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CURRENT OPINION

Beyond COVID-19 deaths during the COVID-19 pandemic in the United States

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Abstract
COVID-19 has disrupted society and health care systems, creating a fertile environment for deaths beyond the virus. The year 2020 will prove to be the most deadly year on record in the United States. Direct deaths due to COVID-19 have been well documented and reported. Older people (those over 65) have been hardest hit, with over 80% of the COVID-19 deaths in this age group. What has been less clear is the impact on those under 65 years old, particularly those under 44 years old. This study considers both COVID-19 deaths and non-COVID-19 deaths during a 39 weeks period beginning 1 March in both 2020 and averaged over the five years from 2015 to 2019. Across 22 age and gender cohorts, death risks are compared using odds ratios. The results indicate that younger people (those under 15 years old) have experienced the same or a reduction in death risk between 2020 and the average from 2015 to 2019, suggesting that societal changes were protective for some of them. With all COVID-19 deaths removed from the 2020 death counts, 15–64 year olds experienced increased death risk between 2020 and the 2015 to 2019 average. For example, 15–44 year old males experienced a significant increase in their death risk, even though the absolute number of COVID-19 deaths for this cohort is small. The key take away from this study is that COVID-19 resulted in a large number of additional deaths in 2020 compared to the average from 2015 to 2019, both directly from the virus and indirectly due to societal responses to the virus.

Keywords Covid-19 · Risk analysis · Odds ratios

1 Background

It probably will be confirmed that more people died in the United States in 2020 than in any previous year on record [1, 8, 14], with COVID-19 the driving factor for many of these deaths [5, 13]. However, COVID-19 also precipitated major societal changes, such as stay-at-home orders, school closings, and widespread reductions in business and leisure travel. With hospital systems consumed with caring for COVID-19 patients, challenges arose with treating other chronic and acute conditions, and providing preventive screening [4]. Although it is still too early to measure the full impact of such disruptions, it is hypothesized that such issues have contributed to more deaths which under prior circumstances would have been avoided [7, 9, 10].

The objective of this analysis is to measure such impacts. This is done by estimating death risks (defined as the odds of dying) both including and excluding COVID-19 deaths in the US by age and gender from 1 March 2020 through 28 November 2020, a period of 39 weeks (labelled as the *designated time period*). This is compared to death risks during the same time period, with deaths and population averaged from 2015 to 2019 (for brevity, this will be referred to as 2015–2019 death risks).

2 Methods

The US Centers for Disease Control and Prevention (CDC) reports the total number of US provisional deaths from all causes including those directly attributed to COVID-19 [2].

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The difference between deaths from all causes and those due to COVID-19 provides the number of non-COVID-19 deaths in 2020.

This paper compares death risks both including and excluding COVID-19 deaths across 22 age and gender cohorts in the US during the designated time period to the 2015–2019 death risks during the designated time period [1]. By subtracting COVID-19 deaths from the total death counts in 2020, the resulting analysis provides one approach to capture the potential societal mortality impact of COVID-19 not directly due to COVID-19. It also accounts for deaths in 2020 that would have occurred independent of COVID-19 even though they may have been attributed to COVID-19, providing a means to determine if other causes of deaths changed from the previous five years to 2020. Odds ratios [12] are used to quantify the relative death risks between 2020 and 2015 to 2019 during the designated time period for the 22 age and gender cohorts.

3 Results

Table 1 (columns 2–5) reports 99% confidence intervals for the odds ratios between the death risks during the designated time period in 2020 and the 2015 to 2019 death risks during the same 39-week time period for 22 age and gender cohorts. Columns 6–9 of the table reports the same estimators with COVID-19 deaths excluded.

For a given age and gender cohort, a 2×2 contingency table is constructed with the number of deaths and number not dying for 2020 and the same data type averaged from 2015 to 2019 [12]. To illustrate, consider the 25–34 year old female cohort. Then for 2020, let $\beta 1 =$ number of deaths in this cohort during the designated time period, and $\beta 2 =$ number of people in this cohort that did not die in the designated time period. Using data from 2015 to 2019, let $\delta 1 =$ average number of deaths (per year) in this cohort during the designated time period, and $\delta 2 =$ average number of people in this cohort that did not die (per year) in the designated time period. Then the odds ratio point estimator is given by

$$\mathrm{OR} = (\beta 1/\beta 2)/(\delta 1/\delta 2),$$

with 99% confidence interval for the odds ratio given by

$$\exp\left[\ln(\mathrm{OR}) \pm Z_{0.005}\left((1/\beta 1) + (1/\beta 2) + (1/\delta 1) + (1/\delta 2)\right)^{1/2}\right],$$

where *exp* denotes the exponential function, *ln* the natural logarithm function, and $Z_{0.005}$ the 0.005 tail probability for the standard normal distribution.

We report 99% confidence intervals, as opposed to 95% confidence intervals, to mitigate the Bonferroni effect when interpreting coverage across multiple confidence intervals simultaneously [6]. In addition, *p* values for the odd ratios are given, based on two-sided hypothesis tests with the alternative hypothesis given as the odds ratio not equal to one.

Tables 2 provides the male deaths for the designated time period across the 11 age groups in 2020 and deaths averaged between 2015 and 2019. Table 3 contains the same data for females. For 2020, both deaths from all causes and non-COVID-19 deaths (deaths from all causes minus deaths directly attributed to COVID-19) are given.

4 Discussion

We first assess whether there is a statistically significant difference in the odds ratios between the two genders. The log of the odds ratios are asymptotically normal, which is the case given the large values for the death counts and populations in each age and gender cohort in the 2×2 contingency tables

Table 1 99% Odds Ratio Confidence Intervals Comparing Death Risks in 2020 and 2015-2019

Age Cohort	Odds Ratio (All Cause Males Deaths)	p value	Odds Ratio (All Cause Female Deaths)	p value	Odds Ratio (Males Deaths Excluding COVID-19)	p value	Odds Ratio (Female Deaths Excluding COVID-19)	p value
< 1	(0.822, 0.889)	< 0.001	(0.817, 0.892)	< 0.001	(0.819, 0.886)	< 0.001	(0.815, 0.890)	< 0.001
1–4	(0.819, 0.982)	0.002	(0.767, 0.950)	< 0.001	(0.814, 0.977)	< 0.001	(0.760, 0.942)	< 0.001
5–14	(1.004, 1.163)	0.006	(0.900, 1.075)	0.63	(0.989, 1.147)	0.027	(0.889, 1.062)	0.40
15–24	(1.170, 1.234)	< 0.001	(1.113, 1.217)	< 0.001	(1.153, 1.216)	< 0.001	(1.082, 1.184)	< 0.001
25–34	(1.251, 1.301)	< 0.001	(1.204, 1.279)	< 0.001	(1.209, 1.258)	< 0.001	(1.148, 1.221)	< 0.001
35–44	(1.309, 1.355)	< 0.001	(1.208, 1.267)	< 0.001	(1.220, 1.264)	< 0.001	(1.130, 1.185)	< 0.001
45–54	(1.219, 1.250)	< 0.001	(1.121, 1.158)	< 0.001	(1.090, 1.119)	< 0.001	(1.024, 1.058)	< 0.001
55–64	(1.188, 1.209)	< 0.001	(1.144, 1.169)	< 0.001	(1.057, 1.075)	< 0.001	(1.034, 1.057)	< 0.001
65–74	(1.171, 1.188)	< 0.001	(1.126, 1.146)	< 0.001	(1.018, 1.033)	< 0.001	(0.997, 1.015)	0.073
75–84	(1.133, 1.149)	< 0.001	(1.110, 1.126)	< 0.001	(0.973, 0.987)	< 0.001	(0.975, 0.990)	< 0.001
85+	(1.136, 1.153)	< 0.001	(1.149, 1.162)	< 0.001	(0.975, 0.991)	< 0.001	(1.003, 1.015)	< 0.001

[12]. Then we apply paired difference Student-t tests for both all causes of deaths and non-COVID-19 deaths over the 11 age groups. For both the all causes of deaths and non-COVID-19 deaths, the two-sided p values are both less than 0.005, which suggests that the odds ratios for males and females can be analyzed separately.

In Table 1 (columns 2–5), for 16 of the 22 age and gender cohorts (15–85+ years old), the odds ratio confidence intervals indicate a statistically significant increase in death risks in 2020 compared to 2015–2019 death risks. For females, the 25–34 years old cohort has the highest observed odds ratio (1.124), while for males, the 35–44 years old cohort has the highest observed odds ratio (1.332). For five age cohorts (covering those 35–84 years old), the odds ratios for the two genders did not overlap, indicating males in these age cohorts experienced a higher death risk increase than females. In addition, the p values for these odds ratios are all less than 0.001.

Males and females under 4 years for age showed a statistically significant decrease in death risk. These findings do not suggest that COVID-19 is beneficial for these children, but that other factors, such as societal changes brought about by COVID-19, shielded them from events such as unintentional injuries and accidents [3], which represent the leading cause of death amongst these groups. For example, stay-at-home orders resulted in fewer automobile accidents since fewer people drove their vehicles and fewer miles were driven [11]. Such insights can be useful to identify ways to keep young children safe as society transitions to more interactive interpersonal engagement and movement.

Given that the CDC reports COVID-19 deaths daily [8], the question arises whether these deaths represent additive deaths, or substitute deaths. To help answer this question, the COVID-19 deaths are subtracted from the 2020 death totals, with the resulting death risks compared to the 2015–2019 death risks.

In Columns 6–9 of Table 1, for 11 of the 22 age and gender cohorts (females 15–64 years old, males 15–74 years old), the odds ratio confidence intervals indicate a statistically significant increase in non-COVID-19 death risk in 2020 compared to 2015–2019 death risks. The 25–34 years old female and the 35–44 years old male cohorts show the highest observed odds ratios. For those 35–64 years old, the odds ratios for the two genders did not overlap, indicating males in these age cohorts experienced a higher non-COVID-19 death risk increase than females. In addition, p values less than 0.001 provide statistical support that non-COVID-19 death risks as measured by the odds ratio changed in 2020 compared to the 2015–2019 death risks.

Tables 2 and 3 provide the actual average death counts from 2015 to 2019 and both the all cause and non-COVID-19 death counts for 2020. These numbers corroborate the increase in death risk in 2020 versus the average from 2015 to 2019, even removing direct COVID-19 deaths [13]. Excluding COVID-19 deaths, for example, 1224 fewer male infants (< 1 years old) and 983 fewer female infants died in 2020 compared to the average number of deaths from 2015 to 2019. In addition, 2992 additional non-COVID-19 deaths occurred amongst 15–24 year old males in 2020 compared to the average number of deaths from 2015 to 2019, an increase of 17%, and 8438 additional non-COVID-19 deaths occurred amongst 25–34 year old males in 2020 compared to the average number of deaths from 2015 to 2019, an increase of 28%. Similar decreases and increases are reported for females in these age groups. Though the absolute number of COVID-19 deaths in these cohorts was small (see column 4 in Tables 2 and 3), the impact of COVID-19 on society had a deleterious impact on them. The cause of such additional non-COVID-19 deaths is unclear at this time. Possibilities include opioid overdoses, domestic violence, or suicide. Another possibility is that COVID-19 deaths were simply undetected,

Table 2 COVID-19 and Non-COVD-19 Deaths in 2020 and 2015–2019 (Males), Designated Time Period

Age Cohort	All Cause Male Deaths (2020)	Non-COVID-19 Male Deaths (2020)	Percentage of Deaths Attributed to COVID-19 (2020)	Male Population (2020)	All Cause Male Deaths Average (2015–19)	Average Male Population (2015–19)
< 1	8070	8043	.33%	2,112,227	9267	2,074,811
1–4	1532	1523	.59%	8,407,948	1675	8,246,467
5–14	2560	2523	1.45%	20,944,619	2369	20,945,141
15–24	20,556	20,261	1.44%	22,048,975	17,269	22,246,948
25–34	40,104	38,762	3.35%	23,942,277	30,324	23,085,425
35–44	51,882	48,368	6.77%	21,370,925	37,464	20,538,688
45–54	90,519	81,031	10.48%	20,191,496	75,952	20,890,268
55–64	201,923	179,741	10.99%	20,798,044	164,672	20,298,286
65–74	289,089	251,955	12.83%	15,467,151	221,253	13,924,304
75–84	313,347	270,795	13.58%	7,320,885	245,104	6,497,419
85+	286,109	249,857	12.67%	2,431,872	238,236	2,283,305
Total	1,305,641	1,152,859	11.70%	165,036,419	1,043,584	161,031,064

Table 3 COVID-19 and Non-COVD-19 Deaths in 2020 and 2015–2019 (Females) Designated Time Period

Age Cohort	All Cause Female Deaths (2020)	Non-COVID-19 Female Deaths (2020)	Percentage of Deaths Attributed to COVID-19 (2020)	Female Population (2020)	All Cause Female Deaths Average (2015–19)	Average Female Population (2015–19)
< 1	6434	6420	.22%	2,016,583	7403	1,980,868
1–4	1082	1073	.83%	8,030,910	1244	7,877,762
5–14	1676	1655	1.25%	20,064,260	1704	20,070,928
15–24	7173	6977	2.73%	21,057,902	6198	21,177,766
25–34	16,532	15,777	4.57%	22,947,659	12,966	22,327,934
35–44	27,228	25,474	6.44%	21,256,845	21,305	20,570,072
45–54	53,144	48,565	8.62%	20,650,440	48,390	21,416,787
55–64	125,269	113,250	9.59%	22,221,321	106,091	21,752,162
65–74	207,333	183,905	11.30%	17,608,023	164,330	15,829,518
75–84	287,723	253,805	11.79%	9,318,438	232,697	8,398,757
85+	450,825	398,990	11.50%	4,294,658	386,346	4,192,508
Total	1,184,419	1,055,891	10.85%	169,467,039	988,675	165,595,063

hence not reported or not attributed to the virus. Further research is needed to better assess the causes of such deaths, so appropriate preventive steps can be taken to protect such individuals in the future.

5 Conclusions

This analysis reports that a large segment of the population experienced a statistically significant increase in death risk in 2020 compared to 2015 to 2019, even with direct COVID-19 deaths subtracted from the death counts. Moreover, the youngest age cohorts experienced a statistically significant decrease in non-COVID-19 death risk. Although the number of COVID-19 deaths in some age cohorts is small, the death risk changes are statistically significant, both including and excluding COVID-19 deaths. These findings illustrate the widespread impact of COVID-19 across the entire US population, with the resulting changes in death risks touching every age and gender cohort.

Availability of data and material All data used is publicly available with citation to data repositories.

Authors' information SHJ is a data scientist with research expertise applied to public health and public policy problems. JAJ is an infectious disease physician with interests in public health.

Code availability Not Applicable.

Authors' contributions Both authors contributed to the ideas that led to the paper. SHJ contributed to the statistical analysis, the literature review, and the manuscript preparation. JAJ contributed to the concept and provided background on infectious diseases and public health. SHJ wrote the first draft of the paper. JAJ provided extensive feedback and comments. Both authors read and approved the final version of the manuscript.

Declarations

Conflicts of interest/competing interests Authors declare no conflicts of interest.

Ethics approval and consent to participate No ethical approval was required for this study. The analysis uses only publicly available data reported in the literature.

Consent for publication Not Applicable.

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