2020	Yes	Daily data, aggregated by week (Monday-Sunday)	Only available starting in 2016	link
Israel	Ministry of Health		Yes	Sunday-Saturday	Received translation assistance	link
Italy	Istat	10 August 2020 – Male, female and total deaths	No		Data only available through June 2020	link
Japan	e-Stat	Current Population Survey / Vital Statistics	No		Data only available through July 2, 2020	link
Netherlands	StatLine	Deaths registered weekly, by sex and age	Yes	Sunday-Saturday		link
Norway	Statistics Norway	07995: Deaths, by sex, age and week. Preliminary figures 2000 - 2020	Yes	Sunday-Saturday		link
South Korea	Statistics Korea	Vital statistics (births/deaths)	No		Received translation assistance; data only available monthly	link
Spain	Instituto Nacional de Estadística	Estimate of Weekly Deaths	Yes	Sunday-Saturday		link
Sweden	Statistics Sweden	Preliminary statistics on deaths in Sweden		Daily data, aggregated by week (Monday-Sunday)		link
Switzerland	Federal Statistics Office	Weekly number of deaths, 2020 & 2010-2019		Sunday-Saturday		link
United Kingdom	Office of National Statistics (GB), National Records of Scotland, Northern Ireland Statistics and Research Agency	Deaths registered weekly in England and Wales, provisional, Deaths involving coronavirus (COVID-19) in Scotland, Weekly death registrations in Northern Ireland, 2020.	Yes	Sunday-Saturday		link, link, link
United States	Centers for Disease Control and Prevention	Deaths involving coronavirus disease 2019 (COVID-19), pneumonia, and influenza reported to NCHS by week ending date, United States. Week ending 2/1/2020 to 9/19/2020.	No	Monday-Sunday		link

Table S1 – Data sources for all-cause mortality. The "Included" column indicates whether available data met inclusion criteria; if not, this is explained in the "Notes" column. Due to differences in reporting, week definition varies slightly (either Monday-Sunday or Sunday-Saturday).