



Excess deaths by sex and Age Group in the first two years of the COVID-19 pandemic in the United States

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Abstract

The COVID-19 pandemic hastened hundreds of thousands of deaths in the United States. Many of these excess deaths are directly attributed to COVID-19, but others stem from the pandemic's social, economic, and health care system disruptions. This study compares provisional mortality data for age and sex subgroups across different time windows, with and without COVID-19 deaths, and assesses whether mortality risks are returning to pre-pandemic levels. Using provisional mortality reports from the CDC, we compute mortality risks for 22 age and sex subgroups in 2021 and compare against 2015–2019 using odds ratios. We repeat this comparison for the first twelve full months of the COVID-19 pandemic in the United States (April 2020–March 2021) against the next twelve full months (April 2021–March 2022). Mortality risks for most subgroups were significantly higher in 2021 than in 2015–2019, both with and without deaths involving COVID-19. For ages 25–54, Year 2 (April 2021–March 2022) was more fatal than Year 1 (April 2020–March 2021), whereas total mortality risks for the 65+ age groups declined. Given so many displaced deaths in the first two years of the COVID-19 pandemic, mortality risks in the next few years may fall below pre-pandemic levels. Provisional mortality data suggest this is already happening for the 75+ age groups when excluding COVID-19 deaths.

Keywords COVID-19 · Risk analysis · Odds ratios

1 Introduction & background

Since the beginning of 2020, the CDC has reported provisional deaths weekly, broken down by age and sex [1]. As of June 1, 2022, the CDC estimates that 1.125 million *excess deaths* have occurred since February 1, 2020 [2]. Of these, 901 thousand involved COVID-19, while 224 thousand were attributed to other causes and did not have COVID-19 on the death certificate. Although we do not precisely understand the mechanisms behind non-COVID-19 excess deaths, we do know that lockdowns in 2020 created

enormous social, economic, and cited and exacerbated mental illness [3]. Drug overdose deaths reached unprecedented levels [4]. Preventive health and cancer screenings were delayed [5–7]. Medical care diverted to treat COVID-19 patients delayed treatments for acute cardiovascular conditions. [8]. Due to these myriad mechanisms, only 67% of the excess deaths during March–July 2020 had COVID-19 as a documented cause [9].

Provisional mortality data for 2021 indicates not only more deaths involving COVID-19 than in 2020 but also more total deaths (3.45 million vs. 3.39 million). But these aggregate comparisons conceal shifts in mortality risks for different age and sex subgroups. Are deaths from causes other than COVID-19 returning to pre-pandemic levels? The objective of this paper is to test this hypothesis for 22 sex and age subgroups.

2 Methods

The US Centers for Disease Control and Prevention (CDC) reports weekly provisional mortality as total deaths

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Table 1 Odds Ratio 99.8% Confidence Intervals for 2021 vs. 2015–2019 Mortality Risks

Ages	Male, Total	<i>p</i> value	Female, Total	<i>p</i> value	Male, NC†	<i>p</i> value	Female, NC†	<i>p</i> value
< 1	(0.793, 0.86)	< 0.001	(0.824, 0.902)	< 0.001	(0.787, 0.854)	< 0.001	(0.816, 0.894)	< 0.001
1–4	(0.836, 1.009)	0.005	(0.886, 1.096)	0.66	(0.822, 0.993)	< 0.001	(0.868, 1.075)	0.317
5–14	(1.024, 1.192)	< 0.001	(0.981, 1.173)	0.015	(0.995, 1.159)	0.004	(0.949, 1.136)	0.198
15–24	(1.208, 1.277)	< 0.001	(1.207, 1.322)	< 0.001	(1.167, 1.233)	< 0.001	(1.126, 1.235)	< 0.001
25–34	(1.354, 1.41)	< 0.001	(1.317, 1.401)	< 0.001	(1.254, 1.306)	< 0.001	(1.168, 1.244)	< 0.001
35–44	(1.512, 1.566)	< 0.001	(1.412, 1.48)	< 0.001	(1.314, 1.363)	< 0.001	(1.191, 1.25)	< 0.001
45–54	(1.36, 1.395)	< 0.001	(1.253, 1.295)	< 0.001	(1.109, 1.139)	< 0.001	(1.027, 1.063)	< 0.001
55–64	(1.268, 1.29)	< 0.001	(1.241, 1.268)	< 0.001	(1.057, 1.076)	< 0.001	(1.031, 1.054)	< 0.001
65–74	(1.193, 1.211)	< 0.001	(1.164, 1.184)	< 0.001	(1.004, 1.02)	< 0.001	(0.984, 1.002)	0.011
75–84	(1.094, 1.11)	< 0.001	(1.074, 1.09)	< 0.001	(0.928, 0.942)	< 0.001	(0.938, 0.952)	< 0.001
85+	(1.031, 1.047)	< 0.001	(1.009, 1.022)	< 0.001	(0.893, 0.908)	< 0.001	(0.904, 0.916)	< 0.001

†NC denotes non-COVID-19, i.e., excluding deaths involving COVID-19

and those directly involving COVID-19 [1]. Subtracting COVID-19 deaths from total deaths provides the number of non-COVID-19 deaths. This paper uses CDC provisional mortality reports last updated June 2, 2022.

This paper compares mortality risks in the US during 2015–2019 to those during 2021, grouping the population by age and sex [10]. Mortality risks are computed with and without COVID-19 deaths to examine whether total deaths and/or non-COVID-19 deaths are returning to pre-pandemic levels. Relative mortality risks for the same age and sex subgroup between 2021 and 2015–2019 are measured using odds ratios [11]. This follows the methodology of a prior study comparing 2020 and 2015–2019 mortality risks. [12].

For each age and sex subgroup, the odds ratio point estimator, *OR*, is the ratio of deaths to survivals (computed as total population minus deaths) for 2021 divided by the same ratio of the 2015–2019 averages. Let δ denote the number of deaths in 2021 for a particular age and sex subgroup and let β denote the number of people in the subgroup in 2021 that did not die (i.e., the July 1st population estimate minus the deaths). For 2015–2019, let δ' denote the average number of deaths (per year) in the subgroup, and let β' denote the average number of people in the subgroup that did not die (per year). Then the point estimator for the odds ratio is

$$OR = \frac{\delta/\beta}{\delta'/\beta'}$$

and the 99.8% confidence interval for the odds ratio is

$$\exp \left(\ln(OR) \pm Z_{0.001} \cdot \sqrt{\frac{1}{\delta} + \frac{1}{\beta} + \frac{1}{\delta'} + \frac{1}{\beta'}} \right),$$

where *exp* is the exponential function, *ln* the natural logarithm function, and $Z_{0.001}$ the 0.001 tail probability for the standard normal distribution.

The Bonferroni effect can distort interpretations of multiple confidence intervals, so we use a significance level of $0.05/22 = 0.002$, which corresponds to 99.8% confidence intervals for each of the 22 subgroups [13]. The *p* values reported are for a two-sided hypothesis test with the alternative hypothesis being that the odds ratio is not equal to one.

3 Results

Table 1 (columns 2–5) presents 99.8% confidence intervals for the odds ratios between the total mortality risk during 2021 and the total mortality risk during 2015–2019 for 22

Table 2 Odds Ratio 99.8% Confidence Intervals for Year 2 vs. Year 1 Mortality Risks

Ages	Male, Total	<i>p</i> value	Female, Total	<i>p</i> value	Male, NC†	<i>p</i> value	Female, NC†	<i>p</i> value
< 1	(0.962, 1.047)	0.808	(0.975, 1.071)	0.154	(0.955, 1.04)	0.802	(0.967, 1.062)	0.379
1–4	(1.03, 1.249)	< 0.001	(1.041, 1.298)	< 0.001	(1.016, 1.235)	< 0.001	(1.017, 1.27)	< 0.001
5–14	(0.966, 1.121)	0.099	(1.006, 1.203)	0.001	(0.947, 1.101)	0.392	(0.979, 1.174)	0.018
15–24	(0.984, 1.037)	0.253	(1.014, 1.106)	< 0.001	(0.965, 1.018)	0.298	(0.976, 1.067)	0.163
25–34	(1.039, 1.078)	< 0.001	(1.052, 1.113)	< 0.001	(1.002, 1.041)	< 0.001	(0.986, 1.046)	0.108
35–44	(1.095, 1.131)	< 0.001	(1.104, 1.152)	< 0.001	(1.039, 1.074)	< 0.001	(1.014, 1.062)	< 0.001
45–54	(1.055, 1.081)	< 0.001	(1.062, 1.096)	< 0.001	(1.001, 1.028)	0.001	(0.985, 1.019)	0.778
55–64	(1.01, 1.027)	< 0.001	(1.048, 1.07)	< 0.001	(0.999, 1.017)	0.006	(1.013, 1.036)	< 0.001
65–74	(0.955, 0.969)	< 0.001	(0.985, 1.001)	0.006	(0.997, 1.012)	0.042	(1.001, 1.018)	< 0.001
75–84	(0.918, 0.93)	< 0.001	(0.936, 0.95)	< 0.001	(0.992, 1.007)	0.783	(0.997, 1.012)	0.048
85+	(0.867, 0.88)	< 0.001	(0.861, 0.872)	< 0.001	(0.958, 0.973)	< 0.001	(0.953, 0.965)	< 0.001

†NC denotes non-COVID-19, i.e., excluding deaths involving COVID-19

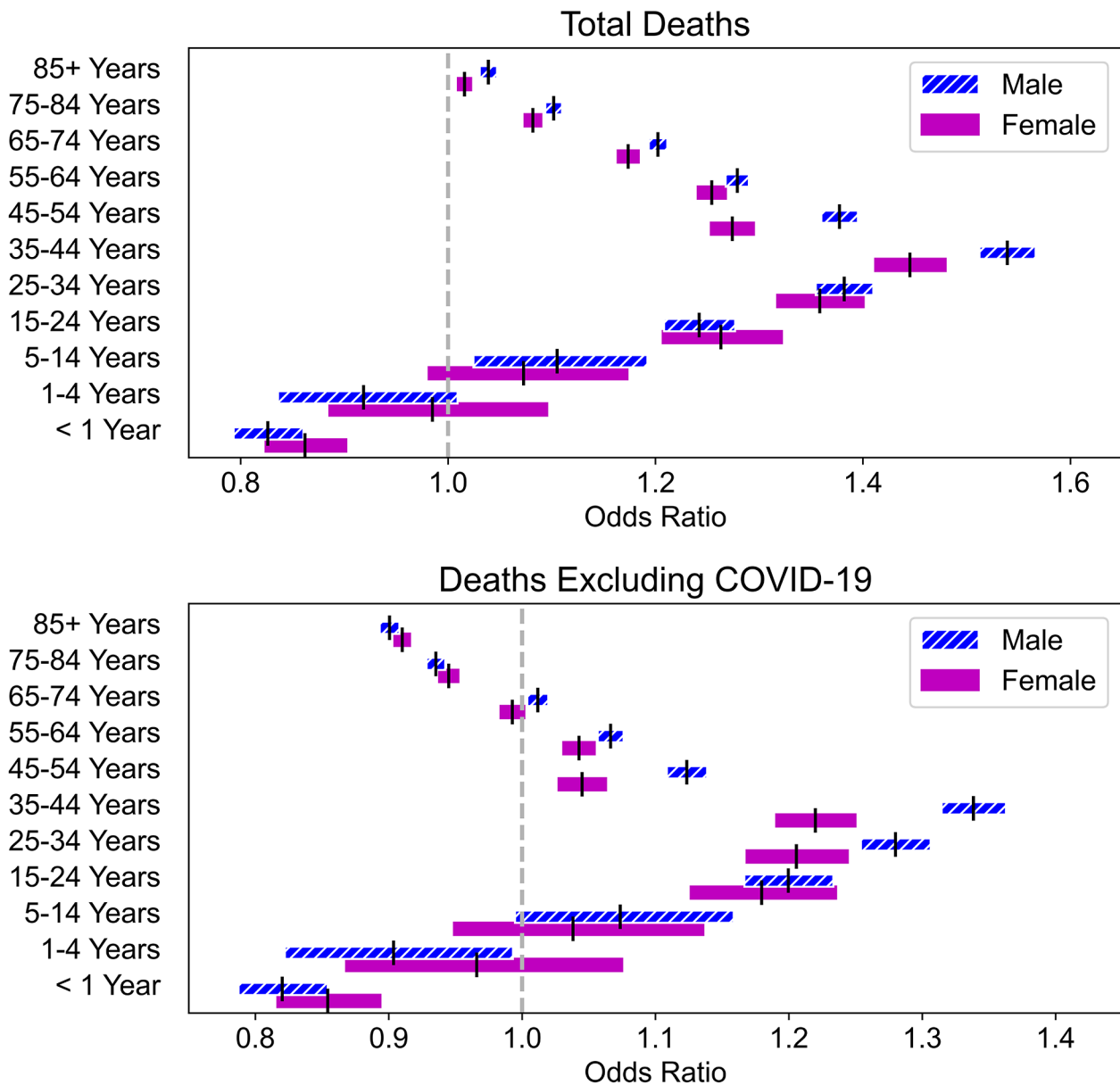


Fig. 1 Odds ratio 99.8% confidence intervals for 2021 vs. 2015–2019 mortality risks across 22 sex and age subgroups, with (top) and without (bottom) deaths involving COVID-19. An odds ratio below (above) 1 indicates greater death risk in 2015–2019 (2021)

age and sex subgroups. Columns 6–9 of Table 1 present the same confidence intervals restricted to non-COVID-19 deaths. Cells in italics have confidence intervals entirely below one and *p* values less than 0.001. For these subgroups, the data suggest 2021 was safer than 2015–2019. Cells in bold have confidence intervals entirely above one and *p* values below 0.001, indicating statistically significant evidence that the subgroup experienced a higher mortality risk in 2021 than in 2015–2019.

Table 2 presents mortality risk odds ratio 99.8% confidence intervals for Year 2 (April 2021–March 2022) against

Year 1 (April 2020–March 2021) for the same 22 age and sex subgroups.

Figures 1 and 2 visualize the odds ratio confidence intervals reported in Tables 1 and 2, respectively. For each subgroup, a vertical black line indicates the odds ratio point estimator, and a horizontal bar depicts the 99.8% confidence interval.

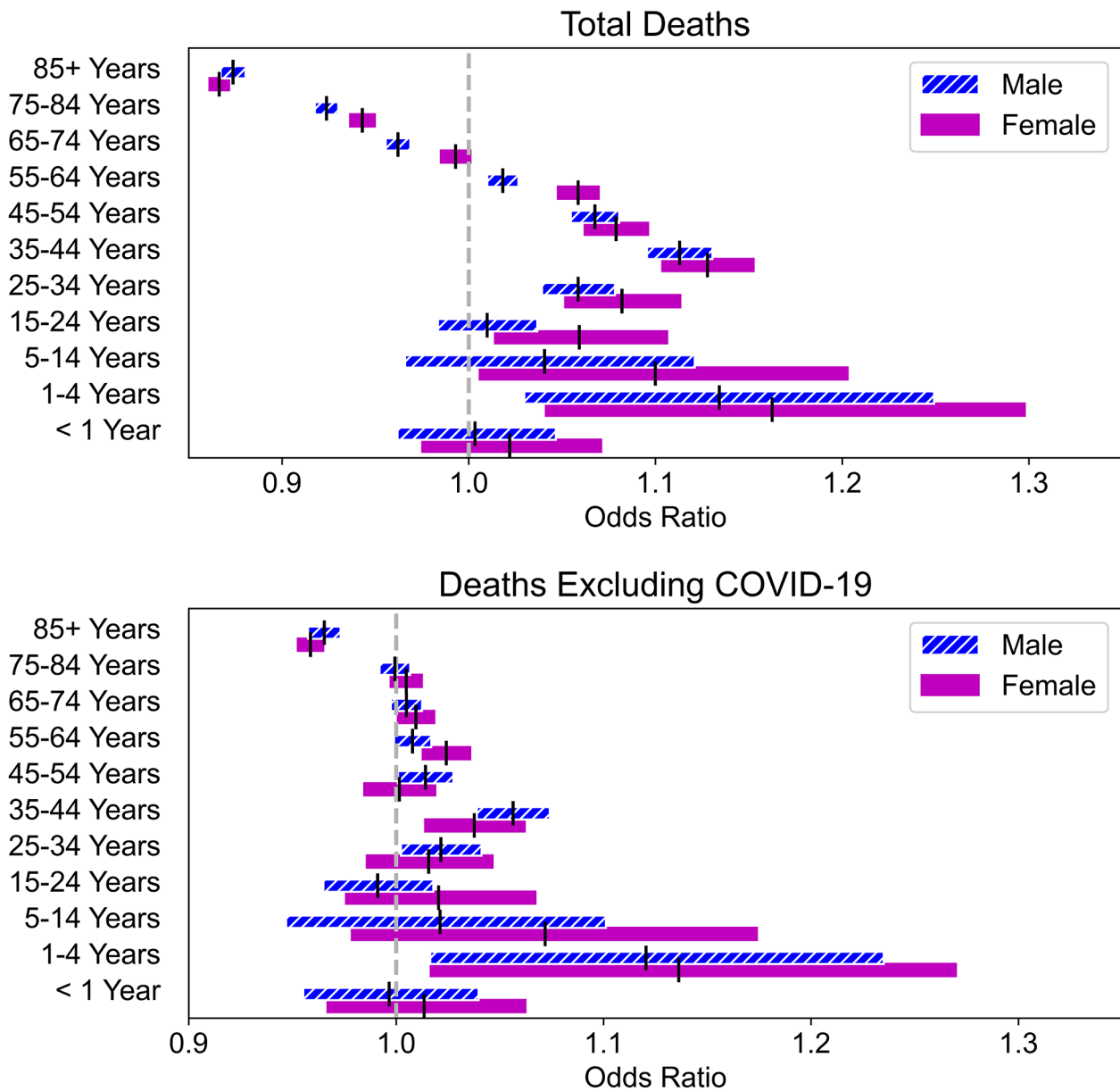


Fig. 2 Odds ratio 99.8% confidence intervals for Year 2 (April 2021–March 2022) vs. Year 1 (April 2020–March 2021) mortality risks across 22 sex and age subgroups, with (top) and without (bottom) deaths involving COVID-19. An odds ratio below (above) 1 indicates greater death risk in Year 1 (Year 2)

4 Discussion

Though non-COVID-19 excess deaths did not have COVID-19 on their death certificates, the pandemic's societal, economic, and health care system changes likely contributed to many such deaths. Elective surgery postponements, hospital staffing shortages, delayed stroke responses, and other disruptions may have deprived non-COVID-19 patients of life-saving care.

Table 1 reports most age and sex subgroups faced greater mortality risks in 2021 than in 2015–2019. But for both males and females in the 75+ age groups, mortality risks from causes other than COVID-19 appear lower in 2021 than in 2015–2019. A possible explanation for this observation is the high COVID-19 death rates for these subgroups in 2020. Some of the expected 2021 deaths in these subgroups from causes other than COVID-19 may have been replaced by excess deaths in 2020 from COVID-19 or other causes,

a process referred to as *harvesting*. [14] With COVID-19 included, however, the odds ratio confidence intervals for the 75–84 and 85+ subgroups provide statistically significant evidence that mortality risks were higher in 2021 than in 2015–2019. This could mean persons in these age groups were dying of COVID-19 instead of other expected diagnoses. One way to view this situation is that the 2020 deaths from these subgroups that were expected to occur in 2021 have been replaced by 2021 deaths that were expected to occur in 2022 or beyond. This suggests these age groups are approaching a turning point, so that as vaccine uptake increases, and new effective therapeutics and treatments are introduced, the total death rates in future years may fall below pre-pandemic levels.

Comparing subgroups' mortality risks between Year 2 (April 2021–March 2022) and Year 1 (April 2020–March 2021) reveals the pandemic's evolving impact on different age groups. Table 2 indicates that several of the subgroups 65 years of age and older experienced lower mortality risks in Year 2 than in Year 1, potentially explained by both the success of vaccines at preventing hospitalizations and deaths and the extensive mortality displacement for these subgroups in the first year of the pandemic. The subgroups from 25 to 64 years of age, however, were hit harder by COVID-19 in Year 2 than in Year 1. These subgroups have lower average vaccination rates than the 65+ subgroups, which may partially explain their increased mortality risks in Year 2.

One limitation of this analysis is that the provisional mortality reports list “deaths involving COVID-19 (ICD-code U07.1)” without distinguishing comorbidities. [1] That is why total deaths, not COVID-19 deaths, is a better way to measure the pandemic's impact. Another limitation is that results will continue changing slightly throughout the next year as the CDC processes late death reports and corrections.

5 Conclusions

The COVID-19 pandemic hastened thousands of deaths in the United States. Many age and sex subgroups continued to face higher mortality risks in 2021 compared to the 2015–2019 average, both with and without deaths involving COVID-19.

With the preponderance of displaced deaths in the first two years of the COVID-19 pandemic, mortality risks in the next few years may fall below pre-pandemic levels. Provisional mortality data suggest this is already happening for the 75+ age groups when excluding COVID-19 deaths.

The most informative way to report the mortality risk and impact of COVID-19 is not by COVID-19 deaths, but by

all deaths compared to previous years. That way the entire impact of the pandemic, not just direct COVID-19 deaths, can be captured and communicated.

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