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Population-level COVID-19 mortality risk for non-elderly individuals overall and for non-elderly individuals without underlying diseases in pandemic epicenters

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Abstract

Objective

To provide estimates of the relative rate of COVID-19 death in people <65 years old versus older individuals in the general population, the absolute risk of COVID-19 death at the population level during the first epidemic wave, and the proportion of COVID-19 deaths in non-elderly people without underlying diseases in epicenters of the pandemic.

Eligible data

Cross-sectional survey of countries and US states with at least 800 COVID-19 deaths as of April 24, 2020 and with information on the number of deaths in people with age <65. Data were available for 14 countries (Belgium, Canada, France, Germany, India, Ireland, Italy, Mexico, Netherlands, Portugal, Spain, Sweden, Switzerland, UK) and 13 US states (California, Connecticut, Florida, Georgia, Illinois, Indiana, Louisiana, Maryland, Massachusetts, Michigan, New Jersey, New York, Pennsylvania). We also examined available data on COVID-19 deaths in people with age <65 and no underlying diseases.

Main outcome measures

Proportion of COVID-19 deaths in people <65 years old; relative mortality rate of COVID-19 death in people <65 versus ≥65 years old; absolute risk of COVID-19 death in people <65 and in those ≥80 years old in the general population as of June 17, 2020; absolute COVID-19 mortality rate expressed as equivalent of mortality rate from driving a motor vehicle.

Results

Individuals with age <65 account for 4.5–11.2% of all COVID-19 deaths in European countries and Canada, 8.3–22.7% in the US locations, and were the majority in India and Mexico. People <65 years old had 30- to 100-fold lower risk of COVID-19 death than those ≥65 years old in 11 European countries and Canada, 16- to 52-fold lower risk in US locations, and less than 10-fold in India and Mexico. The absolute risk of COVID-19 death as of June 17, 2020 for people <65 years old in high-income countries ranged from 10 (Germany) to 349 per million (New Jersey) and it was 5 per million in India and 96 per million in Mexico. The absolute risk of COVID-19 death for people ≥80 years old ranged from 0.6 (Florida) to 17.5 per thousand (Connecticut). The COVID-19 mortality rate in people <65 years old during the period of fatalities from the epidemic was equivalent to the mortality rate from driving between 4 and 82 miles per day for 13 countries and 5 states, and was higher (equivalent to the mortality rate from driving 106–483 miles per day) for 8 other states and the UK. People <65 years old without underlying predisposing conditions accounted for only 0.7–3.6% of all COVID-19 deaths in France, Italy, Netherlands, Sweden, Georgia, and New York City and 17.7% in Mexico.

Conclusions

People <65 years old have very small risks of COVID-19 death even in pandemic epicenters and deaths for people <65 years without underlying predisposing conditions are remarkably uncommon. Strategies focusing specifically on protecting high-risk elderly individuals should be considered in managing the pandemic.

Keywords: COVID-19, Mortality, Risk, Age, Underlying diseases

1. Introduction

As the coronavirus disease 2019 (COVID-19) pandemic has spread widely around the globe (Fauci et al., 2020; Gates, 2020), estimates about its eventual impact in terms of total number of deaths have varied widely, as they are mostly based on mathematical models with various speculative assumptions. It is crucial to estimate how much smaller the risk of death is among non-elderly people (<65 years old) as opposed to older individuals and how frequent deaths are in people who are <65 years old and have no underlying predisposing diseases. Media have capitalized on stories of young healthy individuals with severe, fatal outcomes. However, exaggeration should be avoided in responding to the pandemic (Ioannidis, 2020a). Accurate estimates of mortality rate at different age groups have important implications. Deaths of young, healthy people contribute far more quality-adjusted life-years lost than deaths in elderly individuals with pre-existing morbidity. Knowledge of COVID-19 mortality rates for people <65 years old at the population level can help guide different management strategies for the pandemic. People <65 years old represent the lion's share of the workforce.

Here, we used data from 14 countries and 13 states in the USA that have been epicenters of the pandemic with a large number of deaths and where data were available for deaths according to age stratification. We aimed to evaluate the relative mortality rate in people <65 years old versus older individuals in the general population, to provide estimates of absolute risk of COVID-19 death in these epicenters during the first epidemic wave, and to understand what proportion of COVID-19 deaths occur in people <65 years old and without underlying diseases.

2. Methods

We considered data from publicly reported situational reports of countries and US states or major cities that had already been major epicenters of the pandemic as of late April, 2020; thus epidemic waves are likely to be mostly completed almost two months later (by mid-June, 2020). Eligibility criteria included: (1) at least 800 deaths accumulated as of April 24, 2020 (so as to qualify for an early hotbed of the epidemic and to have a meaningful amount of data to analyze); and (2) information available on death counts per age strata, allowing to calculate numbers of deaths in people with age <65 or, alternatively, at least in people with age <60.

Different dates for extractions are listed throughout the manuscript, depending on data availability; Supplementary Table 1 provides all the dates of collection of the various COVID-19-related data.

For each of the eligible geographical locations, we extracted information from the most up-to-date situational reports as of May 23, 2020 (countries) or May 24, 2020 (US locations) focusing on total number of deaths with available age stratification, and number of deaths in age <65 (or, if not available, number of deaths in age <60 and in age 60–69), and ≥65. Information was extracted independently in duplicate by two authors (JI, CA) and discrepancies were resolved. Whenever information was unavailable for the desirable <65 years cut-off, we contacted the respective authorities issuing the situational report. For secondary analyses, we also extracted information on deaths in the more granular age subgroups of <40, 40–64, 65–79, and ≥80.

One author (DC-I) downloaded information on the proportion of the population in each eligible location for each age group. We used census information from populationpyramid.net/world/2019 for countries and from https://worldpopulationreview.com for the US states.

We calculated the population-level relative mortality rate of COVID-19 death for an individual <65 years old as compared with an individual ≥65 years old for each eligible country and US state/city. This we calculated as the ratio of absolute risks (COVID-19 deaths with age <65/population with age <65 in the respective age-pyramid) divided by (COVID-19 deaths with age ≥65/population with age ≥65 in the respective age-pyramid). Inverting this relative mortality rate shows how many fold lower the risk of COVID-19 death is for an individual <65 years old as compared with an individual ≥65 years old.

We also calculated the absolute risk of dying with COVID-19 during the first epidemic wave for a person <65 years old in each eligible country and state by dividing the number of COVID-19 deaths (updated as of the end of day June 17, 2020) in this age group by the census population in this age group. Certainly, the number of deaths will increase and there is some uncertainty about the total projected number of deaths in each of these locations when this epidemic wave has passed, and all deaths have been counted. With the exception of India and Mexico, all other locations had largely completed the epidemic wave as of June 17 (for a visualization see Supplementary Fig. 1) – at least the first wave, since it remains unknown whether they may be any second waves. We also documented for each country and state the peak 7-day moving up to June 17, 2020. We used a 7-day moving frame, because there is some unavoidable noise fluctuation in death counts every day, plus for several countries and states there may be worse reporting delays for deaths during the weekend days. We used the actual date that deaths occurred for these estimates, but, whenever this was unavailable, we used the date of death reporting.

The magnitude of COVID-19 mortality rates is difficult to grasp, especially when population-level risks are small. Therefore, we converted the absolute risks of COVID-19 death into equivalents of mortality rate by a well-known, almost ubiquitous activity (Ioannidis, 2013), driving/travelling by motor vehicle. We used estimates from the International Transport Forum Road Safety Annual Report 2018 for the number of road deaths per billion vehicle miles driven for each European country (OECD, 2020). For Spain, Italy, Portugal, and Mexico there were only data available for number of road fatalities per 100,000 inhabitants and for India we found similar data from Wikipedia. Since road deaths per 100,000 inhabitants tend to correlate reasonably well with road deaths per billion vehicle miles in Europe, we used for Italy and Portugal the same road deaths per billion miles as for Belgium, since Italy and Portugal have the same road deaths per 100,000 inhabitants as Belgium. Similarly, we used for Spain the same road deaths per billion miles as Germany. For Mexico and India, their road fatalities per 100,000 inhabitants were close to the USA values and we used the USA value road deaths per billion miles with adjustment for the difference. For USA locations, we used the state-specific data provided for 2018 by the Insurance Institute for Highway Safety (Insurance Institute for Highway safety, 2020). In other words, for each location we identified the distance that one has to travel by motor vehicle to expose oneself to the same hazard as the absolute COVID-19 mortality rate observed until June 17, 2020. We then divided the estimated miles travelled by the number of days that have passed since the first COVID-19 death was recorded in each location and until June 17, 2020. The result transforms the average risk of COVID-19 death per day during the period where COVID-19 deaths occur into an equivalent of miles travelled by car per day. The longer the distance, the higher the risk. Of note, for a typical death curve, e.g. as documented in Wuhan (Du et al., 2020), the miles travelled per day estimate may be overestimated, if the covered fatality period extends beyond the peak of the curve (as is the case in all high-income locations that we analyzed), and may be underestimated otherwise – this situation may apply to India and Mexico.

Finally, we sought information from the situational reports and from personal communications with the respective health authorities on how many COVID-19 deaths had been documented in people <65 years old who had no underlying predisposing conditions. Predisposing conditions for worse outcome in COVID-19 may include (Guan et al., 2020; Wang et al., 2020a; World Health Organization, 2020) cardiovascular disease, hypertension, diabetes, chronic obstructive pulmonary disease and severe asthma, kidney failure, severe liver disease, immunodeficiency, and malignancy. We followed the data collection principles of each national and state organization on how underlying conditions were defined. Data were readily available in published reports or public datasets for France (Santé publique France, 2020), Mexico (Secretaría de Salud, 2020), Georgia (Georgia Department of Public Health, 2020) and New York City (New York City Health, 2020). We contacted all other national agencies and state departments of health when we could find contact information and thus we obtained additional such data according to the presence or not of underlying conditions from the Italian COVID-19 team (personal communication, Luigi Palmieri), from the Dutch COVID-19 team (personal communication, Susan van den Hof), and from the Swedish National Board of Health and Welfare (personal communication, Erik Wahlström) (Socialstyrelsen, 2020). We encourage other organizations to send us similar data, as they become available, so that they can be incorporated in further updates. We avoided performing a formal meta-analysis, since these data are using different definitions of eligible comorbidities and data collection methods.

3. Results

3.1. Eligible data

Eighteen countries (Belgium, Brazil, Canada, China, France, Germany, India, Iran, Ireland, Italy, Mexico, Netherlands, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom) and 13 US states (California, Connecticut, Florida, Georgia, Illinois, Indiana, Louisiana, Maryland, Massachusetts, Michigan, New Jersey, New York, Pennsylvania) fulfilled the first eligibility criterion and of those, 14 countries (Belgium, Canada, France, Germany, India, Ireland, Italy, Mexico, Netherlands, Portugal, Spain, Sweden, Switzerland, United Kingdom) as well as all 13 states had some available data on required age categories so that they could be included in our analysis. (Santé publique France, 2020; Secretaría de Salud, 2020; Georgia Department of Public Health, 2020, Sciensano: the Belgian Institute for Health, 2020; Public Health Agency of Canada, 2020; Robert Koch Institut, 2020; Ministry of Health and Family Welfare, 2020; Health Protection Surveillance Centre/Lárionad Faire um Chosaint Sláinte, 2020; Epidemiology for public health/Istituto Superiore di Sanità, 2020; Rijksinstituut voor Volksgezondheid en Milieu – RIVM, 2020; Serviço Nacional de Saúde/Direção-Geral da Saúde, 2020; Centro de Coordinación de Alertas y Emergencias Sanitarias, 2020; Folkhälsomyndigheten, 2020; Bundesamt für Gesundheit BAG, 2020; Office for National Statistics, 2020; State of California, 2020; State of Connecticut, 2020; Florida Department of Health Open Data, 2020; Illinois Department of Public Health, 2020; Indiana State Department of Health, 2020; Louisiana Department of Health/Office of Public Health, 2020; Maryland Department of Health, 2020; Massachusetts Department of Public Health/Executive office of Health and Human Services, 2020; State of Michigan, 2020; New Jersey Department of Health, 2020; New York State Department of Health, 2020; Pennsylvania Department of Health/Bureau of Health Statistics and Registries, 2020)

3.2. Deaths with age stratification

Age distribution of COVID-19 deaths are shown in Fig. 1 and detailed in Table 1 (raw data in Supplementary Table 2). Individuals with age <65 accounted for only 4.5–11.2% of all COVID-19 deaths in all European countries and Canada. Among the 13 US locations, the proportion of deaths contributed by individuals <65 ranged from 8.3 to 22.7% of all deaths. Conversely, in Mexico and India, they were the majority.

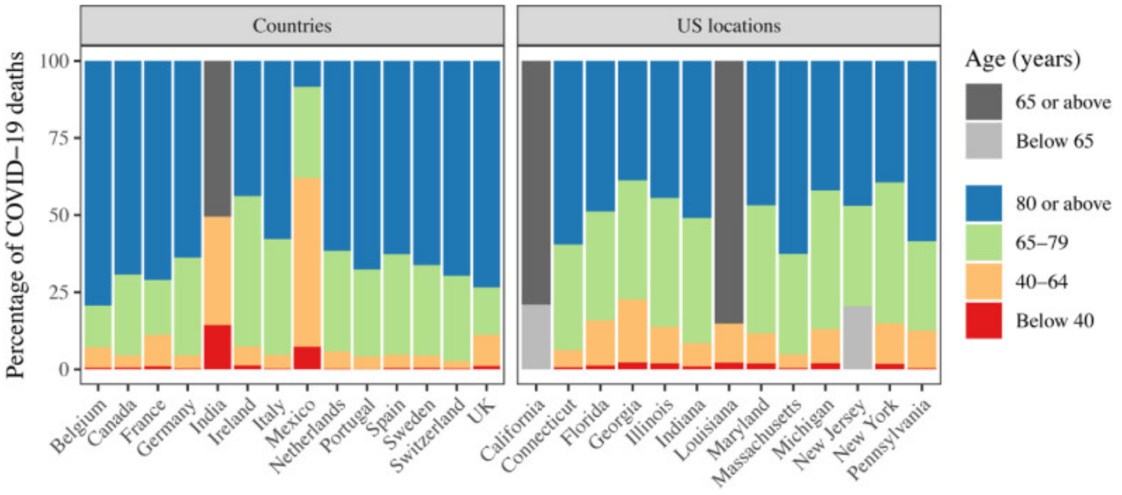

Fig. 1

Proportion of COVID-19 deaths by specific age group category. For detailed numbers, and deviations from age category cutoffs (when data were not provided for these exact age-categories), see Table 1.

Table 1

Proportion of COVID-19 deaths in specific age groups.

Location (date report)	Total deaths[a]	% of deaths age <40 among total deaths	% of deaths age 40–64 among total deaths	% of deaths age 65–79 among total deaths	% of age ≥80 among total deaths	% of deathsage <65 among total deaths
Countries						
Belgium (May 22)	6579	0.5[b]	6.7[c]	13.5[d]	79.2[e]	7.2
Canada (May 22)	2305	0.6	3.9[f]	26.3[g]	69.2	4.5
France (May 18)	17488	1.0[b]	10.2[c]	17.7[d]	70.6[e]	11.2
Germany (May 23)	8211	0.4	4.2[f]	31.3[g]	63.7	4.5 [7.6][h]
India (May 21)	3435	14.4[b]	35.1[i]	ND	ND	49.5[h]
Ireland (May 20)	1330	1.3[b]	6.1[c]	48.8[j]	43.8[k]	7.4
Italy (May 20)	31017	0.3	4.4[f]	37.6[g]	57.7	3.6 [7.1][h]
Mexico (May 24)	7394	7.3	54.7	29.6	8.3	62.1
Netherlands (May 22)	5788	0.2	5.6	32.7	61.5	5.8
Portugal (May 22)	1302	0.1	4.2[f]	28.2[g]	67.6	4.2 [7.2][h]
Spain (May 22)	20552	0.5	4.3[f]	32.6[g]	62.7	4.7 [7.7][h]
Sweden (May 22)	3992	0.5	4.0[f]	29.3[g]	66.1	4.5 [6.9][h]
Switzerland (May 23)	1640	0.3	2.4[f]	27.7[g]	69.6	2.7 [5.1][h]
UK (May 8)	41020	1.1[b]	10.1[c]	15.4[d]	73.4[e]	11.2
US locations						
California	3708	ND	ND	ND	ND	21.0

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The proportions of deaths across different categories may change if late-occurring or late-reported deaths have a different age distribution. This may be an issue specifically for Mexico and India where the epidemic wave was still far from mature at the time of data collection. As of June 26, 2020, no updated age-group death data could be found for India, but such updated data were available for Mexico, and the age distribution had not changed much, e.g. 58.3% of deaths were in people with age <65 years. ND: no data.

[a]Using deaths' data with available information on age.

[b]Group <45 years (not available for <40 years).

[c]Group 45–64 years (not available for 40–64 years).

[d]Group 65–74 years (not available for 65–79 years).

[e]Group ≥75 years (not available for ≥80 years).

[f]Group 40–59 years (not available for 45–64 years).

[g]Group 60–79 years (not available for 65–79 years).

[h]Group <60 years [the number shown in brackets is the approximated estimate for age <65 assuming that a third of the deaths in the 60–69 bracket are in <65 years old people, as suggested by other countries where data are available on 5-year age intervals].

[i]Group 45–59 years (not available for 45–64 years).

[j]Group 65–84 years (not available for 65–79 years).

[k]Group ≥85 years (not available for ≥80 years).

Individuals with age <40 accounted for <1.3% of all COVID-19 deaths in European countries and Canada and 0.4–2.3% in the US states, but were a much larger proportion in Mexico and India. Individuals 80 years or older accounted for the large majority of deaths (half to four-fifths or more) in Europe (except Ireland) and Canada, while in the US there was wider variability across states (range, 39–63%). In Mexico, they accounted for only 8.3% of deaths (no data on India).

3.3. Relative rate of dying with COVID-19 for individuals <65 years old versus older individuals at the population level

As shown in Fig. 2 (raw data in Supplementary Tables 3–4), the percentage of the population <65 years old varied from 75.18% to 86.31% in high-income countries' locations and exceeded 90% in India and Mexico. People <65 years old had overall a 30- to 100-fold lower risk of COVID-19 death than those ≥65 years old in European countries and Canada, for the US locations, the relative mortality rate was somewhat smaller (16–52-fold), while for Mexico and India the relative mortality rate was less than 10-fold.

Location	Percentage of population <65 years in the general population (%)	Relative risk of COVID–19 death for those >=65 years versus those <65 years	95% CI lower	95% CI upper
Countries				
Canada	82.35%	100	80	122
Switzerland	81.16%	80	64	99
Ireland	85.78%	76	62	93
Netherlands	80.39%	67	60	74
Belgium	80.99%	55	50	60
Sweden	79.80%	53	47	60
Spain	80.35%	49	47	52
Portugal	77.64%	45	37	56
Germany	78.44%	44	41	48
Italy	76.99%	44	42	46
UK	81.49%	35	34	36
France	79.61%	31	29	32
India	93.62% (90.13%)	9	9	10
Mexico	92.58%	8	7	8
US locations				
Massachusetts	82.57%	52	48	57
Connecticut	84.02%	46	41	51
Indiana	83.63%	32	28	36
Pennsylvania	82.38%	32	30	35
Illinois	86.31%	26	24	27
Maryland	84.30%	26	23	29
Louisiana	85.82%	23	21	25
California	85.38%	22	20	24
Michigan	83.00%	21	19	22
New York	85.03%	21	20	21
New Jersey	83.98%	20	19	21
Georgia	83.32%	17	15	19
Florida	75.18%	16	14	18

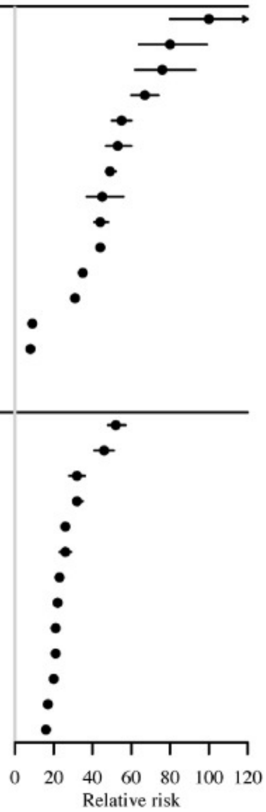

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Fig. 2

Age distribution in the general population and relative mortality rate (relative risk of dying from COVID-19) for age ≥65 versus <65. For India, the value in parenthesis is for the group <60 years old, and relative mortality rate is given for ≥60 versus <60 years.

3.4. Absolute risk of death with COVID-19 at the population level

Table 2 shows the estimates of the absolute risk of dying with COVID-19 at the population level for people <65 years old and for those ≥80 years old as of June 17. For these estimates we used the total number of deaths as of the close of day June 17, 2020 (for sources see Supplementary Table 5), and not just those where age information was available (as in Table 1). Also shown is the 7-day moving period that had the largest number of deaths. As shown, with the exception of India and Mexico, the peak period was already long before June 17, suggesting that the epidemic fatality waves had already reached substantial maturity as of June 17. Visual perusal (Supplementary Fig. 1) also agrees that these epidemic waves are practically complete. The absolute risk of death for people <65 years old in high-income countries ranged widely from 10 per million in Germany to 349 per million in New Jersey. Connecticut, Illinois, Louisiana, Massachusetts, Michigan, New Jersey, and New York had an absolute risk of death exceeding 100 per million. The risk was 5 per million in India (data on <60 years old) and 96 per million in Mexico.

Table 2

COVID-19 deaths, peak 7-day period for deaths, population count and absolute risk of COVID-19 death for age groups <65 (per million) and ≥80 (per thousand).

Location	Day of first documented COVID-19 death[a]	Peak 7-day COVID-19 death count as of June 17	Total COVID-19 deaths as of June 17 (n)[b]	Risk for people <65 (per million)	Risk for people ≥80 (per thousand)
Countries					
Belgium	Mar 10	Apr 7–13	9675	75	ND
Canada	Mar 9	Apr 30-May 6	8213	12	3.5
France	Feb 14	Apr 2–8	29575	64	ND
Germany	Mar 9	Apr 12–18	8830	10	1.0
India	Mar 12	June 11–17	11903	5[c]	ND
Ireland	Mar 11	Apr 19–25	1449	25	ND
Italy	Feb 22	Mar 27-Apr 2	33168	50	4.3
Mexico	Mar 19	June 3–9	18310	96	0.8
Netherlands	Mar 6	Mar 30-Apr 5	6074	26	4.6
Portugal	Mar 16	Apr 7–13	1523	14	1.5
Spain	Feb 13	Mar 27-Apr 2	27136	55	5.9
Sweden	Mar 10	Apr 9–15	5041	44	6.4
Switzerland	Mar 5	Apr 2–8	1678	12	2.6
UK	Feb 28	Apr 7–13	42153	86	ND
US locations					
California	Feb 6	Apr 18–24	5208	32	ND
Connecticut	Mar 17	Apr 20–26	4219	145	17.5
Florida	Mar 6	May 5–11	3018	29	0.6
Georgia	Mar 12	Apr 16–22	2575	65	1.4
Illinois	Mar 17	May 5–11	6485	117	8.8
Indiana	Mar 15	Apr 21–27	2289	56	3.3
Louisiana	Mar 14	Apr 5–11	2950	155	ND
Maryland	Mar 17	Apr 24–30	2866	96	4.6
Massachusetts	Mar 18	Apr 18–24	7734	111	11.3
Michigan	Mar 18	Apr 10–16	5792	132	5.0
New Jersey	Mar 11	Apr 15–21	12769	349	14.2
New York	Mar 14	Apr 7–13	24629	319	14.6

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Peak 7-day period of deaths is based on data as of June 17 (June 14 for Ireland and June 15 for Italy) and thus higher peaks and/or a second wave cannot be fully excluded. For France, Germany, Ireland, Italy, Portugal, Spain, Michigan, New Jersey, and New York only date of deaths reported were available, not actual date of death. ND: no data to allow calculation.

[a]Based on official reports or news articles, but cannot exclude earlier COVID-19 deaths that went undetected.

[b]Sources for total death counts are available in Supplementary Table 5.

[c]For India: risk for people <60 years (per million) since <65 was not available.

The absolute risk of death for people ≥80 years old in high-income countries ranged from approximately 0.6 in a thousand in Florida to 17.5 in a thousand in Connecticut. For middle-income countries, it was 0.8 in a thousand in Mexico as of June 17 (no data for India).

Table 3 shows the conversion of the absolute risk of COVID-19 death as of June 17 into the equivalent mortality rate from motor vehicle travelled miles. The distances (corresponding to equivalent mortality rates) ranged from driving a total of 416 miles to 47773 miles. Dividing by the number of days since the first documented COVID-19 death, the average daily risk of COVID-19 death for an individual <65 years old in 11 of the 12 European countries or Canada is equivalent to driving between 12 and 82 miles per day during this period (94–126 days). California, Florida, Georgia, Indiana, and Pennsylvania are also in the same range of daily risk over 92–151 days. Conversely, the risk is higher in the UK and in the other 8 states in the USA (driving 106–483 miles per day) for the 92–111 days during which they have witnessed COVID-19 deaths. In India it was only 4 miles per day and in Mexico it was 79 miles per day.

Table 3

Absolute risk of COVID-19 death expressed as equivalent of mortality rate from associated with motor vehicle driving over given distances.

Location	Road deaths per billion miles Travelled	Risk of COVID-19 death for <65 year old people as total miles travelled equivalent until June 17	Days with COVID-19 deaths (as of June 17)	Risk of COVID-19 death for <65 year old people as miles travelled per day equivalent
Countries				
Belgium	11.7	6388	100	64
Canada	8.2	1453	101	14
France	9.3	6888	125	55
Germany	6.8	1511	101	15
India	11.5[a]	416	98	4[b]
Ireland	6.1	4179	95	44
Italy	11.7[a]	4302	115	37
Mexico	13.4[a]	7178	91	79
Netherlands	7.6	3375	104	32
Portugal	11.7[a]	1171	94	12
Spain	6.8[a]	8143	126	65
Sweden	5.3	8211	100	82
Switzerland	5.1	2417	105	23
UK	5.5	15608	111	141
US locations				
California	10.2	3146	151	21
Connecticut	9.3	15632	93	168
Florida	14.1	2057	104	20
Georgia	11.4	5741	98	59
Illinois	9.6	12235	93	132
Indiana	10.5	5339	93	57
Louisiana	15.3	10155	96	106
Maryland	8.4	11390	93	122
Massachusetts	5.4	20601	92	224
Michigan	9.5	13889	92	151

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[a]Approximation (see Methods, we welcome provision of any more precise estimates).

[b]For India: risk for people <60 years since <65 was not available.

3.5. COVID-19 deaths in individuals <65 years old without underlying conditions

Data on deaths in patients <65 years old without any underlying conditions (comorbidities) were available for France, Italy, Mexico, Netherlands, Sweden, Georgia, and New York City. As shown in Table 4 , the proportion of these deaths ranged from 0.7 to 3.6% of all COVID-19 deaths with the exception of Mexico that had a much higher percentage (17.7%). Excluding Mexico, the highest proportions were in France, Sweden, and Georgia. France data were based on deaths for which electronic death certificates were available, and completeness of death certificate information is unknown (Santé publique France, 2020). Data on Sweden were based on death counts that included also probable deaths without laboratory confirmation; moreover, only cardiovascular disease, hypertension, diabetes, and pulmonary disease were counted as comorbidities in this assessment, so it is possible that additional patients may have had other comorbidities (Socialstyrelsen, 2020).

Table 4

COVID-19 deaths in individuals <65 years old without underlying conditions.

Location (date report)	Deaths: total; age <65 (n)	Deaths assessed for comorbidities: total; age <65 (n)	Deaths with age <65 without comorbidities (n)	Percentage of deaths in age <65 without comorbidities[a]
Countries				
France (June 23)	29720; 2080	11071; 1071	307	2.0%
Italy (April 2)	12550; 1135	917; ND	6	0.7%
Mexico (June 26)	25779; 15035	25638; 14947	4535	17.7%
Netherlands (April 25)	4409; 257	2730; 204	23	0.7%
Sweden (June 24)	5082; 300	5082; 300	121	2.4%
US locations				
Georgia (June 26)	2770; 609	2089; 482	114	3.6%
New York City (June 26)	17753; 4681	15694; 4215	104	0.7%

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ND: no data available.

[a]In the estimation, it is assumed that among deaths in patients <65, the presence of comorbidities is equally frequent in the patients whose medical records have not been assessed and in those whose medical records have been assessed.

The lowest percentage (0.65% of all COVID-19 deaths) was seen in New York City. Similarly low percentages (0.7% of all COVID-19 deaths) were seen in Italy and Netherlands based on more detailed medical chart review. In Italy, this review is done on a subset of the deaths (n = 917 as of April 2). In the Netherlands, information on underlying diseases is sought since April 10th only for those who died <70 years of age.

4. Discussion

The evaluation of data from 14 countries and 13 US locations that are epicenters of the COVID-19 pandemic shows that non-elderly people <65 years old represent a small fraction (4.5–11.2%) of all COVID-19 deaths in European countries and Canada and between 8.3% and 22.7% of all COVID-19 deaths in 13 US locations, even though this age group represents the majority of the general population. Conversely, in Mexico and India, most COVID-19 deaths occurred in the <65 age group. Overall, the risk of death is 15-100-fold lower in non-elderly people <65 years old than in older individuals in high-income countries and US states, but less than 10-fold lower in India and Mexico. The age-dependent risk gradient is modestly sharper in European countries and Canada versus most of the US locations. Regardless, the absolute risk of death in the non-elderly population is consistently very low even in these pandemic hotbeds. As of June 17, 2020, only 5 to 349 per million people in this age group have died with a COVID-19 diagnosis and the epidemic wave is practically complete in Europe and North America. Moreover, the vast majority of deaths in this age group occur in the age group 40–65 that comprises 37–48% of the population in the 0–65 years old bracket.

Unless there is a further peak of deaths downstream, the total risk of death for the entire epidemic wave in these locations may not be much larger than what has been documented as of June 17 (with the exception of Mexico and India), assuming a fairly symmetric epidemic wave, as in the case of Wuhan (World Health Organization, 2020). The risk observed in this first wave cannot be extrapolated to any future second wave, which is unknown whether it will exist and, if so, how high it might be.

For the whole COVID-19 fatality season to-date (starting with the date the first death was documented in each location), the average daily risk of dying from coronavirus for a person <65 years old is equivalent to the risk of dying driving a distance of 4–82 miles by car per day during that COVID-19 fatality season in 18 of the 27 hotbeds and 106–483 miles per day in the other 9 hotbeds (UK and 8 USA locations). For many hotbeds, the risk of death is in the same level roughly as dying from a car accident during daily commute, although it can be higher in the locations that are most hit. For example, the average commute is 31.5 miles per day for Americans according to the American Driving Survey (Kim et al., 2019) and 16.9 miles per day round trip in Sweden (Swedish National Mediation Office, 2019). The highest daily risk of COVID-19 death (in New Jersey) corresponds roughly to the risk of dying in a traffic accident while travelling daily from Manhattan to Washington, DC round trip for these 99 days of COVID-19 fatalities-period. We provide raw data for diverse age groups (<40, 40–65, 65–80, >80), so that one can calculate risks in these age groups as well. People who are 40–65 years old may have about double the risk of the overall <65 age stratum, while those 40 years old or younger have almost no risk at all of dying. Moreover, females may have approximately 2-times lower risk than males (Williamson et al., 2020).

These risk estimates correspond to the main epicenters of the pandemic that accounted for almost 300,000 of the COVID-19 deaths as of June 17, 2020 and (with the exception of India and Mexico) exceeded 100 deaths per million inhabitants. The majority of countries around the world and the majority of states and cities in the USA have much lower fatality rates; in these places, the risk of death from COVID-19 this season for people <65 years old may typically be similar or even smaller to the risk of dying from a car accident during daily commute. We acknowledge that we cannot make any statement about the occurrence and magnitude of any second wave (e.g. in the fall/winter or next spring), but even for influenza the magnitude of the 2020–2021 wave is largely unpredictable.

The absolute mortality rate in an age group depends on the proportion of people infected and on the infection fatality rate in that age group. The proportion of people infected depends on the natural spread of the virus and the impact of preventive measures taken. The relative mortality rate between different age groups depends mostly on the difference in the infection fatality rate of these age groups and may also be modulated if preventive measures are taken that decrease exposure and spread in one age group more than in another. Most seroprevalence studies to-date suggest fairly similar rates of spread of the virus in different ae groups. But some exceptions may exist (Ioannidis, 2020b).

We should acknowledge that the risk estimates presented in our analysis integrate the composite effects of all the measures taken by the authorities in each location. Population-level mortality rates would have been different if no measure to limit disease transmission was taken. Absolute risks may be shaped by these preventive measures, although we have no "control" data to see what the risk would have been if some of these measures had not been taken or if different measures had been adopted. It is also likely that in most of the examined epicenters most of the preventive measures (e.g. lockdowns) were probably implemented horizontally, in the whole population, without substantial differences between age groups. If so, the relative population-level mortality rates (comparing young with elderly) may be more stable than absolute risk estimates. Nevertheless if specific measures focus more on protecting specific age-groups (e.g. focusing more on specifically protecting the elderly in the future), mortality rates in different age groups may change by different amounts and this may thus affect also the relative mortality rate estimates.

We should also acknowledge that most of the epicenters considered in this analysis are high-income countries with generally high life expectancy. For lower-income countries, the proportion of deaths among younger age strata appears substantially larger. This may reflect differences in life expectancy and age pyramids. For example, in India, life expectancy is almost a decade less than in the USA and almost 15 years less than in Switzerland, making octogenarians and nonagenarians few in relative terms. The overall population level mortality rate across all age groups is much lower compared with the other epicenters we analyzed; thus the absolute population risk of death for non-elderly individuals in India is extremely low. For Mexico, the proportion of elderly people is higher than India but still very low (<8% above 65).

Some caveats about the data need to be discussed. Even though mortality is an unambiguous endpoint, attribution of death to a specific cause is often challenging and definitions of "COVID-19 death" vary across countries and sometimes even change within countries over time. For example, the presented age-stratified data on Canada do not seem to include deaths that happened outside the hospitals. Different countries and US locations differ on the threshold of including deaths at care homes. For example, in Belgium, 53% of deaths come from care homes, but 94% of them have not had laboratory confirmation (Rankin et al., 2020). Several US locations have also started counting also "probable" deaths without any COVID-19 laboratory confirmation, a debatable practice at best. On the other hand, this may be defended as a justified approach since in some locations testing was not available or not performed. Overall, some COVID-19 deaths may be missed, and others may be overcounted. Different death tallies are derived by different sites, e.g. CDC (Centers for Disease Control and Prevention, 2020a) and the popular Worldometer site. (Worldometer.info) Arbitration and proper calibration of death counts may need to await careful, in depth medical chart review and autopsy efforts. Under- and over-counting may be responsible for some of the heterogeneity observed in risk estimates.

We should also acknowledge that we focused on mortality risk and not on hospitalizations. Empirical experience shows that COVID-19 has the potential to overwhelm specific hospitals (e.g. Lombardy, Queens or Bronx), especially in settings where hospitals run close to maximum capacity even under regular circumstances, and when they serve high risk populations in cities with high population density and major congregations in mass events. Therefore, hospital preparedness is essential, regardless of whether the risk of death is very low in the general population. Similarly, work modeling hospital bed needs is useful. However, for understanding the risk of individuals from the general population, the analogy against deaths by motor vehicle accidents is still relevant, since motor vehicle accidents also result in many more people who require hospitalizations and who suffer major injuries beyond the numbers of those who die.

The mortality rate estimates that we calculated may also be corroborated by the perusal of patterns of excess mortality in the general population during the period of COVID-19 fatalities. For example, data from 24 European countries (EUROMOMO, 2020) show that in the 11 weeks between week 10 and week 21 in 2020, the excess of deaths increased by 13780 deaths in the <65 years age category and by 152418 deaths in the older age category. Therefore, the excess deaths in the <65 years category accounted for 8.3% of the total excess, a number very compatible with the 4.5–11.2% figure observed in the 11 European countries that we analyzed. However, one should be cautious in this comparison, because changes in other causes of deaths may also affect the magnitude of the overall excess during this period. In fact, there is concern that COVID-19 measures may have taken a toll on other causes of death, e.g. people with heart attacks may fear for coming to hospitals for treatment (Krumholtz, 2020; Metzler et al., 2020).

The large majority of the deaths in non-elderly individuals occur in patients who have underlying diseases. Based on existing data to-date (Guan et al., 2020; Wang et al., 2020a; World Health Organization, 2020), cardiovascular disease, hypertension, chronic obstructive pulmonary disease and severe asthma, diabetes, kidney failure, severe liver disease, immunodeficiency, and malignancy may confer an increased risk of adverse outcome. Individuals with these diseases should consider that their risk may be higher than average and rigorous prognostic models need to be developed to estimate with accuracy this increased risk. In non-elderly populations, the more prevalent of these conditions is cardiovascular disease and hypertension, with prevalence of approximately 10% in the 20–39 age group and 38% in the 40–59 age group in the USA (Yazdanyar and Newman, 2009) and similarly high percentages in many other countries. We encourage public health authorities to start reporting systematically data separately on each of the major comorbidities according to age strata. Some data are available for the prevalence of these conditions across all age groups of COVID-19 deaths. Data from the UK from the OpenSafely study suggest that hypertension alone does not increase the risk of death, while uncontrolled diabetes, controlled diabetes, severe asthma, and chronic heart disease increases the risk 2.36-, 1.50-, 1.27- and 1.25 -fold (Williamson et al., 2020).

We could retrieve data from 7 locations on the COVID-19 mortality of people who were both <65 years old and had no underlying diseases. Consistently, the data suggest that these deaths are remarkably uncommon in high-income countries, although their exact percentage contribution to all COVID-19 deaths varies modestly across locations (0.7–3.6%). It is likely that much of this variability may reflect differences on how underlying conditions are captured. We also caution that some people with no recorded comorbidities may have had some underlying diseases, but these where not reported in a crisis setting, or these conditions may have been undiagnosed. Overall, this further strengthens the notion that for healthy non-elderly people, the risk of dying from COVID-19 in the first half of 2020 was very small. This is in stark contrast with many news stories that focus on the demise of young people and the panic and horror that these widely reverberated stories are causing (Hundreds of young America, 2020; WHO says, 2020). Conversely, the available data from Mexico suggest that one out of six deaths were in people <65 and without underlying conditions (Secretaría de Salud, 2020). This may primarily reflect a different age-pyramid, although additional reasons might be deleterious effects of deprivation, lower access to health services, or higher rates of undiagnosed conditions in lower-income countries. It is very important for authorities in all countries and US locations to report carefully curated data on comorbidities and related death rates.

Another interesting observation is the higher share of deaths in the <65 years old group in most of the US locations as opposed to the European countries. This pattern requires further investigation, but it may reflect unfavorable socioeconomic circumstances for victims of COVID-19 in the USA. It is important to study in more detail the socioeconomic profile of the COVID-19 victims, but preliminary data show that deaths cluster in areas with high levels of poverty and underprivileged populations and ethnic/racial minorities are over-represented among the victims (Centers for Disease Control and Prevention, 2020b). Some mostly low-wage occupations, including essential jobs, also may be prone to more exposure risk than other jobs where working remotely is feasible. COVID-19 may thus be yet another disease with a profile dependent on inequalities and generating even more inequalities. The difference in the proportion of deaths in people <65 years old across different US locations may be due to chance, or may reflect genuine differences in the proportion of deaths occurring in nursing homes and/or the proportion of deaths occurring in younger populations of disadvantaged people, differences in reporting of COVID-19 deaths, or other unclear reasons. Of interest, influenza deaths seem to have a similar difference in age distribution between the USA and European countries like Italy: a larger proportion of influenza deaths in the USA tend to be in the <65 age group (Estimated Influenza, 2018), as compared with Italy (Rosano et al., 2019). Of course, a major difference between influenza and COVID-19 is that the latter typically does not cause deaths in otherwise healthy children, in contrast to influenza (Wang et al., 2020b).

The vast majority of COVID-19 victims are elderly people and in all European countries analyzed as well as Canada and most US locations, more than half and up to three quarters are at least 80 years old. The median age of death for COVID-19 tends to be similar or slightly smaller than the life expectancy of the population in each respective location. In several locations, large clusters of deaths come from nursing home facilities. Data from European countries suggest that 42–57% of all deaths have happened in care homes (Booth, 2020) and many deaths in the US have also occurred in nursing homes (Nursing Homes and Assisted, 2020). Moreover, the differentiation between dying "with" SARS-CoV-2 versus dying "from" SARS-CoV-2 may be difficult to make, and the vast majority of patients with COVID-19 have comorbidities and these could also contribute to the fatal outcome or may be even more important than SARS-CoV-2 in causing the death (Boccia et al., 2020). Nursing homes and hospitalized patients (nosocomial infection) appear to account for a lion's share of COVID-19 mortality. Overall, the loss of quality-adjusted life-years from COVID-19 may be much smaller than a crude reading of the number of deaths might suggest, once these features are accounted for.

The data that we have compiled allow to estimate also absolute risks of death in the highest risk group, i.e. elderly individuals ≥80 years old in these hot epicenters of the pandemic. These are markedly higher than the risks of death in individuals <65 years old. However, the absolute risk of death even in this highest age category to-date barely reach up to 1.75% in the most hit location and in several locations it is lower than 1 in a thousand. Nevertheless, these risks are clearly high enough to warrant high alert. They suggest that, no matter what strategy is selected for addressing COVID-19 in the current or future epidemic waves should include special emphasis in protecting very elderly individuals.

Knowledge of relative and absolute risks for different population strata are instrumental for carefully choosing next steps. Lockdowns have been implemented in many countries and this was a fully justified initial "better safe than sorry" approach in the absence of good data. However, long-term lockdowns may have major adverse consequences for health (suicides, domestic violence, worsening mental health, cardiovascular disease, loss of health insurance from unemployment, and famine, to name a few) and also creating new major issues for society at large (Krumholtz, 2020; COVID's Other casualties, 2020; Docherty et al., 2020; Sud et al., 2020; Moser et al., 2020; Parmet and Sinha, 2020). Lockdowns originally aimed to save the health care system, but as patients avoid coming to the hospitals for common, treatable problems (De filippo et al., 2020), deaths may rise from non-treatment; also hospitals face an emerging crisis also leading to their demise. It is even argued that lockdowns may be even harmful as a response to COVID-19 itself, if they broaden rather than flatten the epidemic curve (Wittkowski, 2020). Information from seroprevalence and universal screening studies suggest that the frequency of infections is much larger than the documented cases and thus the overall infection fatality rate is likely to be much lower than previously thought (Ioannidis, 2020b; Bendavid et al., 2020; Shakiba et al., 2020; Iwata et al., 2020). It seems that the majority of infections are either asymptomatic or mildly symptomatic and thus do not come to medical attention (Gudbjartsson et al., 2020). These data also suggest that the infection fatality rate may be close to that of a severe influenza season (<0.2%) when the health system does not collapse and when massive nosocomial infections and nursing home spread are averted. Conversely, high infection fatality rates are seen when hospitals are overrun, and when there are massive death loads from nosocomial-infected hospitalized patients and nursing home residents. Therefore, the finding of very low risk in the vast majority of the general population has major implications for strategic next steps in managing the COVID-19 pandemic. Tailored measures that maintain social life and the economy functional to avoid potentially even deaths from socioeconomic disruption, plus effective protection of select high-risk individuals (in particular in hospitals and nursing homes) may be a sensible option. Draconian measures of hygiene and infection control and universal, repeated testing of personnel in hospital and care facilities may achieve drastic reductions in deaths. Concurrently, the vast majority of the population may be reassured that their risks are very low.

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Data sharing

All data used are in the manuscript and its supplements.

CRediT authorship contribution statement

John P.A. Ioannidis: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Project administration. **Cathrine Axfors:** Conceptualization, Software, Formal analysis, Investigation, Data curation, Writing - review & editing. **Despina G. Contopoulos-Ioannidis:** Conceptualization, Methodology, Investigation, Data curation, Writing - review & editing.

Declaration of competing interest

None.

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Footnotes

Appendix A Supplementary data to this article can be found online at https://doi.org/10.1016/j.envres.2020.109890.

Appendix A. Supplementary data

The following are the Supplementary data to this article:

Multimedia component 1:

Click here to view. (8.8K, txt) Multimedia component 1

Multimedia component 2:

Click here to view. (334K, pdf) Multimedia component 2

References

1. Bendavid E., Mulaney B., Sood N. COVID-19 antibody seroprevalence in santa clara county, California. 2020. medRxiv. [CrossRef]
2. Boccia S., Ricciardi W., Ioannidis J.P.A. What other countries can learn from Italy during the COVID-19 pandemic. JAMA Internal Medicine. 2020 doi: 10.1001/jamainternmed.2020.1447. [Epub ahead of print] [PubMed] [CrossRef] [Google Scholar]
3. Booth R. Half of coronavirus deaths happen in care homes, data from EU suggests. Guardian. https://www.theguardian.com/world/2020/apr/13/half-of-coronavirus-deaths-happen-in-care-homes-data-from-eu-suggests Published April 13, 2020.
4. Bundesamt für Gesundheit BAG Daten des Situationsberichtes [200325_Datengrundlage_Grafiken_COVID-19-Bericht.xlsx] 2020. https://www.bag.admin.ch/bag/de/home/krankheiten/ausbrueche-epidemien-pandemien/aktuelle-ausbrueche-epidemien/novel-cov/situation-schweiz-und-international.html#-1222424946 Retrieved from:
5. Centers for Disease Control and Prevention Daily updates of totals by week and state. 2020. https://www.cdc.gov/nchs/nvss/vsrr/covid19/index.htm Updated May 23. 23, 5.

6. Centers for Disease Control and Prevention COVID-19 in racial and ethnic minority groups. https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/racial-ethnic-minorities.html Updated April 24, 2020.
7. Centro de Coordinación de Alertas y Emergencias Sanitarias Actualización nº 113. Enfermedad por el coronavirus (COVID-19) https://www.mscbs.gob.es/profesionales/saludPublica/ccayes/alertasActual/nCov-China/situacionActual.htm Published May 22, 2020. Available from:
8. COVID's Other casualties https://www.reuters.com/investigates/special-report/health-coronavirus-usa-cost/
9. De filippo O., D'Ascenzo F., Angelini F. Reduced rate of hospital admissions for ACS during Covid-19 outbreak in Northern Italy. N. Engl. J. Med. 2020 doi: 10.1056/NEJMc2009166. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
10. Docherty K., Butt J., de Boer R., Dewan P., Koeber L., Maggioni A. Excess deaths during the Covid-19 pandemic: an international comparison. 2020. medRxiv. [CrossRef]
11. Du Y., Tu L., Zhu P., Mu M., Wang R., Yang P. Clinical features of 85 fatal cases of COVID-19 from wuhan: a retrospective observational study. Am. J. Respir. Crit. Care Med. 2020 doi: 10.1164/rccm.202003-0543OC. [Epub ahead of print] [PMC free article] [PubMed] [CrossRef] [Google Scholar]
12. Epidemiology for public health/Istituto Superiore di Sanità Epidemia COVID-19 Aggiornamento nazionale 20 maggio 2020 – ore 16:00. https://www.epicentro.iss.it/en/coronavirus/sars-cov-2-integrated-surveillance-data Published May 22, 2020. Available from:
13. Estimated Influenza Illnesses, Medical visits, Hospitalizations, and Deaths in the United States - 2018-2019 influenza season. Centers for Disease Control and Prevention (https://www.cdc.gov/flu/about/burden/2018-2019.html.
14. EUROMOMO Graphs and maps: excess mortality. 2020. https://www.euromomo.eu/graphs-and-maps/ Updated week 18.
15. Fauci A.S., Lane H.C., Redfield R.R. Covid-19 - navigating the uncharted. N. Engl. J. Med. 2020;382(13):1268–1269. [PMC free article] [PubMed] [Google Scholar]
16. Florida Department of Health Open Data . 2020. [Florida_COVID19_Case_Line_Data.csv]https://open-fdoh.hub.arcgis.com/search?q=covid19 [Google Scholar]
17. Folkhälsomyndigheten Antal fall av covid-19 i Sverige. https://experience.arcgis.com/experience/09f821667ce64bf7be6f9f87457ed9aa Updated May 23, 2020.
18. Gates B. Responding to COVID-19 – a once-in-a-century pandemic? N. Engl. J. Med. 2020 doi: 10.1056/NEJMp2003762. ([Epub ahead of print]) [PubMed] [CrossRef] [Google Scholar]
19. Georgia Department of Public Health Georgia overall COVID-19 status. https://dph.georgia.gov/covid-19-daily-status-report Updated June 26, 2020. Accessed.
20. Guan W.J., Liang W.H., Zhao Y., Liang H.R., Chen Z.S., Li Y.M. Comorbidity and its impact on 1590 patients with covid-19 in China: a nationwide analysis. Eur. Respir. J. 2020:2000547. doi: 10.1183/13993003.00547-2020. ([Epub ahead of print]) [PMC free article] [PubMed] [CrossRef] [Google Scholar]
21. Gudbjartsson D.F., Helgason A., Jonsson H., Magnusson O.T., Melsted P., Norddahl G.L. Spread of SARS-CoV-2 in the Icelandic population. N. Engl. J. Med. 2020 doi: 10.1056/NEJMoa2006100. ([Epub ahead of print]) [PMC free article] [PubMed] [CrossRef] [Google Scholar]
22. Health Protection Surveillance Centre/Lárionad Faire um Chosaint Sláinte Epidemiology of COVID-19 in Ireland. https://www.hpsc.ie/a-z/respiratory/coronavirus/novelcoronavirus/casesinireland/epidemiologyofcovid-19inireland/ Report prepared by HPSC on 22/05/2020 for NPHET. Published May 22, 2020. Available from:
23. Hundreds of young Americans have now been killed by coronavirus, study shows. Washington Post. https://www.washingtonpost.com/health/2020/04/08/young-people-coronavirus-deaths/
24. Illinois Department of Public Health COVID-19 Statistics. https://www.dph.illinois.gov/covid19/covid19-statistics Updated May 24, 2020.

25. Indiana State Department of Health Indiana's novel coronavirus response. https://www.coronavirus.in.gov/index.htm Updated May 24, 2020.
26. Insurance Institute for Highway safety. https://www.iihs.org/topics/fatality-statistics/detail/state-by-state Report available from:
27. Ioannidis J.P. Expressing death risk as condensed life experience and death intensity. Med. Decis. Making. 2013;33(6):853–859. [PubMed] [Google Scholar]
28. Ioannidis J.P.A. Coronavirus disease 2019: the harms of exaggerated information and non-evidence-based measures. Eur. J. Clin. Invest. 2020 [PMC free article] [PubMed] [Google Scholar]
29. Ioannidis J. 2020. The infection fatality rate of COVID-19 inferred from seroprevalence data; p. 2020. medRxiv. 05.13.20101253. version 2. [CrossRef] [Google Scholar]
30. Iwata K., Kuroda H., Hasuike T. Estimation of seroprevalence of novel coronavirus disease (COVID-19) using preserved serum at an outpatient setting in Kobe, Japan: a cross-sectional study. 2020. medRxiv. [CrossRef]
31. Kim W., Añorve V., Tefft B.C. AAA Foundation for Traffic Safety; 2019. American Driving Survey, 2014 – 2017. [Google Scholar]
32. Krumholtz H.M. Where have all the heart attacks gone? New York times. https://www.nytimes.com/2020/04/06/well/live/coronavirus-doctors-hospitals-emergency-care-heart-attack-stroke.html
33. Louisiana Department of Health/Office of Public Health Louisiana coronavirus (COVID-19) information. http://ldh.la.gov/Coronavirus/ Updated May 24, 2020.
34. Maryland Department of Health Coronavirus disease 2019 (COVID-19) outbreak. https://coronavirus.maryland.gov/ Updated April 24, 2020.
35. Massachusetts Department of Public Health/Executive office of Health and Human Services COVID-19 dashboard. https://www.mass.gov/info-details/covid-19-response-reporting Published May 24, 2020. Available from:
36. Metzler B., Siostrzonek P., Binder R.K., Bauer A., Reinstadler S.J. Decline of acute coronary syndrome admissions in Austria since the outbreak of COVID-19: the pandemic response causes cardiac collateral damage. Eur. Heart J. 2020 doi: 10.1093/eurheartj/ehaa314. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
37. Ministry of Health and Family Welfare Press information bureau, government of India [press release] https://pib.gov.in/PressReleseDetail.aspx?PRID=1625744 Updates on COVID-19. Published May 21, 2020. Available from:
38. Moser D.A., Glaus J., Frangou S., Schechter D.S. Years of life lost due to the psychosocial consequences of COVID19 mitigation strategies based on Swiss data. Eur. Psychiatr. 2020 May 29;63(1):e58. doi: 10.1192/j.eurpsy.2020.56. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
39. New Jersey Department of Health COVID-19 confirmed case summary. https://covid19.nj.gov/index.html#live-updates Published May 22, 2020.
40. New York City Health COVID-19: data. Details on deaths. https://www1.nyc.gov/site/doh/covid/covid-19-data-deaths.page Updated June 26, 2020. Available from:
41. New York State Department of Health COVID-19 updated may 23, 2020. https://covid19tracker.health.ny.gov/views/NYS-COVID19-Tracker/NYSDOHCOVID-19Tracker-Fatalities?%3Aembed=yes&%3Atoolbar=no&%3Atabs=n
42. Nursing homes & assisted living facilities account for 43% of COVID-19 deaths. https://freopp.org/the-covid-19-nursing-home-crisis-by-the-numbers-3a47433c3f70
43. WHO says more and more young people are dying from the coronavirus, CNBC. https://www.cnbc.com/2020/04/03/who-says-more-and-more-young-people-are-dying-from-the-coronavirus.html
44. International Transport Forum/Organisation for Economic Co-operation and Development (OECD) International traffic safety data and analysis group (IRTAD) road safety annual report 2018. https://www.itf-oecd.org/road-safety-annual-report-2018 Published 2018-05-18. Available from:

45. Office for National Statistics Deaths registered weekly in England and Wales, provisional; up to week ending 8 May 2020 [publishedweek192020.xlsx] 2020. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/datasets/weeklyprovisionalfiguresondeathsregisteredinenglandandwales Updated May 19, 2020.
46. Parmet W.E., Sinha M.S. Covid-19 — the law and limits of quarantine. N. Engl. J. Med. 2020;382:e28. [PubMed] [Google Scholar]
47. Pennsylvania Department of Health/Bureau of Health Statistics and Registries Weekly report for deaths attributed to COVID-19 issued may 22. 2020. https://www.health.pa.gov/topics/disease/coronavirus/Pages/Death-Data.aspx Published May 22, 2020. Retrieved from:
48. Public Health Agency of Canada Coronavirus disease 2019 (COVID-19) - daily epidemiology update. https://health-infobase.canada.ca/covid-19/epidemiological-summary-covid-19-cases.html?topic=tilelink#a3 Published May 23, 2020. Available from:
49. Rankin J., Burgen S., Willsher K., Walker S. Is comparing Covid-19 death rates across Europe helpful? Guardian. https://www.theguardian.com/world/2020/apr/24/is-comparing-covid-19-death-rates-across-europe-helpful- Published April 24, 2020.
50. Rijksinstituut voor Volksgezondheid en Milieu – RIVM Epidemiologische situatie COVID-19 in nederland. https://www.rivm.nl/documenten/epidemiologische-situatie-covid-19-in-nederland-22-mei-2020 Published May 22, 2020. Available from:
51. Robert Koch Institut Coronavirus disease 2019 (COVID-19). Daily situation report of the Robert Koch Institute. https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/Situationsberichte/Gesamt.html Published May 23, 2020. Available from:
52. Rosano A., Bella A., Gesualdo F., Acampora A., Pezzotti P., Marchetti S. Investigating the impact of influenza on excess mortality in all ages in Italy during recent seasons (2013/14-2016/17 seasons) Int. J. Infect. Dis. 2019;88:127–134. [PubMed] [Google Scholar]
53. Santé publique France COVID-19 – point épidémiologique hebdomadaire du 25 juin 2020. https://www.santepubliquefrance.fr/maladies-et-traumatismes/maladies-et-infections-respiratoires/infection-a-coronavirus/articles/infection-au-nouveau-coronavirus-sars-cov-2-covid-19-france-et-monde#block-242818 Published June 25, 2020. Available from:
54. Sciensano: the Belgian Institute for Health Sciensano: the Belgian Institute for HealthCOVID-19 - bulletin Epidemiologique du 23 Mai 2020. https://epistat.wiv-isp.be/covid/ Published May 23, 2020. Available from:
55. Secretaría de Salud Bases de datos COVID-19 [200626COVID19Mexico.csv] 2020. https://datos.gob.mx/busca/dataset/informacion-referente-a-casos-covid-19-en-mexico Retrieved from: (Información referente a casos COVID-19 en México; Datos y Recursos)
56. Serviço Nacional de Saúde/Direção-Geral da Saúde COVID-19 Relatório de Situação no 082. https://covid19.min-saude.pt/relatorio-de-situacao/ Published May 23, 2020. Available from:
57. Shakiba M., Nazari S., Mehrabian F. Seroprevalence of COVID-19 virus infection in Guilan province, Iran. 2020. medRxiv. [CrossRef]
58. Socialstyrelsen Statistik över antal avlidna i covid-19. https://www.socialstyrelsen.se/statistik-och-data/statistik/statistik-over-antal-avlidna-i-covid-19/ Updated June 26, 2020. Accessed.
59. State of California COVID-19 statewide case Statistics. https://public.tableau.com/views/COVID-19PublicDashboard/Covid-19Public?:embed=y&:display_count=no&:showVizHome=no Updated May 24, 2020.
60. State of Connecticut [Connecticut_COVID-19 tests, confirmed cases, hospitalizations, and Deaths_Statewide.csv] 2020. https://data.ct.gov/stories/s/COVID-19-data/wa3g-tfvc/#covid-19-testing-data Retrieved from: (Connecticut Open Data: COVID-19 Data Resources; COVID-19 testing data)
61. State of Michigan Coronavirus Michigan data. https://www.michigan.gov/coronavirus/0,9753,7-406-98163_98173---,00.html Updated May 24, 2020.
62. Sud A., Jones M., Broggio J., Loveday C., Torr B., Garrett A., Nicol D.L., Jhanji S., Boyce S.A., Gronthoud F., Ward P., Handy J.M., Yousaf N., Larkin J., Suh Y.E., Scott S., Pharoah P.D.P., Swanton C., Abbosh C., Williams M., Lyratzopoulos G., Houlston R., Turnbull C. Collateral

damage: the impact on outcomes from cancer surgery of the COVID-19 pandemic. Ann. Oncol. 2020 May 16 doi: 10.1016/j.annonc.2020.05.009. S0923-7534(20)39825-2. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
63. Swedish National Mediation Office . E-print; Stockholm: 2019. Löneskillnader mellan kvinnor och män 2018. Vad säger den officiella lönestatistiken? [Google Scholar]
64. Wang B., Li R., Lu Z., Huang Y. Does comorbidity increase the risk of patients with COVID-19: evidence from meta-analysis. Aging. 2020;12(7):6049–6057. [PMC free article] [PubMed] [Google Scholar]
65. Wang X., Li Y., O'Brien K.L., Madhi S.A., Widdowson M.A., Byass P. Global burden of respiratory infections associated with seasonal influenza in children under 5 years in 2018: a systematic review and modelling study. The Lancet Global health. 2020;8(4):e497–e510. [PMC free article] [PubMed] [Google Scholar]
66. Williamson E., Walker A.J., Bhaskaran K.J., Bacon S., Bates C., Morton C.E. OpenSAFELY: factors associated with COVID-19-related hospital death in the linked electronic health records of 17 million adult NHS patients. medRxiv. 2020 2020.05.06.20092999. [Google Scholar]
67. Wittkowski K.M. The first three months of the COVID-19 epidemic: epidemiological evidence for two separate strains of SARS-CoV-2 viruses spreading and implications for prevention strategies. medRxiv. 2020 doi: 10.1101/2020.03.28.20036715. [CrossRef] [Google Scholar]
68. World Health Organization Report of the WHO-China joint mission on coronavirus disease 2019 (COVID-19) 16-24 february 2020. https://www.who.int/publications-detail/report-of-the-who-china-joint-mission-on-coronavirus-disease-2019-(covid-19 Published 2020-02-28. Available from:
69. Worldometer.info Coronavirus: United States. https://www.worldometers.info/coronavirus/country/us/ Updated May 23. 23, 5.
70. Yazdanyar A., Newman A.B. The burden of cardiovascular disease in the elderly: morbidity, mortality, and costs. Clin. Geriatr. Med. 2009;25(4) 563-vii. [PMC free article] [PubMed] [Google Scholar]