Excess Deaths During the COVID-19 Pandemic and 2021 Heat Dome

Washington State
2020 & 2021

Washington State Department of
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Report Authors

Jon Downs, MPH
Ian Painter, PhD
Katie Hutchinson, PhD
Sean Coffinger, MA

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Executive Summary

Each year, the Washington State Department of Health reports the number of deaths and the death rate of our residents. Death rates typically change little from year to year. Because of this, historical trends can be used to predict an expected number of deaths each year. Any deaths above what was expected are called excess deaths.

Washington experienced two public health crises in 2020 and 2021. First, the COVID-19 pandemic began in 2020. By the end of 2021, 10,084 COVID-19 deaths were reported by the COVID-19 death surveillance team at the Washington State Department of Health (DOH). Additionally, in 2021, record-breaking temperatures created a "heat dome" that led to 157 heat-related deaths, much higher than prior years. Furthermore, given the widespread disruptions to daily life during the first two years of the pandemic there may have been additional impacts beyond the reported death totals.

This report examines excess deaths in the state of Washington for 2020 and 2021. We have three main study questions:

1) How did excess death rates compare to reported COVID-19 death rates?
2) Did excess death rates drop after COVID-19 vaccinations became available? If so, was the drop larger in areas with higher vaccination rates?
3) How did excess deaths during the 2021 heat dome compare to other weeks in the year?

We used death data from 2011 to 2019 to produce an expected number of deaths in 2020 and 2021, had historical trends continued. In 2020, the number of excess deaths were lower than the reported number of COVID-19 deaths. In 2021, excess deaths were higher than reported COVID-19 and heat-related deaths. After COVID-19 vaccines were introduced, excess deaths decreased statewide, with the largest drops occurring in areas with the highest rates of vaccination.

Key Findings

- In 2020, there were 2,930 (5 percent) more deaths than expected in Washington, based on historical trends. This is 827 fewer than the number of reported COVID-19 deaths (3,757), meaning some COVID-19 deaths were offset by declines in other types of death.
- In 2021, there were 7,367 (12 percent) more deaths than expected. This is 883 more than deaths attributed to COVID-19 (6,327) and the heat dome (157) combined.
- In the two-year period, excess death rates were highest for American Indian/Alaska Native (AI/AN), Native Hawaiian and Other Pacific Islander (NHOPI), and Black persons.
- Those that lived in areas with the highest vaccination rates were three times less likely to die from COVID-19 than the areas with the lowest vaccination rates.
- During the heat dome, there were 1,232 excess deaths. This is 826 more than reported COVID-19 (249) and heat-related (157) deaths around this time. Comparing heat dome

weeks to all other weeks in 2021, excess deaths increased most in people who are at least 85 years old, Black persons, or American Indian/Alaska Native.

Introduction

During 2020 and 2021, Washington State experienced dual public health emergencies. First, COVID-19 was declared a national public health emergency in January 2020 [1]. In Washington, 10,084 COVID-19 deaths were reported in 2020 and 2021 [2]. In addition to COVID-19, we experienced dangerously hot temperatures in the summer of 2021, most severely between June 26 and July 31. The conditions leading to these extreme temperatures are known as a heat dome [3]. From June 26 to August 31, 157 heat-related deaths were reported, a significant increase from years prior [4].

Traditionally, statistical reports categorize deaths by either the underlying cause of death or the disease or injury initiating the chain of events that led to death [5]. A single cause of death is useful for tracking trends over time, but it does not capture deaths where multiple events interacted. For example, a heat-related event or COVID-19 infection may have worsened an existing heart condition, leading to death months later. Facility closures and the threat of COVID-19 infection may have interrupted necessary medical care. The COVID-19 pandemic may have reduced some types of death, as well. For example, someone could have died because of another medical condition had they not first died of COVID-19. Likewise, social distancing and masking requirements might have reduced flu deaths. Given the many changes to daily life during the COVID-19 pandemic, reported COVID-19 death rates do not fully capture the impact of the pandemic.

This report is an excess death analysis for Washington State in 2020 and 2021. We produced expected weekly death rates using historical data. Excess deaths are defined as the difference between the number of deaths that were observed and the number that were expected. We used a series of similar models for deaths statewide and by demographic factors.

Our first objective was to compare reported COVID-19 death rates to excess death rates. The two are not the same. Reported COVID-19 deaths meet specific criteria, such as a report of COVID-19 on the death certificate and a positive COVID-19 test reported in the weeks prior to death [6]. Excess deaths apply to aggregate counts and rates, and no single death is an excess death. Deaths due to undetected COVID-19 infections contribute to excess deaths, not reported COVID-19 deaths. Additionally, some people who died from COVID-19 were also at risk of death from other causes. An excess death rate assumes some of these deaths would have occurred anyway. Moreover, the relationship between COVID-19 death rates and excess death rates changes over time. For example, the chance of an undetected COVID-19 death rises as COVID-19 testing falls.

A second objective was to compare excess death rates of different communities by their rate of COVID-19 vaccination. The first recorded COVID-19 vaccination was administered on December 15, 2020 [7]. If vaccinations reduced the risk of death at the community level, death rates should decline after vaccines became available, with the largest declines occurring in the most

vaccinated areas. We categorized Washington census tracts by the number of COVID-19 vaccinations administered per person as of December 31, 2021. Then, we compared each category's excess death rates over time. Death from COVID-19 happens days or weeks after getting sick, and vaccines take time to produce immunity. Because of this, we expected death rates to decline weeks after receiving a vaccine.

Finally, we explored excess death rates during the heat dome from June 26 to July 31, 2021. We compared average excess and COVID-19 deaths during the weeks of the heat dome to all other weeks in 2021. An increase in excess, but not COVID-19, death rates during the heat dome would support the idea of excess deaths due to heat.

Methods

A summary of our methodology is provided below. More details are available in **Appendix B**.

Deaths and population were aggregated by week of death and age group. This was done statewide and for each of the following demographics: sex, race/ethnicity, Accountable Community of Health (ACH), and community COVID-19 vaccination rate on December 31, 2021. ACHs are groups of counties that share a border and have common health goals.

Population data came from the Population Interim Estimates (PIE), which were produced by Public Health, Seattle & King County in consultation with the Washington State Department of Health (DOH), the Washington State Office of Financial Management (OFM), and other organizations in the state.

We also counted deaths for the occupation category "Miscellaneous Agricultural workers" ages 18 to 65 years. This report refers to this job category as "farm workers". This occupation category includes migrant workers, and previous reports found high COVID-19 death rates in this group [8]. Farm worker population estimates were not available, so only counts are used.

To estimate excess deaths for 2020 and 2021, we used data from 2011 to 2019 to determine how many deaths would have been expected if COVID-19 and the heat dome didn't occur. Deaths above what was expected from historical trends are excess deaths. We looked at annual rates of excess death statewide, by demographics, and by community vaccination uptake. We compared excess deaths to the reported number of COVID-19 deaths for each group. Finally, we compared excess deaths during the week of the heat dome to all other weeks of 2021.

Results

Overall Excess Deaths and Reported COVID-19 Deaths

Based on observed trends from 2011-2019, in the absence of unexpected events such as COVID-19 and the heat dome, we expected 59,981 in 2020 and 61,261 deaths in 2021 (**Table 1**). The real death counts exceeded this. We found 62,911 reported deaths in 2020 and 68,628 deaths in 2021, resulting in 2,930 (5%) excess deaths in 2020 and 7,367 (12%) excess deaths in 2021. This translates to 37.9 excess deaths per 100,000 persons in 2020 and 94.5 excess deaths per 100,000 persons in 2021.

Table 1: **Expected, Observed, Excess, and Reported COVID-19 Deaths and Death Rates, Washington State, 2020 – 2021**

	2020		2021	
	Num	*Rate**	*Num*	*Rate**
Expected Deaths	59,981	776.6	61,261	785.6
Observed Deaths	62,911	814.5	68,628	880.1
Excess Deaths (Observed - Expected)	2,930	37.9	7,367	94.5
Reported COVID-19 deaths	3,757	48.6	6,327	81.1

* Per 100,000 persons

In 2020, reported COVID-19 deaths (3,757) were greater than excess deaths (2,930), meaning COVID-19 deaths were partially offset by declines in other causes of death. In 2021, reported COVID-19 deaths (6,327) were less than excess deaths (7,367), meaning there were excess deaths beyond those directly attributed to COVID-19. A time series of observed and expected weekly death rates from 2011–2021 are shown in **Figure 1**. Over that period, death rates for most weeks were within the 95 percent prediction interval. A notable exception was during 2017, when a severe flu season accompanied high rates of death. Following the emergence of COVID-19 in 2020, observed death rates exceeded the upper bound of the 95% prediction interval in most weeks.

Figure 1. Observed and Expected Death Rate per 100,000 by Week, Washington, 2011-2022
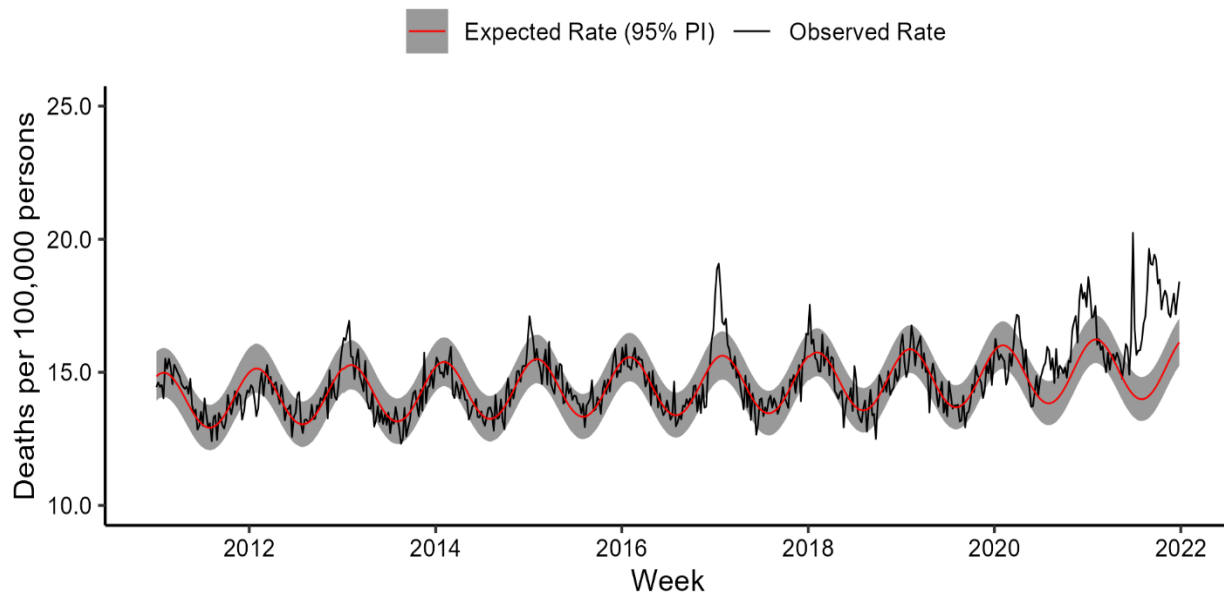
Excess Deaths by Age Group, Demographics, and State Region

Reported COVID-19 and excess death rates by demographic and year are shown in **Table 2**. Reported COVID-19 death rates were greater than excess deaths in the age groups of 75-84 and 85+. This means that COVID-19 death rates were partially offset by declines in other causes of death. Meanwhile, ages 0-54 and 55-64 had excess death rates higher than reported COVID-19 death rates, meaning there were excess deaths beyond the reported COVID-19 deaths. The 65-74 age range had fewer excess deaths than COVID-19 deaths in 2020 and more excess deaths than COVID-19 deaths in 2021. While older adults had the highest rates of excess death, younger adults had the highest percentage increase in deaths over the expected value.

In 2020, results showed 1,958 (6 percent) more deaths than expected in men and 997 (4 percent) in women (**Table 2**). By race and ethnicity, 2020 excess death rates were highest in Hispanic (27 percent), American Indian and Alaska Native (AI/AN) (14 percent), and Black (9 percent) persons. Excess mortality for Native Hawaiian and Other Pacific Islander (NHOPI) persons was 2 percent higher than expected, but this change was not statistically significant. There are few deaths annually for NHOPI persons, meaning large increases in rates of death are required for a result to be statistically significant. For farm workers, 38 (25 percent) more deaths than expected were found in 2020.

In 2021, we report 4,814 (15 percent) excess deaths in men and 2,581 (9 percent) excess deaths for women. By race and ethnicity, we found the highest excess death rates in American Indian/Alaska Native persons (34 percent), Hispanic persons (33 percent), and persons of two or more races (32 percent). For farm workers, we found 66 (44 percent) more deaths than

expected in 2021. All excess mortality estimates by individual demographics were statistically significant in 2021.

Excess death rates by Accountable Community of Health (ACH) for each year are shown in **Table 3** and **Figure 2**. In 2020, we found the highest excess death rates in the Greater Columbia ACH (107.6 deaths per 100,000, a 14 percent increase). In 2020, deaths were not statistically significantly higher than expected in the Cascade Pacific Action Alliance ACH, the Olympic ACH, and the Pierce County ACH. For 2021, excess deaths were highest in the Better Health Together ACH (160.7 deaths per 100,000, 17 percent) and lowest in the Healthier Here - King County ACH (55.8 deaths per 100,000, 9 percent). All ACH's had a statistically significant excess death rate in 2021.

Table 2: COVID-19 Versus Excess Deaths and Death Rates per 100,000 Persons by Select Demographic and Community Characteristics, Washington, 2020-2021

	2020						2021					
	COVID-19		Excess Mortality				COVID-19		Excess Mortality			
	Num	*Rate*	*Num*	*Rate*	*%*	*Sig‡*	*Num*	*Rate*	*Num*	*Rate*	*%*	*Sig‡*
OVERALL	3,757	48.6	2,930	37.9	5%	*	6,327	81.1	7,367	94.5	12%	*
Sex												
Female	1,751	45.4	997	25.9	4%	*	2,587	66.5	2,581	66.4	9%	*
Male	2,006	51.8	1,958	50.6	6%	*	3,740	95.7	4,814	123.2	15%	*
Race/Eth†												
AI/AN	77	83.9	118	128.3	14%	*	149	161.7	293	318.5	34%	*
Asian	282	38.3	186	25.3	7%	*	312	40.8	384	50.3	14%	*
Black	135	44.8	159	52.7	9%	*	219	70.4	355	114.1	18%	*
Hispanic	463	42.4	587	53.8	27%	*	543	48.5	763	68.3	33%	*
NHOPI	65	101.8	9	14.9	2%	NS	119	180.7	105	158.7	25%	*
Two or More	46	9.2	57	11.4	8%	*	92	18.2	250	49.5	32%	*
White	2,670	54.1	2,333	47.2	5%	*	4,867	98.5	5,641	114.2	11%	*
Age Group												
0 - 54	234	4.3	868	15.8	13%	*	914	16.6	2,179	39.6	31%	*
55 - 64	374	38.3	435	44.5	6%	*	1,030	105.8	1,511	155.1	20%	*
65 - 74	757	97.4	688	88.5	6%	*	1,562	195.2	2,068	258.4	17%	*
75 - 84	1,044	291.1	633	176.5	4%	*	1,455	381.0	1,188	311.1	8%	*
85+	1,348	1017.7	307	231.6	2%	*	1,366	1,022.5	421	315.4	2%	*
COVID-19 Vaccinations (quintile)^												
1 (lowest rate)	639	40.9	740	47.3	7%	*	1,622	103.8	2,404	153.9	21%	*
2	868	56.1	830	53.6	6%	*	1,690	108.1	2,083	133.3	15%	*
3	967	62.9	699	45.5	5%	*	1,592	102.3	1,473	94.7	10%	*
4	695	45.1	441	28.6	4%	*	920	59.0	997	63.9	9%	*
5 (highest rate)	579	37.7	308	20.1	4%	*	477	30.6	478	30.7	6%	*
Farm Workers §	32	-	38	-	25%	*	37	-	66	-	44%	*

^ Vaccinations per person by census tract as of 12/31/2021. Note that most COVID-19 vaccinations were given in 2021.

† Abbreviations: AI/AN = American Indian/Alaska Native, NHOPI = Native Hawaiian or other Pacific Islander. Non-Hispanic unless otherwise specified

‡ Asterisk (*) if excess deaths are higher than the upper bound of the 95% Prediction Interval of the expected rate, not significant (NS) otherwise

§ "Misc. agricultural workers" as defined by the decedent's reported occupation. Includes migrant farm workers. Rates cannot be calculated.

Table 3: COVID-19 Versus Excess Deaths and Death Rates per 100,000 Persons by Accountable Community of Health, Washington 2020-2021

	2020						2021					
	COVID-19		Excess Mortality				COVID-19		Excess Mortality			
	Num	Rate	Num	Rate	%	Sig†	Num	Rate	Num	Rate	%	Sig†
Better Health Together	441	69	347	54.3	6%	*	950	147.4	1,029	159.6	17%	*
Cascade Pacific Action	174	26.4	123	18.6	2%	NS	904	136.3	1,072	161.6	15%	*
Greater Columbia	715	95.9	796	106.6	14%	*	872	116.2	1,022	136.2	18%	*
Healthier Here (King)	1,152	50.6	694	30.5	5%	*	1020	44.4	1,276	55.6	9%	*
North Central	144	54.5	164	62.1	7%	*	332	124.1	410	153.3	18%	*
North Sound	558	43.2	409	31.6	4%	*	733	56.2	783	60.0	8%	*
Olympic	62	16	-55	-14.3	-1%	NS	319	81.9	324	83.3	8%	*
Pierce County	351	38	163	17.7	2%	NS	695	74.6	752	80.8	10%	*
SW WA Regional	160	29.6	280	51.8	7%	*	502	91.2	693	125.9	16%	*

† Asterisk (*) if excess deaths are higher than the upper bound of the 95% Prediction Interval of the expected rate, not significant (NS) otherwise

Figure 2. Excess Deaths per 100,000 Persons by Accountable Community of Health, 2020-2021

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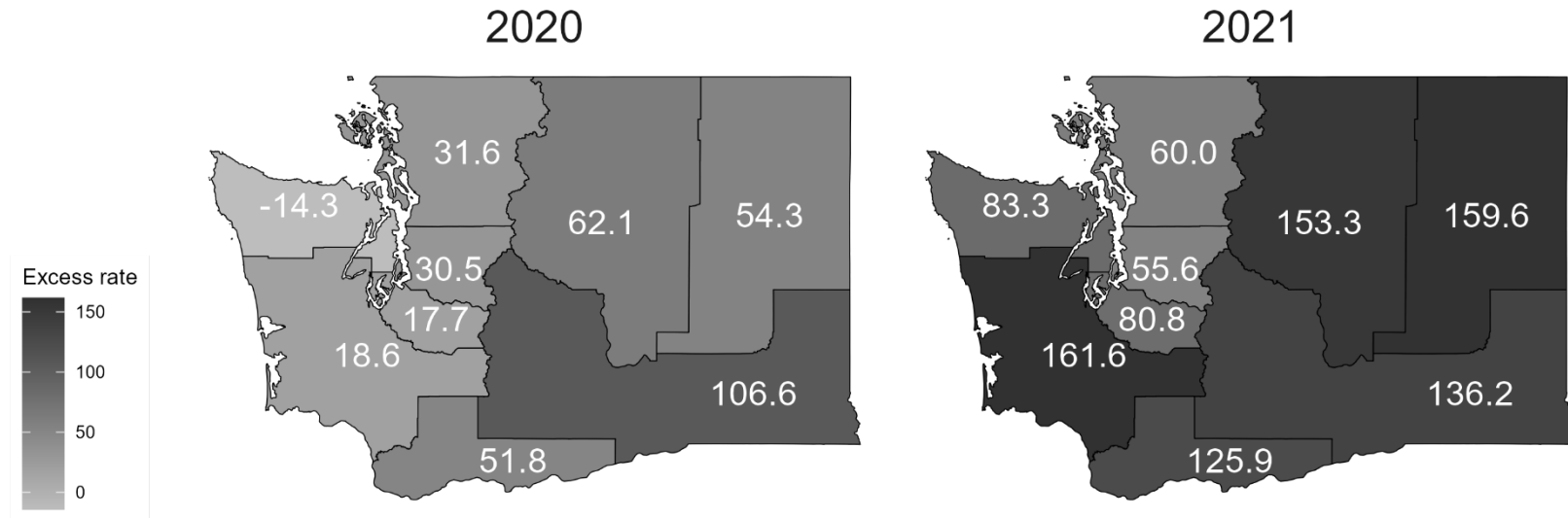
Timeline of Excess and COVID-19 Deaths

Weekly excess and COVID-19 death rates for 2020 and 2021 are shown in **Figure 3**. Before COVID-19 emerged in Washington, fewer deaths were found than expected due to a relatively mild flu season. On January 21, 2020, Washington State reported the first lab-confirmed case of coronavirus nationally [9]. Governor Inslee issued the "Stay Home, Stay Healthy" order on March 20, 2020 [10]. Nine months later, on December 15, 2020, vaccine roll-out began for the most vulnerable, later expanding to other groups [7, 11]. Excess death rates and COVID-19 death rates both decreased from February to May. COVID-19 and excess death patterns changed in June of 2021 [12]. Before this point, COVID-19 death rates were higher than excess death rates. From the summer of 2021 until the end of the year, weekly excess death rates were higher than reported COVID-19 death rates. One potential explanation is the COVID-19 delta variant, an infectious variant that became the dominant strain statewide in early July [13]. Other contributing factors may have been the heat dome and statewide reopening, both of which began in late June.

**Figure 3. Annotated COVID-19 and Excess Death Rate by Week, Washington, 2020-2021**
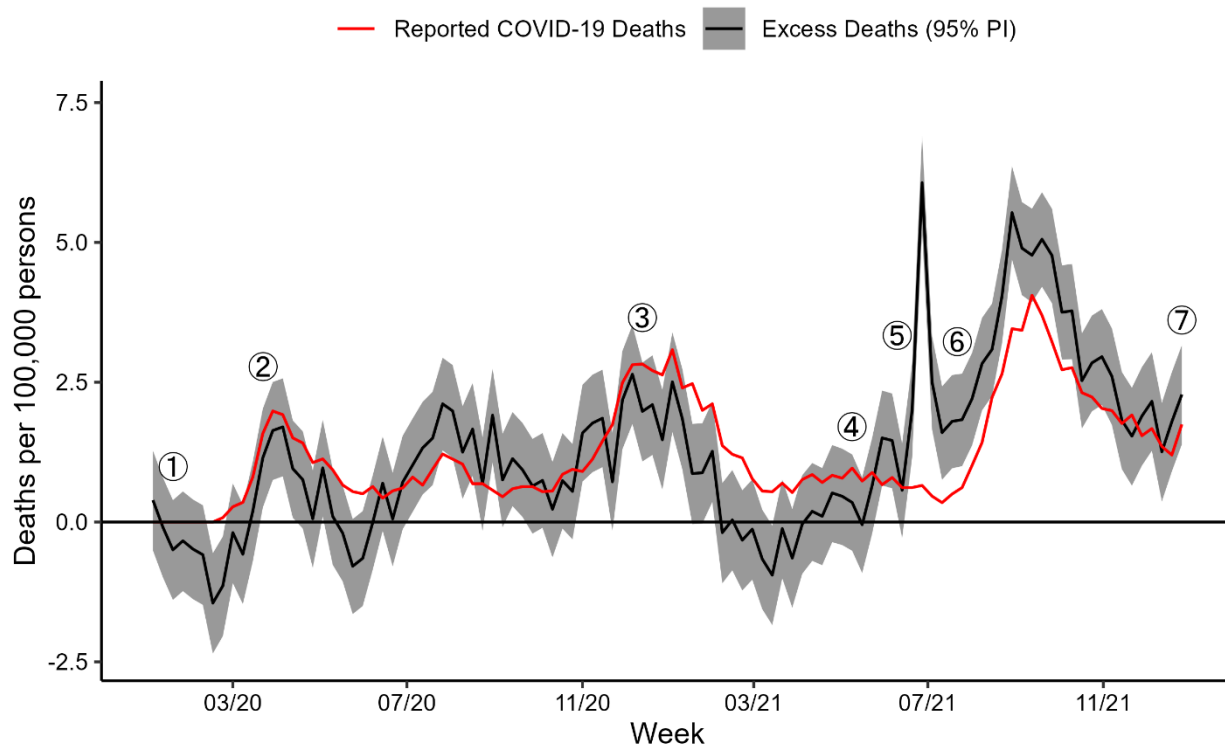
Annotations: ① *First laboratory-confirmed case of coronavirus in the United States reported in Washington State (1/21/2020) [9]* ② *First stay at home order issued (3/20/2020) [10];* ③ *First COVID-19 vaccination (12/15/2020) [7];* ④ *Genetic sequencing data show alpha variant most commonly detected statewide (5/9/2021) [13];* ⑤ *Heat dome begins (6/26/2021)* ⑥ *Delta variant becomes the dominant variant statewide (7/11/2021) and statewide opening begins (6/30/2021) [12, 13];* ⑦ *Omicron variant becomes dominant variant during the last report week (week ending 1/2/2022) [13].*

Excess Deaths by COVID-19 Vaccination Uptake

Census tracts were split into five groups by their vaccination rate as of December 31, 2021. A map of vaccination quintiles by census tract are shown in **Figure 4**. In general, vaccination rates per person were highest in areas with higher population density and lowest in areas with less population density.

Figure 4. Washington Census Tracts by COVID-19 Vaccinations per Person as of 12/31/2021
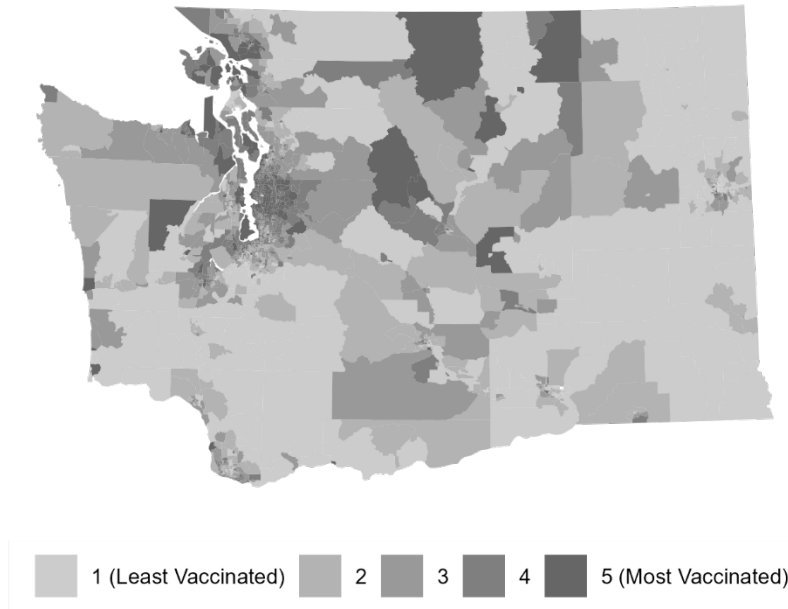

Excess death rates by vaccination quintile are presented in **Table 2**. In 2020, before vaccines were widely available, excess death rates were 4 percent to 7 percent in areas with the highest and lowest COVID-19 vaccination rates, respectively. In 2021, when most vaccinations occurred, census tracts with the highest vaccination rates had 478 (6 percent) excess deaths compared to 2,404 (21 percent) excess deaths in the least vaccinated census tracts. **Figure 5** shows weekly excess and COVID-19 death rates as well as cumulative COVID-19 vaccinations per person by vaccination quintile.

Differences in excess death rates, COVID-19 death rates, and COVID-19 vaccine doses per person are most apparent after boosters were first approved by the U.S. Food and Drug Administration on September 22, 2021 [14]. By the end of 2021, the most vaccinated areas had administered 2.08 COVID-19 vaccine doses per person, and the least vaccinated areas had administered 0.98 vaccine doses per person. From the week of September 22, 2021, through the end of 2021, the most vaccinated areas had 0.75 (7 percent) more deaths than expected per 100,000 persons each week, while the least vaccinated areas had 4.54 (32 percent) more deaths than expected each week per 100,000 persons. In the same period, average weekly

COVID-19 death rates were 0.70 deaths per 100,000 persons in the most vaccinated areas and 3.08 deaths per 100,000 persons in the least vaccinated areas.

Figure 5. Excess Death Rate, Reported COVID-19 Death Rate, and Cumulative COVID-19 Vaccination Rate by Week. Split by Quintile of Census Tract Vaccination Uptake as of 12/31/2021
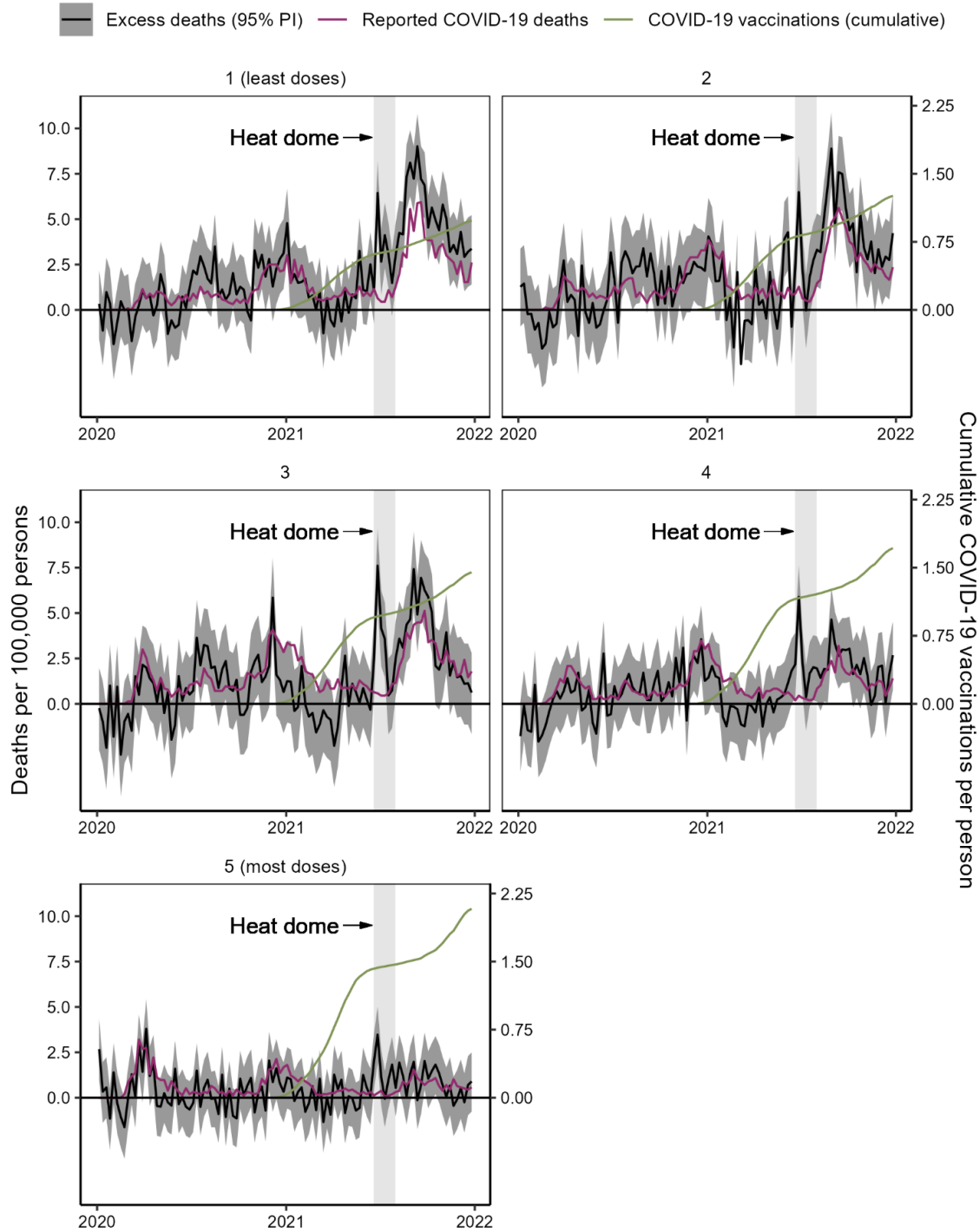
The 2021 Heat Dome

A comparison of average weekly death rates during the heat dome versus all other weeks in 2021 is shown in **Table 4**. Overall, we find 1,232 excess deaths during the heat dome (June 20, 2021 to July 31, 2021). During the heat dome, there were 205.4 excess deaths each week compared to 133.4 average excess deaths for all other weeks of 2021. This higher rate of excess death is not explained by reported COVID-19 deaths, because reported COVID-19 deaths were lower during the heat dome than the rest of the year. Excess death rates for those aged 85 and older changed most during the heat dome, with an average of 22.1 excess deaths each week during the heat dome compared to 6.3 excess deaths for all other weeks of the year.

Table 4. Average Reported COVID-19 Deaths, Excess Deaths, and Excess Death Rate per 100,000 Persons in Heat Dome vs. All Other Weeks, Washington, 2021

|	In Heat Dome (6/20 to 7/31)					All Other Weeks (2021)				
	COVID-19	Excess Deaths				COVID-19	Excess Deaths			
	Num	Num	Rate	%	Sig‡	Num	Num	Rate	%	Sig‡
OVERALL	41.5	205.4	2.6	19%	*	132.1	133.4	1.7	11%	*
Sex										
Female	15.5	75.7	1.9	15%	*	54.2	46.2	1.2	8%	*
Male	26.0	130.1	3.3	23%	*	77.9	87.7	2.2	14%	*
Race/Eth†										
AI/AN	-^	3.9	4.2	24%	*	3.2	5.9	6.4	35%	*
Asian	1.0	9.9	1.3	20%	*	6.7	7.1	0.9	13%	*
Black	2.5	14.4	4.6	41%	*	4.4	5.8	1.9	15%	*
Hispanic	4.5	16.2	1.4	38%	*	11.2	14.5	1.3	32%	*
NHOPI	-^	0.2	0.3	3%	NS	2.5	2.2	3.4	27%	*
Two or More	-^	8.9	1.8	62%	*	1.9	4.3	0.8	28%	*
White	31.3	161.2	3.3	18%	*	101.7	101.6	2.1	10%	*
Age Group										
0 - 54	6.7	45.7	0.8	35%	*	19.0	41.4	0.8	31%	*
55 - 64	6.8	30.0	3.1	22%	*	21.5	28.9	3.0	20%	*
65 - 74	10.7	66.2	8.3	29%	*	32.6	36.3	4.5	15%	*
75 - 84	9.5	41.4	10.8	15%	*	30.4	20.4	5.3	7%	*
85+	7.8	22.1	16.5	7%	*	28.7	6.3	4.7	2%	*

† Abbreviations: AI/AN = American Indian/Alaska Native, NHOPI = Native Hawaiian or other Pacific Islander. Non-Hispanic unless otherwise specified

‡Significance values: * = significant 95% Prediction Interval, NS = not significant

^ Counts and rates based on ≤5 deaths are excluded due to a lack of estimate stability.

Daily high temperatures, weekly excess death rates, and weekly reported COVID-19 death rates during the heat dome are shown in **Figure 6**. On the hottest day (June 29), temperatures reached 102.8°F. In the same week (June 27 to July 3), weekly excess were higher than all other weeks in 2020 and 2021. The last day of the heat dome (July 31) was also the last day with temperatures above 90.0 F of the year.

Figure 6: Daily High Temperatures vs. Weekly COVID-19 and Excess Death Rates During the 2021 Heat Dome
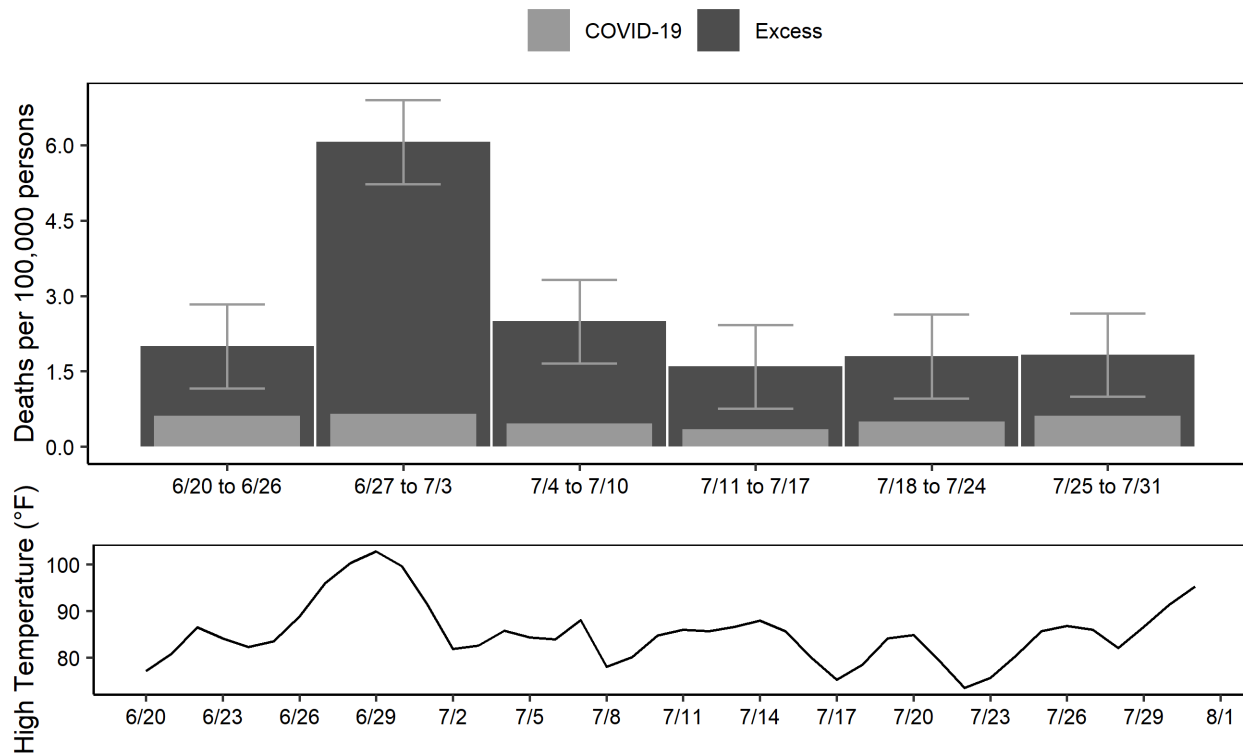
Statewide high temperature is the average high from all 4x4 km grids statewide. Specific state regions will have higher or lower temperatures than the statewide average. Climate data comes from PRISM [15].

Discussion

Washington State experienced both a global pandemic and a notable heat dome during 2020 – 2021. We found death rates far above what was expected from historical trends. The pattern of excess deaths compared to COVID-19 deaths was different in the two years examined. In 2020, more COVID-19 deaths were reported than excess deaths, indicating COVID-19 deaths were offset by other kinds of death. In 2021, excess deaths were higher than deaths attributed to COVID-19 and the heat dome combined. This could be due to undetected COVID-19 infections, an increased risk of death from chronic health conditions due to COVID-19 or excessive heat, or other unexpected impacts of life during the pandemic.

Younger age groups had excess death rates above those directly attributed to heat or COVID-19, meaning the true burden of the heat dome and COVID-19 is higher than the number of deaths directly attributed to either event. Older adults had excess death rates lower than reported COVID-19 death rates, meaning COVID-19 deaths were partially offset by declines in other types of death. Some deaths may have occurred even in the absence of COVID-19, or

pandemic-related social distancing measures could have reduced deaths due to the flu and other infectious diseases.

Our analysis is the first we are aware of that compares excess deaths and COVID-19 vaccination rates at the census tract level. Census tracts with higher vaccination rates fared better than those with lower vaccination rates, most notably after vaccination began in Washington. This is consistent with other findings that COVID-19 vaccines, including boosters, reduce the risk of infection and death [16, 17]. Despite the wide availability of vaccines, excess death rates were highest in the last 6 months of 2021.

The six weeks of the heat dome were among the deadliest weeks of 2020 and 2021. Heat waves and heat domes have become more common, and it is likely that this trend will continue. A special report from the Climate Impacts Group at the University of Washington finds that, by 2050, the average year in Washington will be warmer than the hottest year of the 20th century without significant reductions in greenhouse gas emissions [18]. In addition to reducing greenhouse gas emissions, we must protect the communities most vulnerable to extreme heat, pollution, and climate change. AI/AN, Hispanic, and Black persons had the highest rates of excess death during the heat dome. This is consistent with prior research showing neighborhoods with more persons of color have fewer features to mitigate heat, meaning these neighborhoods reach higher temperatures than white neighborhoods [19]. Other research finds Black and Hispanic persons are exposed to higher levels of many types of pollution than white persons, including construction, industrial, and overall pollution levels. [20].

Our excess death estimates are lower than those from the National Center for Health Statistics (NCHS) dashboards and research from the Institute for Health Metrics and Evaluation (IHME) [22, 23]. One reason for this might be related to population data sources. The IHME analysis was published in March of 2022 and used unpublished population data from the GBD database. The NCHS dashboards do not include a population offset. A sensitivity analysis using 2020 population estimates as the offset for 2021 deaths produces results closer to IHME and NCHS estimates.

Finally, excess death rates were inequitable. Reducing health disparities is a goal of the Washington State Department of Health Transformational Plan [22]. Disparities in death grew over 2020 and 2021. Before the pandemic, age-adjusted death rates were highest in AI/AN, Black, and NHOPI persons. These same groups had the highest excess death rates in the first two years of the pandemic. These health inequities are unjust and avoidable. We must prioritize the communities most impacted by COVID-19 and heat. This will improve the health of all Washingtonians and better prepare us for the next public health emergency.

Acknowledgements

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Appendix A: 95% Prediction Intervals for Main Results

The following tables show prediction intervals for the excess death rates. **Tables A-1a and A-b** show excess deaths by select demographics in 2020 and 2021, respectively. **Table A-2** shows excess deaths by Accountable Community of Health (ACH). Finally, **Table A-3** compares heat dome weeks to other weeks and provides prediction intervals.

Table A-1a. Prediction Intervals for Excess Deaths and Excess Death Rates by Demographics, Washington, 2020

	Observed	Expected		Excess Number		Excess Percent	
	Num	*Num*	*95% PI*	*Num*	*95% PI*	*Pct*	*95% PI*
OVERALL	62,911	59,981	59,501 to 60,461	2,930	2,450 to 3,410	4.9%	4.1% to 5.7%
Sex							
Female	29,803	28,806	28,474 to 29,139	997	664 to 1,329	3.5%	2.3% to 4.6%
Male	33,108	31,150	30,804 to 31,496	1,958	1,612 to 2,304	6.3%	5.2% to 7.4%
Race/Eth†							
AI/AN	961	843	787 to 901	118	60 to 174	14.0%	7.1% to 20.6%
Asian	2,780	2,594	2,494 to 2,694	186	86 to 286	7.2%	3.3% to 11.0%
Black	2,027	1,868	1,784 to 1,953	159	74 to 243	8.5%	4.0% to 13.0%
Hispanic	2,798	2,211	2,119 to 2,304	587	494 to 679	26.5%	22.3% to 30.7%
NHOPI	397	388	349 to 427	9	-30 to 48	2.4%	-7.7% to 12.4%
Two or More	820	763	709 to 818	57	2 to 111	7.5%	0.3% to 14.5%
White	52,825	50,492	50,052 to 50,933	2,333	1,892 to 2,773	4.6%	3.7% to 5.5%
Age Group							
0 - 54	7,771	6,903	6,741 to 7,067	868	704 to 1,030	12.6%	10.2% to 14.9%
55 - 64	7,829	7,394	7,226 to 7,563	435	266 to 603	5.9%	3.6% to 8.2%
65 - 74	12,803	12,115	11,900 to 12,331	688	472 to 903	5.7%	3.9% to 7.5%
75 - 84	15,199	14,566	14,330 to 14,803	633	396 to 869	4.3%	2.7% to 6.0%
85+	19,309	19,002	18,733 to 19,273	307	36 to 576	1.6%	0.2% to 3.0%
COVID-19 Vaccinations (quintile)^							
1	12,055	11,315	11,107 to 11,524	740	531 to 948	6.5%	4.7% to 8.4%
2	14,819	13,989	13,758 to 14,221	830	598 to 1,061	5.9%	4.3% to 7.6%
3	15,764	15,065	14,825 to 15,306	699	458 to 939	4.6%	3.0% to 6.2%
4	11,448	11,007	10,802 to 11,213	441	235 to 646	4.0%	2.1% to 5.9%
5	8,574	8,266	8,088 to 8,445	308	129 to 486	3.7%	1.6% to 5.9%
Farm Workers§	187	149	126 to 174	38	13 to 61	25.0%	7.4% to 48.4%

Abbreviations: AI/AN = American Indian/Alaska Native, NHOPI = Native Hawaiian or other Pacific Islander

^ Vaccinations per person by census tract as of 12/31/2021. Note that most COVID-19 vaccinations were given in 2021.

† Non-Hispanic unless otherwise specified

§ "Misc. agricultural workers" as defined by the decedent's reported occupation. Includes migrant farm workers. Rates cannot be calculated.

Table A-1b. Prediction Intervals for Excess Deaths and Excess Death Rates by Demographics, Washington, 2021

	Observed	Expected		Excess Number		Excess Percent	
	Num	Num	95% PI	Num	95% PI	Pct	95% PI
OVERALL	68,628	61,261	60,776 to 61,747	7,367	6,881 to 7,852	12.0%	11.2% to 12.8%
Sex							
Female	31,938	29,357	29,021 to 29,693	2,581	2,245 to 2,917	8.8%	7.6% to 9.9%
Male	36,681	31,867	31,518 to 32,217	4,814	4,464 to 5,163	15.1%	14.0% to 16.2%
Race/Eth†							
AI/AN	1,163	870	812 to 928	293	235 to 351	33.7%	27.0% to 40.4%
Asian	3,113	2,729	2,627 to 2,831	384	282 to 486	14.1%	10.3% to 17.8%
Black	2,331	1,976	1,889 to 2,063	355	268 to 442	18.0%	13.6% to 22.4%
Hispanic	3,081	2,318	2,224 to 2,412	763	669 to 857	32.9%	28.9% to 37.0%
NHOPI	526	421	382 to 462	105	64 to 144	24.8%	15.2% to 34.2%
Two or More	1,035	785	731 to 840	250	195 to 304	31.8%	24.8% to 38.7%
White	56,981	51,340	50,896 to 51,784	5,641	5,197 to 6,085	11.0%	10.1% to 11.9%
Age Group							
0 - 54	9,115	6,936	6,773 to 7,100	2,179	2,015 to 2,342	31.4%	29.1% to 33.8%
55 - 64	8,905	7,395	7,226 to 7,564	1,511	1,341 to 1,679	20.4%	18.1% to 22.7%
65 - 74	14,492	12,424	12,206 to 12,643	2,068	1,849 to 2,286	16.6%	14.9% to 18.4%
75 - 84	16,477	15,289	15,047 to 15,532	1,188	945 to 1,430	7.8%	6.2% to 9.4%
85+	19,639	19,218	18,946 to 19,490	421	149 to 693	2.2%	0.8% to 3.6%
COVID-19 Vaccinations (quintile)^							
1	13,855	11,451	11,242 to 11,661	2,404	2,194 to 2,613	21.0%	19.2% to 22.8%
2	16,384	14,301	14,067 to 14,536	2,083	1,848 to 2,317	14.6%	12.9% to 16.2%
3	16,908	15,435	15,192 to 15,679	1,473	1,229 to 1,716	9.5%	8.0% to 11.1%
4	12,233	11,236	11,029 to 11,444	997	789 to 1,204	8.9%	7.0% to 10.7%
5	8,905	8,427	8,248 to 8,607	478	298 to 657	5.7%	3.5% to 7.8%
Farm Workers§	215	149	126 to 174	66	41 to 89	44.3%	23.6% to 70.6%

Abbreviations: AI/AN = American Indian/Alaska Native, NHOPI = Native Hawaiian or other Pacific Islander

^ Vaccinations per person by census tract as of 12/31/2021. Note that most COVID-19 vaccinations were given in 2021.

† Non-Hispanic unless otherwise specified

§ "Misc. agricultural workers" as defined by the decedent's reported occupation. Includes migrant farm workers. Rates cannot be calculated.

Table A-2. Prediction Intervals for Excess Deaths and Excess Death Rates by Accountable Community of Health, Washington, 2020 and 2021

	Observed	Expected		Excess Number		Excess Percent	
2020	Num	Num	95% PI	Num	95% PI	Pct	95% PI
Better Health Together	6327	5,980	5,829 to 6,132	347	195 to 498	5.8%	3.3% to 8.3%
Cascade Pacific Action	6,953	6,830	6,669 to 6,993	123	-40 to 284	1.8%	-0.6% to 4.2%
Greater Columbia	6,536	5,741	5,592 to 5,889	796	647 to 944	13.9%	11.3% to 16.4%
Healthier Here (King)	14,351	13,657	13,429 to 13,887	694	464 to 922	5.1%	3.4% to 6.8%
North Central	2,410	2,246	2,153 to 2,339	164	71 to 257	7.3%	3.2% to 11.4%
North Sound	10,486	10,077	9,881 to 10,274	409	212 to 605	4.1%	2.1% to 6.0%
Olympic	3,854	3,909	3,787 to 4,032	(55)	-178 to 67	-1.4%	-4.6% to 1.7%
Pierce County	7,481	7,318	7,151 to 7,486	163	-5 to 330	2.2%	-0.1% to 4.5%
SW WA Regional	4,511	4,231	4,104 to 4,359	280	152 to 407	6.6%	3.6% to 9.6%
2021							
Better Health Together	7,155	6,126	5,973 to 6,280	1,029	875 to 1,182	16.8%	14.3% to 19.3%
Cascade Pacific Action	8,115	7,043	6,879 to 7,208	1,072	907 to 1,236	15.2%	12.9% to 17.5%
Greater Columbia	6,876	5,854	5,705 to 6,005	1,022	871 to 1,171	17.5%	14.9% to 20.0%
Healthier Here (King)	15,069	13,793	13,563 to 14,024	1,276	1,045 to 1,506	9.3%	7.6% to 10.9%
North Central	2,688	2,278	2,185 to 2,372	410	316 to 503	18.0%	13.9% to 22.1%
North Sound	11,097	10,314	10,115 to 10,513	783	584 to 982	7.6%	5.7% to 9.5%
Olympic	4,350	4,026	3,902 to 4,150	324	200 to 448	8.1%	5.0% to 11.1%
Pierce County	8245	7,493	7,324 to 7,663	752	582 to 921	10.0%	7.8% to 12.3%
SW WA Regional	5,032	4,339	4,210 to 4,468	693	564 to 822	16.0%	13.0% to 18.9%

Table A-3. Average Weekly Excess Deaths and Excess Death Rates per 100,000 Persons in Heat Dome vs. All Other Weeks, Washington, 2021

	In Heat Dome (6/20 to 7/31)				All Other Weeks (2021)			
	Excess Deaths		Excess Rate (per 100,000)		Excess Deaths		Excess Rate (per 100,000)	
	n	95% PI	Rate	95% PI	n	95% CI	Rate	95% PI
OVERALL	205.0	178.8 to 231.8	2.6	2.3 to 3.0	133.4	123.4 to 143.3	1.7	1.6 to 1.8
Sex								
Female	75.7	57.3 to 94.0	1.9	1.5 to 2.4	46.2	39.3 to 53.1	1.2	1.0 to 1.4
Male	130.1	110.8 to 149.2	3.3	2.8 to 3.8	87.7	80.5 to 94.8	2.2	2.1 to 2.4
Race/Eth†								
AI/AN	3.9	0.7 to 7.0	4.2	0.7 to 7.6	5.9	4.7 to 7.0	6.4	5.1 to 7.6
Asian	9.9	4.2 to 15.5	1.3	0.5 to 2.0	7.1	5.0 to 9.2	0.9	0.6 to 1.2
Black	14.4	9.5 to 19.0	4.6	3.1 to 6.1	5.8	4.0 to 7.6	1.9	1.3 to 2.5
Hispanic	16.2	10.8 to 21.3	1.4	1.0 to 1.9	14.5	12.5 to 16.4	1.3	1.1 to 1.5
NHOPI	0.2	-2.0 to 2.3	0.3	-3.0 to 3.5	2.2	1.4 to 3.1	3.4	2.1 to 4.7
Two or More	8.9	5.8 to 11.8	1.8	1.2 to 2.3	4.3	3.1 to 5.4	0.8	0.6 to 1.1
White	161.2	136.8 to 185.3	3.3	2.8 to 3.8	101.6	92.5 to 110.7	2.1	1.9 to 2.2
Age Group								
0 - 54	45.7	36.3 to 54.8	0.8	0.7 to 1.0	41.4	38.1 to 44.7	0.8	0.7 to 0.8
55 - 64	30.0	20.5 to 39.2	3.1	2.1 to 4.0	28.9	25.5 to 32.4	3.0	2.6 to 3.3
65 - 74	66.2	54.2 to 78.2	8.3	6.8 to 9.8	36.3	31.8 to 40.8	4.5	4.0 to 5.1
75 - 84	41.4	28.2 to 54.5	10.8	7.4 to 14.3	20.4	15.4 to 25.4	5.3	4.0 to 6.7
85+	22.1	7.3 to 36.7	16.5	5.5 to 27.4	6.3	0.7 to 11.8	4.7	0.5 to 8.9

Abbreviations: AI/AN = American Indian/Alaska Native, NHOPI = Native Hawaiian or other Pacific Islander

† Non-Hispanic unless otherwise specified

Appendix B: Detailed Methodology

Population Data

Population data came from the Population Interim Estimates (PIE), produced by Public Health, Seattle & King County in consultation with the Washington State Department of Health, the Washington State Office of Financial Management (OFM), and other organizations in the state.

PIE estimates were created to address data product delays and methodological adjustments made during the 2020 U.S. Census. PIE estimates population characteristics as of April 1 each year. We used linear interpolation to spread changes in annual estimates across the weeks between each estimate.

COVID-19 Vaccinations per Person by Census Tract

We retrieved COVID-19 immunization records administered by week for all weeks in 2020 and 2021 using the Washington State Immunization Information System [21]. The first vaccine was administered on December 15, 2020. Of 11,877,070 vaccination records listing Washington as the state of residence, 11,740,819 (98.9 percent) provided sufficient information to be geocoded to the census tract of residence [22]. We calculated vaccination rates for each tract as of the last week of 2021. Census tracts were then split into 5 groups (quintiles) according to the number of vaccinations administered per person. Since population size varies by census tract, quintiles were population-weighted to produce similarly sized groups.

Death Data

We included all deaths of Washington residents in the years 2011 – 2021. Data came from the Washington Health and Life Events (WHALES) database [23]. After excluding eighteen deaths without a valid age, 616,270 deaths remained. Individual demographics of interest included sex (male or female)[1], race/ethnicity (White, Black, Asian, Native Hawaiian or Other Pacific Islander, Two or more races, and Hispanic), and the Accountable Community of Health (ACH) for each death. ACH's are groups of counties that share a border and have common health goals.

Aggregation of Deaths and Population

Deaths and population were aggregated by week of death and age group, both statewide and for each demographic group described above. Age groups were 0-54, 55-64, 65-74, 75-84, and 85+. Deaths with missing demographic information are excluded from aggregation for that demographic only. Missingness was below 1 percent for all demographics. Weeks began on

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[1] 7 deaths were reported with sex 'X', likely indicating a non-binary gender. This is too few to analyze statistically.

Sunday, and the year of each week was determined by its first day. Based on this definition, 1/5/2020 – 1/12/2020 was the first week of 2020, and 12/26/2021 – 1/1/2022 was the final week of 2021.

We report crude death rates, or the unadjusted number of deaths per 100,000 persons. While not presented, age-adjusted rates are available on request.

Analyses

Expected Death Model

Within each demographic group, we fit a seasonal over-dispersed Poisson regression model with a linear time trend to weekly deaths from the years 2011-2019:

$$\log(\lambda_{it}) = \alpha_i + \beta_i t + \gamma_i \sin \omega w + \delta_i \cos \omega w + \log(P_{it})$$

Where:
- i is the age group (0 to 54, 55 to 64, 65 to 74, 75 to 84, 85+)
- t is the number of weeks since January 1, 2011
- λ_{it} is the expected number of deaths for the age group (i) and week number (t)
- α_i is the intercept for age group i
- β_i is a linear time term for age group i
- $\gamma_i \sin \omega w + \delta_i \cos \omega w$ is the seasonal component for age group i, where $\omega = \frac{2\pi}{52}$ sets the length of the season at 52 weeks.
- w is the week of the year (1 - 52). For the two years with 53 weeks (2012 & 2016), the seasonal term for the 53rd week was fixed at the value of the 52nd week.
- P_{it} is the smoothed weekly population offset for age group i at week number t

This model created a baseline of expected deaths if historical trends had continued into 2020 and 2021.

Excess Death Estimates, 2020 and 2021

For each demographic group, the excess number of deaths in age group i on week t was the difference between observed and expected deaths:

$$\Delta_{it} = Y_{it} - \lambda_{it}$$

Where Y_{it} is the observed number of deaths. Excess counts and rates are negative when fewer deaths occur than expected. Dividing excess deaths by the population offset P_{it} yields the excess death rate for age group i during week t. Weekly excess death rates over all ages at week t are then the sum of excess deaths divided by the sum of the population:

$$\mu_t = \frac{\sum_{i=1}^{5} \Delta_{it}}{\sum_{i=1}^{5} P_{it}}$$

While the model was fit on weekly death rates, it is useful to report cumulative excess death rates over longer periods, such as an entire year. We calculated cumulative excess deaths as the sum of excess deaths divided by the average weekly population from the first week (t_0) to the last week (t) in a set of weeks:

$$\mu_{t\ Cumulative} = \frac{\sum_{t_0}^{t} \sum_{i=1}^{5} \Delta_{it}}{\left(\sum_{t_0}^{t} \sum_{i=1}^{5} P_{it}\right) * \frac{1}{(1+t-t_0)}}$$

Prediction Intervals for Excess Death Estimates

Even if historical trends in deaths had continued, some difference between observed and expected deaths would occur due to random chance. To create prediction intervals for estimates, we draw from the 2.5th and 97.5th percentiles of the Poisson distribution centered around each expected death count [2]. A result outside of this prediction interval is statistically significant. The tables indicate statistically significant results, and charts will include 95% prediction intervals. Prediction intervals for all results can be found in the appendix.

Comparison of Excess Death Rates to Prior Reports

Reported COVID-19 Deaths

For reported COVID-19 deaths, we counted confirmed and suspected deaths, consistent with the Washington DOH case definition used during these years [6]. During 2020 and 2021, small changes to these case definitions were made. Such changes had minimal material effect on the total number of reported deaths.

The Heat Dome

The first day of the heat dome was June 26, 2021, and we consider the weeks June 20 to July 31 heat dome weeks based on informal guidance from federal partners. Since excess deaths during this time may have been due to factors unrelated to heat, we compared average weekly excess deaths and COVID-19 deaths during the heat dome to the averages for all other weeks in 2021:

$$\bar{\mu}_{h_1} = \frac{1}{6} \sum_{t=1}^{6} \mu_t \text{ and } \bar{\mu}_{h_0} = \frac{1}{46} \sum_{t=1}^{46} \mu_t$$

Where h_1 indicates heat dome weeks and h_0 is the other 46 weeks of 2021.

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[2] An alternative approach we explored was simulated prediction intervals using the model variance-covariance matrix and Poisson-distributed noise. This yielded similar results, so the simpler approach was used.

Adapted Methods for Farm Workers

Farm workers were an occupation of interest, as high rates of COVID-19 deaths were observed in this population [8, 24]. The decedent's occupation reported on the death certificate was used to assign a Standard Occupational Classification (SOC) code from the Bureau of Labor Statistics. In this report, we use the term farm workers to reference the "Miscellaneous Agricultural Workers" SOC category. Occupation data for deaths had special limitations that required adjustments to the methods used in other groups. Occupation data were first available in 2014, and there are fewer than 3 weekly deaths reported between 2014 and 2019. To account for these limitations, we aggregated all deaths from farm workers ages 18 – 65 by month from 2014 to 2021. The model used monthly deaths from 2014 to 2019 to produce expected deaths in 2020 and 2021. As there is no annual population estimate for this group, excess mortality rates cannot be provided. Additionally, changes in farm workers deaths might be attributable to changes in population size rather than the risk of death.

Supplementary Analyses and Materials Available

Some analyses performed do not appear in this report due to space limitations but are available on request. Available materials include age-adjusted rates, excess deaths by underlying cause of death, and a demographic comparison of each COVID-19 vaccination uptake quintile.