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Social Justice and Exponential Functions: Using Pandemic Data to Increase Student Understanding

Cover Page Footnote

I would like to thank the editors for providing me with helpful feedback on my article and for their support and patience.

Social Justice and Exponential Functions: Using Pandemic Data to Increase Student Understanding

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Synopsis

This paper describes a class activity based on real data about COVID-19 death rates in California. The activity helps students learn about exponential functions while providing an opportunity to integrate social justice concerns into the mathematics classroom.

Keywords: exponential models, environmental justice

1. Introduction

Recent events, recent politics and the pandemic have, for many of us, strengthened our resolve to create more inclusive classrooms. We want our students from all backgrounds and experiences to find mathematics to be a welcoming, supportive and relevant discipline. One way to do this is to integrate applications of mathematics to social justice issues. We can educate students about social justice and mathematics simultaneously.

Students who are uninterested in mathematics or who view mathematics as irrelevant to their interests may become more motivated to learn mathematics if shown how that mathematics can help understand problems in our society. Understanding problems is the first step towards finding solutions. We can show students that math can help illuminate problems of real concern in their communities. We can show students that mathematics is relevant. Mathematics can help understand social justice issues and therefore help us collectively move towards a more just and equitable society.

The pandemic has exacerbated existing inequities. Different groups have had very different pandemic experiences. In particular, death-rates from COVID-19 have been higher in communities of color than in white communities in the USA. This paper describes a class activity which uses exponential functions to model real data on COVID-19 death rates. The data clearly show the differing impacts the pandemic has had on different communities in California.

2. Background

COVID-19 has had an effect on everyone, but it has not had the same effect on all groups. COVID-19 death rates increase with age in all racial groups in the US. However, there are stark disparities in death rates when comparing different racial groups of the same age. COVID-19 has been more deadly in communities of color than in white communities, and this disparity is more extreme at lower ages. Thus in communities of color more lives have been lost younger, leading to more children losing parents, and more total years of life being lost than in white communities [1].

The different impact of COVID-19 on different racial groups in California is clearly apparent in the data found on the website https://www.cdph.ca.gov/Programs/CID/DCDC/Pages/COVID-19/Race-Ethnicity.aspx, last accessed on July 30, 2022.

This website provides data on COVID-19 cases and deaths by age and race in California. Working with real data is motivating. But real data is often messy and noisy. The data here turn out to be quite well modeled by exponential functions. Working with this data thus provides a motivation for understanding exponential functions, because these functions can help us understand COVID-19 death rates. The data do not provide explanations or causes for these disparities, but can provide a launching point for class discussion of what are some likely explanations for the differences and what sort of data would be needed to explore this further.

3. Mathematics Learned or Reinforced

The activity begins by asking questions that help remind students that if we want to compare how deadly COVID-19 is for two groups that we need to compare, not raw numbers of deaths, but death rates. This reminds students that about the importance of ratios.

Some students tend to try to represent everything with linear functions. This may be because linear functions are simpler than other functions, or may be just because these are the most familiar type of function. This activity lets students explore real data that are poorly modeled by linear functions, but well modeled by exponential functions. We use desmos.com, a free online tool to fit the models, so that students are freed from detailed calculations and can concentrate on understanding and interpreting the models. Desmos provides a graphing utility and can be used for model-fitting. In the activity we first fit a linear and then an exponential function to the data. Students can see clearly that the exponential function fits the data very well, while the linear function does not. This can help students overcome their bias in favor of linear functions.

The graph in Figure 1 below shows both the linear and exponential models for death rate as a function of age for African American Californians. The better fit of the exponential model is obvious.

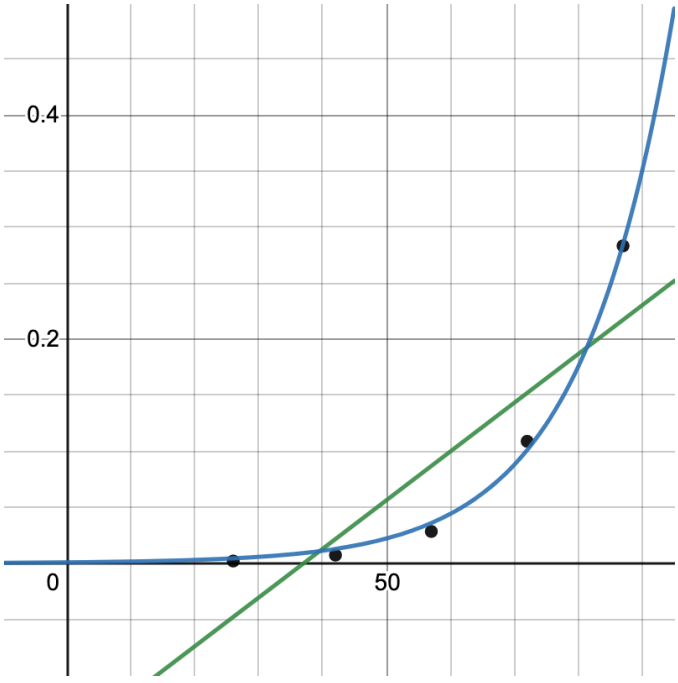


Figure 1: Death rates from COVID-19 as a function of age in years for African American Californians.

In class we found exponential models for the death rates for African American and White Californians and compared them; the disparities are obvious. For homework students were then asked to do similar modeling for another racial group.

If y is the death rate from COVID and x is age then Desmos finds the following models for the data:

$$\text{For African American Californians:} \quad y = .000692782 \times (1.07156)^x.$$
$$\text{For White Californians:} \quad y = .0001444 \times (1.08991)^x.$$

This leads to an interesting discussion of the role of the two parameters in an exponential model of the form $y = a \times b^x$. In the model for African American Californians the value of a is larger than a in the model for White Californians, but the opposite is true for the value of b. In exponential models a dominates for small values of x and b for large values of b. This can be clearly seen when the two models are graphed together (Figure 2). The two graphs intersect at about $x = 92$.

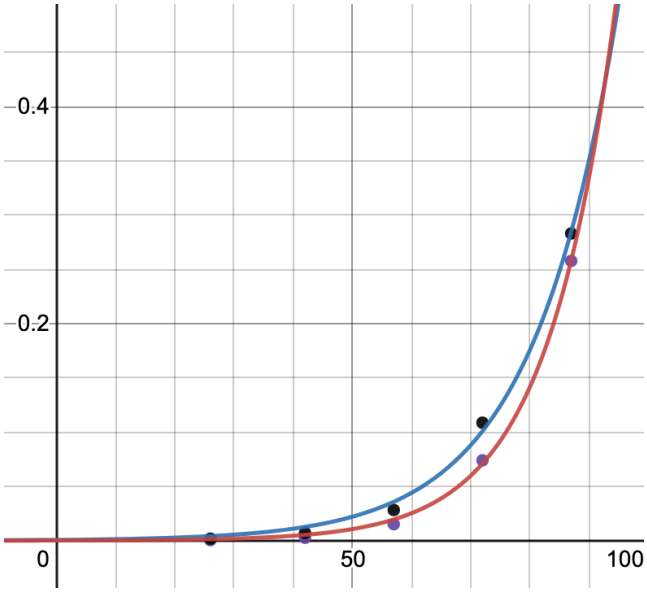


Figure 2: COVID-19 Death rates for African American Californians (blue curve) and White Californians (red curve).

4. Student Reactions

Students responded well to this activity. The activity was implemented during a semester when teaching was fully remote. All classes were conducted over Zoom, a format where it can be hard for students to maintain focus. Students found this activity engaging.

When asked to comment on what they thought might be some of the causes of the racial differences in COVID death rates, students offered suggestions such as differential access to health care, differing income levels, and other reasonable contributing factors. The instructor used this opportunity to introduce the concept of environmental justice. For all or most students the concept of environmental justice as a type of social justice was new.

According to the CDC, people with chronic lung disease are at a higher risk of severe illness when infected with COVID-19 [2]. Air pollution is often higher in communities of color and polluting industries are more likely to be located in those communities than in affluent white communities. These environmental factors increase the prevalence of chronic lung disease [3]. So more pollution in communities of color leads to more chronic lung disease which makes COVID-19 more deadly, a clear example of environmental injustice.

5. Conclusion

The pandemic has brought pain, suffering, and death. And it has brought these ills unequally to different communities and groups. The pandemic has shone a spotlight on health inequities in our country. We can learn from the pandemic, and we can use pandemic data to teach our students mathematics while simultaneously providing opportunities for our students to think about social justice issues. The class activity described here is one way to use COVID-19 data to provide students with an opportunity to better understand exponential models while at the same time clearly illustrating health inequities and bringing to the students' attention environmental justice issues.

References

[1] Mary T. Bassett, Jarvis T. Chen, and Nancy Krieger, "Variation in racial/ethnic disparities in COVID-19 mortality by age in the United

States: A cross-sectional study," *PLOS Medicine*, Volume **17** (2020), pages 1–14. doi:10.1371/journal.pmed.1003402

[2] Centers for Disease Control, *COVID-19. People with certain medical conditions*, web resource at https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/people-with-medical-conditions.html, last accessed on July 30, 2022.

[3] Bongki Woo, Nicole Kravitz-Wirtz, Victoria Sass, Kyle Crowder, Samantha Teixeira, and David T Takeuchi, "Residential segregation and racial / ethnic disparities in ambient air pollution," *Race and social problems*, Volume **11** Issue 1 (2019), pages 60–67.

A. The Class Activity

The website below contains data about deaths from COVID-19 in California and race and age.

https://www.cdph.ca.gov/Programs/CID/DCDC/Pages/COVID-19/Race-Ethnicity.aspx

Below you will find the data from this site as of March 31,2021.

We will be using Desmos (https://desmos.com) to do this work.

We will use this data to build models for the death rate of African American Californians (18 or older) due to COVID-19 with respect to age. We will let x stand for age in years and y stand for death rate.

(1) Is the following reasoning correct? Why or why not? Justify your answer.

For African American Californians ages 65-79 there were 1322 deaths and for African American Californians 50-64 there were 730 deaths. 1322 is about 1.8 times 730, so this means that it's about 1.8 times as likely for an African American Californian age 65-79 infected with COVID-19 to die from the disease as it is for an African American Californian age 50-64 infected with COVID-19.

There are six age ranges in the data on this site. These are 0-17, 18-34, 35-49, 50-64, 65-79, 80+. There were, happily, very few deaths (a total of 16) in the 0-17 year age range as of March 31, 2021. So we will only consider people age 18 and up as we look at death rates.

For our purposes we will associate each age range with its midpoint so we will associate:

$$\text{the 18-34 range with } \tfrac{18+34}{2} = 26$$

$$\text{the 35-49 range with } \tfrac{35+49}{2} = 42$$

$$\text{the 50-64 range with } \tfrac{50+64}{2} = 57$$

$$\text{the 65-79 range with } \tfrac{65+79}{2} = 72.$$

For each of the above age ranges (except 18-34) we are representing the interval with the midpoint of the interval, which is the lower limit of the interval plus 7. So we will represent the 80+, age group by $80+7 = 87$.

These will be the values for the independent variable x. Now we will calculate the death rates for each of these age ranges. The death rates will be the dependent variable y.

For African American Californians ages 18-34 there were 36197 cases and 70 deaths for a death rate of $\frac{70}{36197} = .0019$.

For African American Californians ages 35-49 there were 25546 cases and 185 deaths for a death rate of $\frac{185}{25546} = .0072$.

For African American Californians ages 50-64 there were 25791 cases 730 deaths for a death rate of $\frac{730}{25791} = .0283$.

For African American Californians ages 65-79 there were 12151 cases and 1322 deaths for a death rate of $\frac{1322}{12151} = .1088$.

For African American Californians 80+ there were 4394 cases and 1245 deaths for a death rate of $\frac{1245}{4394} = .2833$.

Our work above gives the following data points

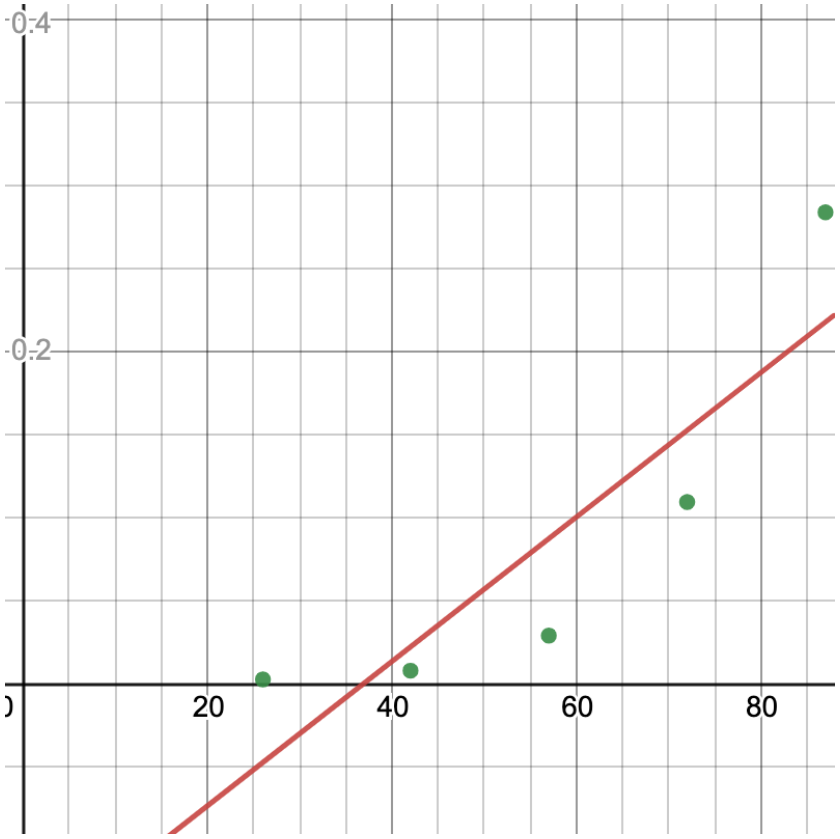
$$(26, .0019), (42, .0072), (57, .0283), (72, .1088), and (87, .2833).$$

Enter this data in a table in Desmos (`https://desmos.com`).

We can use Desmos to find a straight line model for this data.

$$y_1 = mx_1 + b$$

In Desmos enter $y_1 \sim mx_1 + b$ to get:

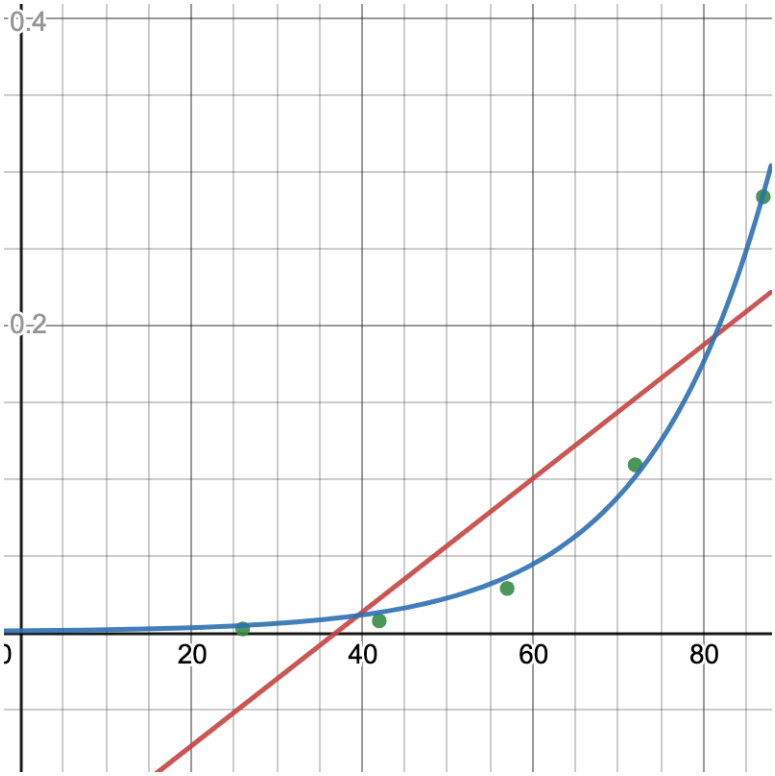


A straight line does not seem to fit this data well. Another way to say this is that a linear model doesn't seem to represent this situation.

Let us try an exponential model instead.

$$y_1 = ab^{x_1}$$

Now Desmos gives us:



Much better. The model is

$$y = .000692782 \times (1.07156)^x$$

(2) What does this model predict would be the death rate from COVID-19 for an African American Californian age 20?

(3) Is the following reasoning correct? Why or why not? Justify your answer.

On March 31, 2021 a total of 77 White Californians aged 18-34 had died from COVID-19, while 70 African American Californians aged 18-34 had died from COVID-19. So it seems that COVID-19 is slightly more deadly for White Californians than African American Californians in the 18-34 age group.

We can calculate death rates from COVID-19 for White Californians the same way as we did above for African American Californians and this will give us the following data points.

$$(26, .0005), (42, .0027), (57, .0152), (72, .0741), (87, .2580)$$

Again we will find that a linear model doesn't fit the data well but that an exponential model does.

Model for White Californians:

$$y = .0001444 \times (1.08991)^x$$

Model for African American Californians:

$$y = .00069782 \times (1.07156)^x$$

(4) About what age would a White Californian be to have the same predicted death rate as a 40 year old African American Californian?

(5) What do these models predict is the death rate for a 60 year old White Californian? About what age would an African American Californian be to have the same predicted death rate?

(6) What do you think might be some of the reasons for the difference in death rates between White and African American Californians? If you wanted to explore these reasons, what kind of data would be useful? You don't need to actually do this exploration, just think about what data would be useful.

(7) Are there ages at which African American Californians would have lower COVID-19 death rates than White Californians, according to these models? How can we see that in the graphs?

(8) What about Latino Californians? Do you think they would be more like White or African American Californians with respect to death rates from COVID-19? Explain your reasoning.

Data from the website as of March 31, 2021.

B. COVID-19 Race and Ethnicity Data

As part of its commitment to reduce health inequities, the state has launched a Health Equity Dashboard on www.COVID19.ca.gov that tracks California's health equity measure and data by race and ethnicity, sexual orientation, and gender identity. CDPH updates data tables on race/ethnicity weekly.

All Cases and Deaths associated with COVID-19 by Race and Ethnicity

Race/Ethnicity	No. Cases	Percent Cases	No. Deaths	Percent Deaths	Percent CA population
Latino	1,563,114	55.6	26,613	46.5	38.9
White	568,169	20.2	17,932	31.3	36.6
Asian	193,642	6.9	6,714	11.7	15.4
African American	115,949	4.1	3,554	6.2	6.0
Multi-Race	46,826	1.7	778	1.4	2.2
American Indian or Alaska Native	9,539	0.3	205	0.4	0.5
Native Hawaiian and other Pacific Islander	15,708	0.6	347	0.6	0.3
Other	300,375	10.7	1,081	1.9	0.0
Total with data	2,813,322	100.0	57,224	100.0	100.0

Cases: 3,570,660 total; 757,338 (21%) missing race/ethnicity
Deaths: 58,090 total; 866 (1%) missing race/ethnicity
*2,188 cases with missing age
**Census data does not include 'other race' category

All Cases and Deaths by Race and Ethnicity Among Ages 18+

Race/Ethnicity	No. Cases	Percent Cases	No. Deaths	Percent Deaths	Percent CA population
Latino	1,318,926	54.1	26,605	46.5	36.3
White	519,434	21.3	17,924	31.3	38.8
Asian	176,471	7.2	6,712	11.7	16.2
African American	104,079	4.3	3,552	6.2	6.1
Multi-Race	40,618	1.7	777	1.4	1.7
American Indian or Alaska Native	8,330	0.3	205	0.4	0.5
Native Hawaiian and other Pacific Islander	14,174	0.6	346	0.6	0.3
Other	254,307	10.4	1,081	1.9	0.0
Total with data	2,436,339	100.0	57,202	100.0	100.0

Cases: 3,570,660 total; 757,338 (21%) missing race/ethnicity
Deaths: 58,090 total; 866 (1%) missing race/ethnicity
*2,188 cases with missing age
**Census data does not include 'other race' category

Proportions of Cases and Deaths by Race and Ethnicity Among Ages 0-17

Race/Ethnicity	No. Cases	Percent Cases	No. Deaths	Percent Deaths	Percent CA Population
Latino	243,635	64.8	7	43.8	47.9
White	48,432	12.9	3	18.8	29.2
Asian	17,091	4.5	2	12.5	12.7
African American	11,808	3.1	2	12.5	5.4
Multi-Race	6,205	1.7	1	6.2	4.0
American Indian	1,197	0.3	0	0.0	0.4
Native Hawaiian and other Pacific Islander	1,529	0.4	1	6.2	0.3
Other	45,946	12.2	0	0.0	0.0
Total	375,843	100.0	16	100.0	100.0

Cases: 3,107,930 total; 671,591 (22%) missing race/ethnicity
Deaths: 58,066 total; 864 (1%) missing race/ethnicity
*Census data does not include 'other race' category

Proportions of Cases and Deaths by Race and Ethnicity Among Ages 18-34

Race/Ethnicity	No. Cases	Percent Cases	No. Deaths	Percent Deaths	Percent CA Population
Latino	540,451	58.6	551	70.9	45.0
White	159,743	17.3	77	9.9	30.2
Asian	57,526	6.2	42	5.4	14.7
African American	36,197	3.9	70	9.0	6.5
Multi-Race	15,254	1.7	9	1.2	2.6
American Indian	3,051	0.3	4	0.5	0.6
Native Hawaiian and other Pacific Islander	4,830	0.5	8	1.0	0.4
Other	105,216	11.4	16	2.1	0.0
Total	922,268	100.0	777	100.0	100.0

Cases: 460,542; 84,699 (18%) unknown race/ethnicity
Deaths: 16 total; 0 (0%) unknown race/ethnicity
*Census data does not include 'other race' category

Proportions of Cases and Deaths by Race and Ethnicity Among Ages 35-49

Race/Ethnicity	No. Cases	Percent Cases	No. Deaths	Percent Deaths	Percent CA Population
Latino	387,594	58.2	2,217	73.2	41.5
White	117,613	17.7	317	10.5	32.5
Asian	45,873	6.9	176	5.8	17.5
African American	25,546	3.8	185	6.1	5.9
Multi-Race	10,952	1.6	41	1.4	1.6
American Indian	2,337	0.4	11	0.4	0.5
Native Hawaiian and other Pacific Islander	4,030	0.6	22	0.8	0.4
Other	72,257	10.8	56	1.9	0.0
Total	666,202	100.0	3,027	100.0	100.0

Cases: 1,194,045 total; 271,777 (23%) unknown race/ethnicity
Deaths: 794 total; 17 (2%) unknown race/ethnicity
*Census data does not include 'other race' category

Proportions of Cases and Deaths by Race and Ethnicity Among Ages 50-64

Race/Ethnicity	No. Cases	Percent Cases	No. Deaths	Percent Deaths	Percent CA Population
Latino	275,805	51.2	7,271	64.6	32.2
White	127,455	23.7	1,936	17.2	43.0
Asian	42,421	7.9	848	7.5	16.3
African American	25,791	4.8	730	6.5	6.4
Multi-Race	9,097	1.7	112	1.0	1.2
American Indian	1,946	0.4	44	0.4	0.5
Native Hawaiian and other Pacific Islander	3,379	0.6	102	0.9	0.4
Other	52,607	9.8	211	1.9	0.0
Total	538,501	100.0	11,254	100.0	100.0

Cases: 851,474 total; 185,272 (22%) unknown race/ethnicity
Deaths: 3,074 total; 47 (2%) unknown race/ethnicity
*Census data does not include 'other race' category

Proportions of Cases and Deaths by Race and Ethnicity Among Ages 65-79

Race/Ethnicity	No. Cases	Percent Cases	No. Deaths	Percent Deaths	Percent CA Population
Latino	90,697	40.4	9,649	49.3	21.8
White	76,008	33.9	5,630	28.7	54.0
Asian	21,138	9.4	2,111	10.8	16.9
African American	12,151	5.4	1,322	6.8	5.5
Multi-Race	3,919	1.7	276	1.4	1.0
American Indian	747	0.3	78	0.4	0.5
Native Hawaiian and other Pacific Islander	1,562	0.7	139	0.7	0.3
Other	18,012	8.0	379	1.9	0.0
Total	224,234	100.0	19,584	100.0	100.0

Cases: 681,723 total; 143,222 (21%) unknown race/ethnicity
Deaths: 11,419 total; 165 (1%) unknown race/ethnicity
*Census data does not include 'other race' category

Proportions of Cases and Deaths by Race and Ethnicity Among Ages 80+

Race/Ethnicity	No. Cases	Percent Cases	No. Deaths	Percent Deaths	Percent CA Population
Latino	24,379	28.6	6,917	30.7	19.6
White	38,615	45.4	9,964	44.2	57.2
Asian	9,513	11.2	3,535	15.7	17.0
African American	4,394	5.2	1,245	5.5	4.8
Multi-Race	1,396	1.6	339	1.5	0.9
American Indian	249	0.3	68	0.3	0.4
Native Hawaiian and other Pacific Islander	373	0.4	73	0.3	0.2
Other	6,215	7.3	419	1.9	0.0
Total	85,134	100.0	22,560	100.0	100.0

Cases: 276,535 total; 52,301 (19%) unknown race/ethnicity
Deaths: 19,851 total; 267 (1%) unknown race/ethnicity
*Census data does not include 'other race' category

Data from the website as of March 31, 2021.