An Investigation Into Effect of US Government-Supplied Protective Personal Equipment on COVID-19 Related Factors By State

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Abstract

This article addresses the effect of Personal Protective Equipment (PPE) score, an aggregate value devised to measure how the federal government of the United States defines the needs of its States and Territories for that equipment. This is calculated by adding the units for each state and standardizing by the resident population. We aim to show some connection between PPE score and COVID-19 related variables over the course of the pandemic until current day through visualization techniques and known research. We also explore race and ethnicity COVID-19 data and discuss the effects of this disease on at-risk minority groups. The major fact we ascertained was that States with highest PPE scores, such as Vermont and Maryland, were actually the least vulnerable for many COVID-19 related factors. Likewise, States with lowest PPE scores were often the most vulnerable against the disease. Our discovery is that the United States mostly did not adequately meet the needs of States to defend and fight against this virus, and suggest that in the future more should be done to quantify and minimize deaths and cases from new, emerging pandemics hereafter.

I. INTRODUCTION

The following paper investigates the question of how the United States' governmental aid of personal protective equipment (PPE) to its States and Territories impacted their COVID-19 associated factors, which include Deaths and Total Cases, Case Month, Race and Ethicity, Sex, Age Group, Hospitalizations and Symptoms. The COVID-19 pandemic became a worldwide phenomenon in March 2020, but was first identified in December 2020, and its effects on every region in the United States were deeply felt on many levels and are reflected in the records published by the Centers for Disease Control and Prevention (CDC) through these COVID-19 associated factors.

On January 21, 2020, the CDC "launched an agency-wide response" to the COVID-19 pandemic and the country panicked. People began rushing into stores and buying up inventory of masks and hand sanitizer, face shields and surgical gowns, and the ever-elusive N-95 mask. This stockpile caused the nation to go haywire, as supplies were limited and the only people prior to the pandemic to use these personal protective equipment were medical professionals, doctors, nurses and technicians. Politicians and local leaders began urging folks to stop hoarding so that healthcare workers could fight the pandemic on the front lines, and, to some degree this worked, but in the spirit of Americans and human nature, a significant proportion of private citizens continued to embody the motto of "every person for themselves". As a result, corporations such as Amazon and Walmart profited with high margins as they advertised "premium supplies" to those who could pay the most, and those desperate enough to protect themselves, their families, and their communities fell into their trap. All over the nation, city and State-level preparations for the pandemic led to bidding wars online and with suppliers, causing world-wide shortages of personal protective equipment, and healthcare workers to scramble to arm themselves against the disease on the front lines. At this time, the Trump Administration was still distancing themselves from the pandemic, with the President and the White House denying that it was anything more dangerous than the flu. Americans were largely on their own, with concerned States being the only ones to take the pandemic seriously.

It wasn't until May of 2020, after the WHO had declared COVID-19 a global pandemic in March, and after California was the first State to institute a stay-at-home order under full lockdown, that the government began to send badly needed PPE supplies to its States and Territories. The Federal Emergency Management

Agency (FEMA), under the orders of the White House Task Force, supplied billions of units of personal protective equipment to the States and Territories, after which point it was up to the States to distribute proportionately to its medical community, agricultural workers, and residents. Our aim is to investigate the impact of these FEMA PPE supplies on the COVID-19 associated factors we discussed earlier, in relevant US States and Territories. We hypothesize that the States with the highest levels of PPE will be better prepared, but there are many influences including demographics, policy, infrastructure, and more that could significantly affect the COVID-19 associated factors that we will use to measure PPE supply effectiveness.

The long-term impact of our analyses of these questions is undeniably crucial to how governments and States respond to future pandemics, and how the citizens of the world will arm themselves against diseases of every kind. Knowing how much personal protective supplies to give can make or break the very fabric of society, as it has unmistakably done in this pandemic, one of the largest pandemics to ever hit the world. Human life of any nationality is precious, and anything that we can do to reduce loss of life is something to strive for and protect. The tools to protect ourselves, personal protective equipment, can and have saved the world, and so we must communicate the results of such studies to the greater scientific community.

II. DESCRIPTIVE ANALYSIS

To perform analysis on our chosen topic of COVID and PPE, we required multiple datasets containing the related information. Our main data was the COVID-19 related data supplied by the CDC, and our secondary data was a PPE (personal protection equipment) dataset from FEMA and the US House Congressional Oversight Committee. We also used two tertiary data sources: race and population demographic estimates in the United States, also sourced from the CDC; and COVID death proportions and population proportions by state.

1. COVID Data

After acquiring the COVID-19 Case Surveillance Public Use Data with Geography supplied by the CDC from January 2020 until May 2021, we restrict and restructure the data for reasonable analysis. First, we perform minor cleaning by dropping certain factors such as county fips code, state fips code, case positive specimen interval, case onset interval, process, exposure indicator, current status, symptom status, icu indicator and

underlying conditions indicator; and formatting numeric variables into numbers. We also remove NA values for States, as well as from Sex, and Ethnicity, in addition to “Unknown” and “Missing”. After cleaning, our variables are limited to the strictly categorical:

- case_month: month and year during which a state reported the case
- res_state: state or territory of the United States
- res_county: county for each state in the united states
- age_group
- sex
- race
- ethnicity: indicator of Hispanic or non-Hispanic
- hosp_yn: indicator of whether the patient in the case was hospitalized
- death_yn: indicator of whether the patient in the case died

2. PPE Data

We obtained the data on Personal Protective Equipment (PPE) Stockpile from the US House Congressional Oversight Committee, which was actually Federal Emergency Management Agency’s (FEMA) data of the number of units of each type of PPE sent to each state and territory of the United States.

Our variables of interest in the PPE dataset (in numerical units) are then:

- Coveralls
- Face Shields
- N95 respirators
- Surgical Masks
- Surgical Gowns
- Ventilators
- Gloves, which we aggregate into PPE score, described in more detail in Exploratory Data Analysis.

III. EXPLORATORY DATA ANALYSIS

As our question of interest regards how COVID-19 cases, PPE, and demographic factors like race are related; we generate various plots and summary statistics of different features to the end of getting a surface level understanding of the data.

1. Summary Tables

TABLE I. Summary statistics of PPE score and case counts

	Mean	Standard Deviation	Minimum	Median	Maximum
PPE Score	15.237	2.154	12.404	14.471	18.283
Cases Count (100,000s)	2.3661	2.8509	0.0036	1.6736	3.6925

This table shows that, the average amount of personal protection equipment (PPE) supplied to each state, **scaled by the population of that state and denoted as PPE score** is 15.237 pieces of equipment per capita. In this data, this amount can be valued at anywhere from a minimum of about 12 to about 18, a somewhat wide range. The differences in the value between the states will be further discussed in later sections.

The table also indicates the summary of every case in the CDC dataset, condensed into the summary of the number of cases for each state. On average, each state has about 236,000 cases with about the same standard deviation. Again, there is a large range of values between the minimum of only about 36 cases in the Virgin Islands territory and the maximum of over 3.6 million in California.

TABLE II. Summary statistics of scaled percent of deaths by race

	Mean	Standard Deviation	Min	Median	Max
White	1.0031	0.1585	0.3514	1.0488	1.1972
Black	1.046	0.289	0.000	1.085	1.769
Asian	0.686	0.329	0.250	0.571	1.833

Hispanic	0.712	0.253	0.250	0.683	1.364
American Indian/Alaska Native	1.916	1.000	1.011	1.650	4.000

This table shows that the average scaled death rates vary widely between the races and, indeed, within, for some races. The means for White and Native American are most noticeable, with that of Native American being between three and four times that of White. Similarly for the maximums, the maximum for Native American is twice as high as that for White. While Asian and Hispanic have lower means than White, they have higher standard deviations; and Black and Asian have a considerably higher maximums of respective approximates 1.8 each compared to 1.2; though still not as high as the nearly two times higher maximum of Native Americans.

2. Preliminary Visualizations

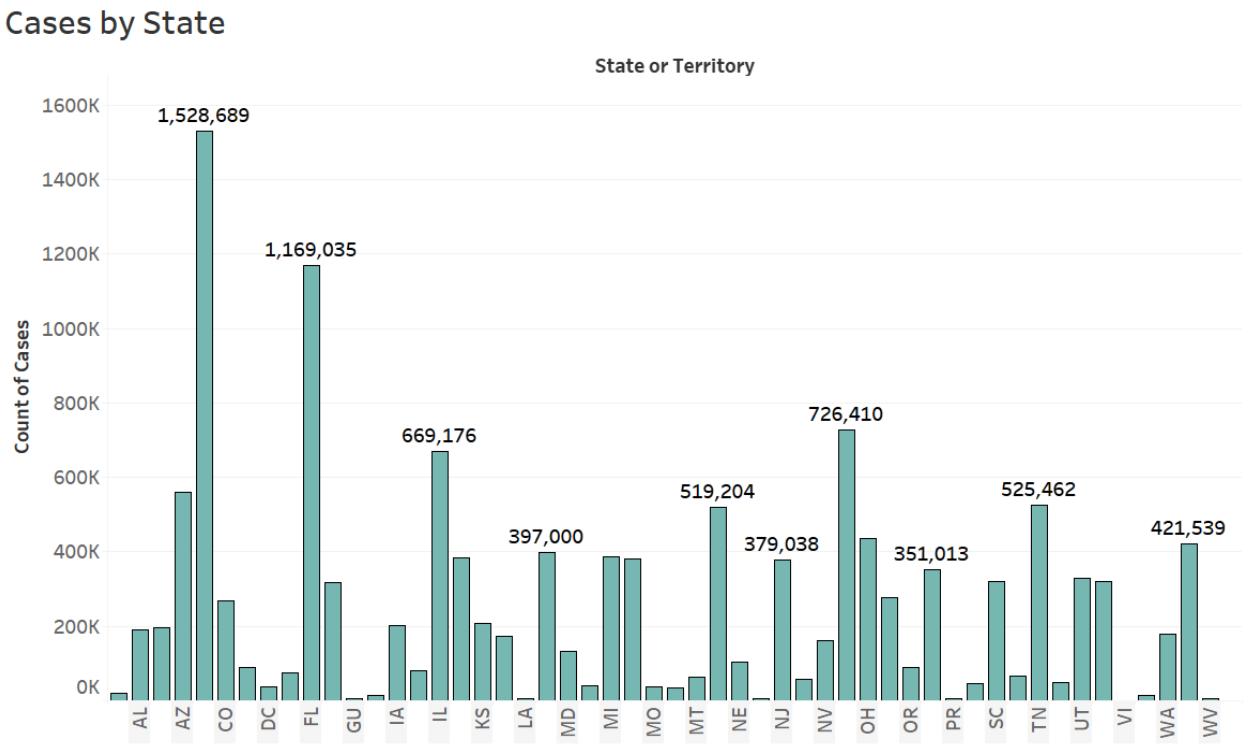

FIG. 1. Number of COVID cases for each state.

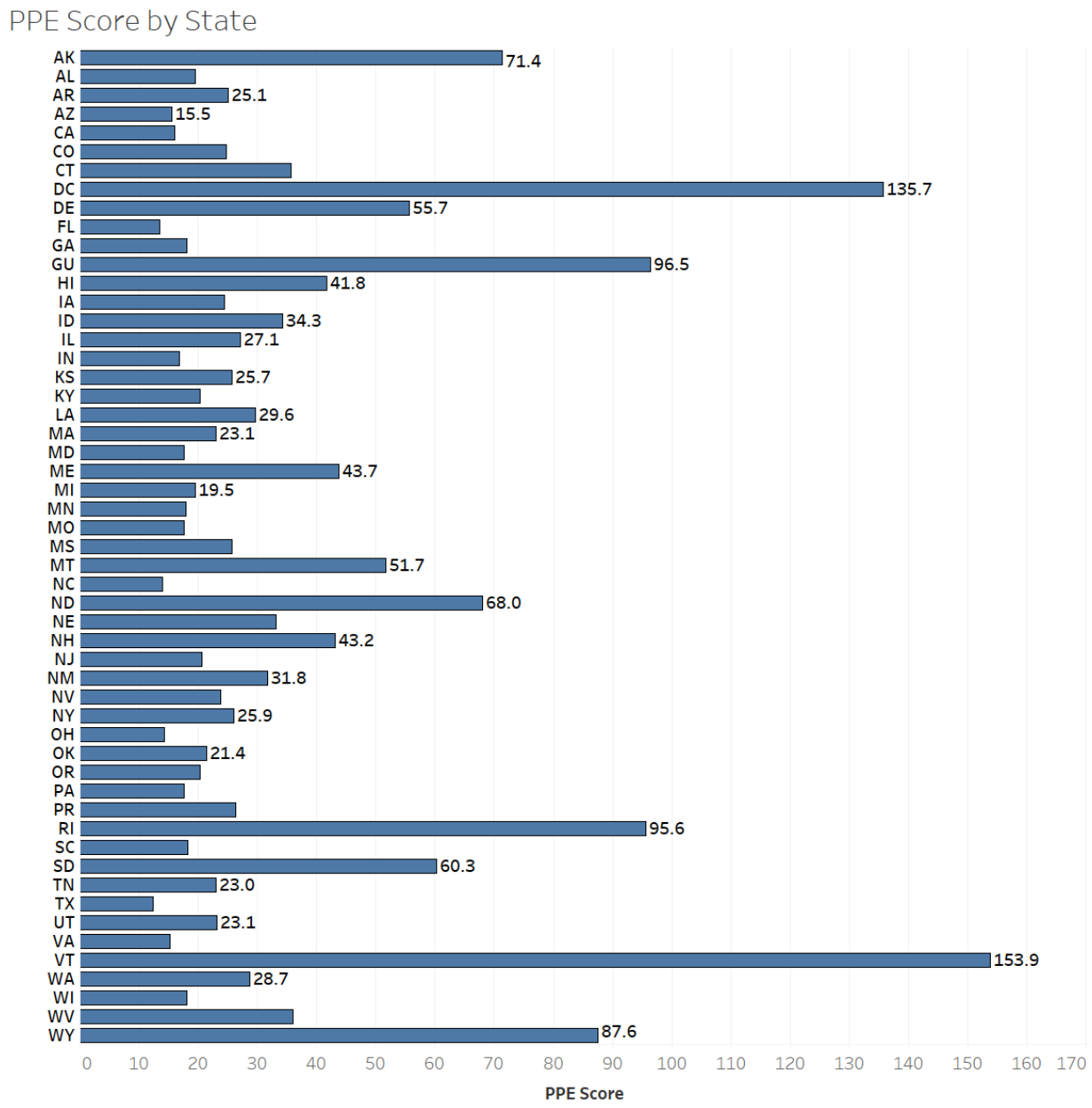

FIG. 2. Normalized PPE score: the total PPE allocation for each state, scaled by its population

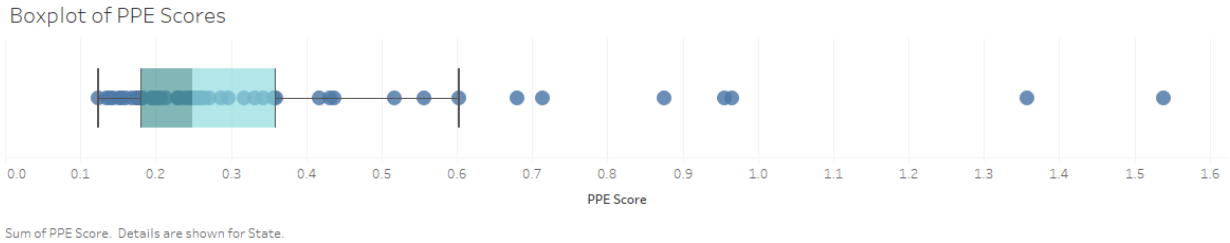

FIG. 3. Boxplot of normalized PPE scores; each dot is the score of state.

These figures reflect the summary statistics of the data: the number of COVID cases and the PPE scores vary tremendously between the states, with a wide gap between the minimum and maximum values. In the following sections, we will consider the connection between the two datasets, as well as other variables.

Having this summary, lets us analyze relevant COVID-19 related and demographic related factors with a quantifier of PPE scores.

IV. DEATH COUNTS AND TOTAL CASES BY STATE WITH PPE SCORE QUANTIFIER

We investigate the States with the highest and lowest death counts, and their corresponding PPE score.

1. Contiguous US

The contiguous United States is geographically connected in the same landmass, and so death counts in the mainland are relatively localized to the United States rather than the Territories that are physically located much farther away, especially the island regions.

A. Death Counts

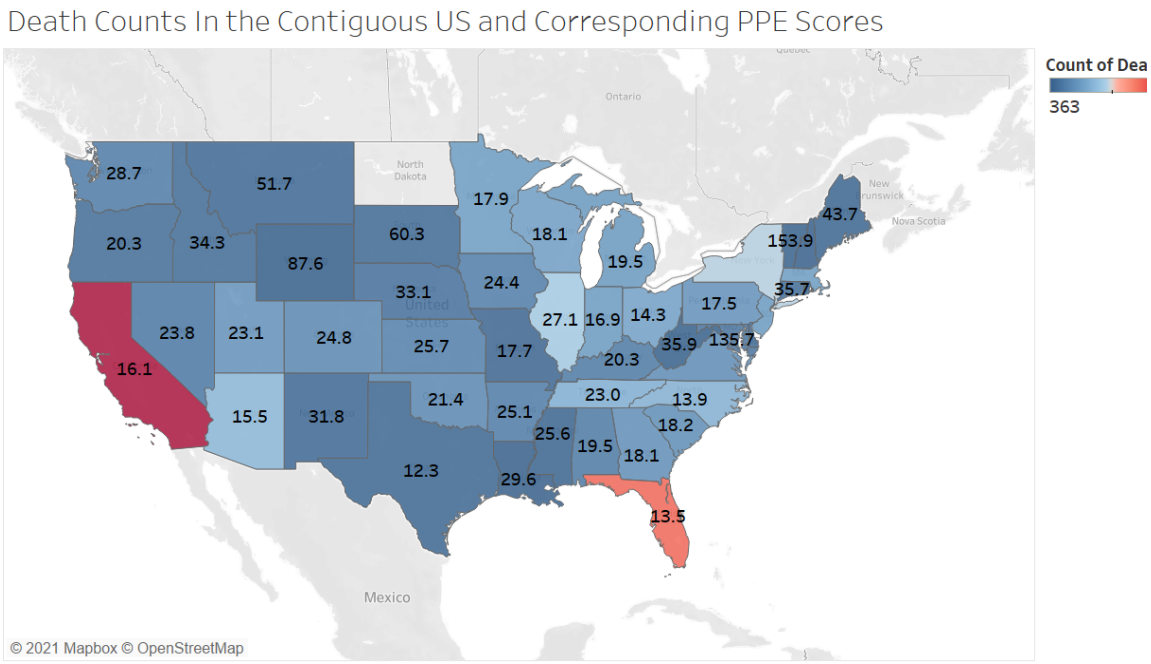

FIG. 4. The map of the United States above is a visual representation of the death counts for each state in the contiguous US, where reddish colors are the highest number of deaths, light blue is a middling number of deaths and dark blue the least deaths. Values on States signify the PPE score.

From FIG. 4 we observe that the states of California and Florida stand out with red and orange colors, which means that the death counts in these two states are the highest in the nation. Notable also is their corresponding PPE scores, which are 16.1 and 13.5 respectively. In fact, out of all the states and territories, Florida has the second lowest PPE score after Texas, which means that any supplies that the government has provided is far too few to protect Floridans from COVID-19. What is interesting is that the number of deaths in Texas are far fewer than either California or Florida despite relatively similar population sizes, while the PPE score is the lowest in the nation. This may be because Texans are underreporting deaths and cases locally to their regional governments in their State, as it is a common belief there that PPE is not useful, and in fact currently there is a ban on mask mandates. Additionally it is likely that the State underreported deaths to the CDC, as the media has reported for an extensive period of time that, during the peak waves, Texas hospitals were overrun with cases and sadly a very large number of deaths (Najmabadi, 2021)[1]. California, in bright red, has the 6th lowest PPE score in the country but the highest number of deaths. California has the largest population in the United States and its Territories, and the most number of people who need masks, including agricultural workers and healthcare professionals. The demand thus is very high and the low PPE score suggests that the supplies given by the government are woefully inadequate, which may in turn cause more deaths of citizens due to lack of protections against COVID-19.

States with the lowest number of total deaths (darkest blue in color) over the course of the pandemic are notably Vermont, Maryland, Texas, New Mexico, Louisiana, Massachusetts, Maine and Wyoming. Their corresponding PPE scores of 153.9, 135.7, 12.3, 31.8, 29.6, 35.7, 43.7 and 87.6 are all on different ends of the scale, which means that there are many factors we cannot account for that can influence deaths, such as private donations of PPE supplies, underreporting of deaths, geographical isolation, relative population size, race, sex and ethnicity demographics, and more.

Vermont and Maryland, with the highest PPE scores, had low numbers of deaths likely due to lower population and thus most supplies per capita provided by the government. The states of Texas and Louisiana are all in the same area of the country and have similar beliefs, so underreporting may be a factor, especially with media coverage in these states reporting high death counts (Briggs, 2021; Najmabadi, 2021)[1]. New Mexico also has a very low population and has the added factor of geographical isolation, as many people who live in the state live far from each other and circulate in small, spread out desert communities. Thus, although their PPE score is relatively low, New Mexicans report less deaths because their interaction levels are limited and they also rigidly followed a stay at home order that reduced these interactions even further. Massachusetts is a generally rich state that had procured supplies in 2020 independent of the federal government, with Governor Baker announcing that "PPE supply orders for Massachusetts are out across the world", and in fact that "the federal government ... had been in a bidding war against Massachusetts for those supplies." (WBZ NewsRadio 1030, 2020)[1]. Thus Massachusetts with a low PPE score from Federal Government supplies just means that Massachusetts' citizens were well supplied with necessary PPE from both the government and their own purchases to fight the virus and thus experienced fewer deaths. In the same way, although Wyoming is a far poorer state than Massachusetts, Wyoming also managed to procure PPE supplies and the "Agency Bid Exception Approval (BEA) Request was submitted to the procurement office and was approved on May 12… with Governor Gordon [directing the Wyoming Office of Homeland Security] to purchase PPE to distribute to non-healthcare related businesses in the state." (Ruiz, 2020)[3,5]. Additionally, Wyoming is a state that has the smallest proportion of total population in the US, at just 0.17% (US Census Bureau, 2020). Therefore their low death rate can be explained by their numerous PPE supplies among other influences.

Thus we see that there is some correlation between low PPE score and high number of deaths, and vice versa, although number of deaths often also depends on other outside factors.

B. Total Cases

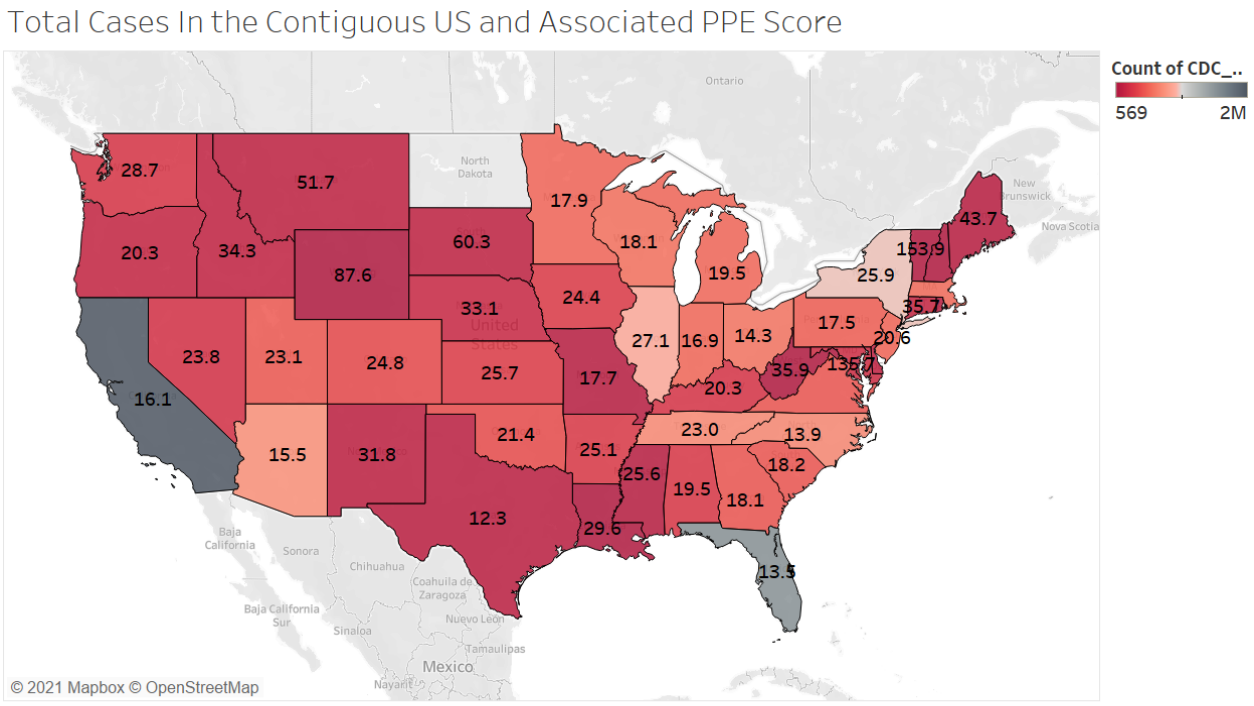

FIG. 5. This map of the United States is a visual representation of the death counts for each state in the contiguous US, where states which have more cases are colored dark grey, states with lighter shades of red or orange have a middling number of cases, and the states with the least number of cases are colored red. Values on States signify the PPE score.

In the mainland US, the total number of cases for each State ranged from 569 cases up to 2,000,000 cases. As in the previous section on death counts in the contiguous United States, we see a similar pattern for total number of cases, with the states of California and Florida leading the pack in most total cases and Vermont, Maryland, Texas, New Mexico, Louisiana, Massachusetts, Maine and Wyoming once again appearing to have fewer cases for reasons mentioned previously. This similar pattern makes sense, since the total number of deaths in each state is proportional to the total number of cases, as total number of cases includes deaths. Again we can say that the PPE scores, which have been standardized for each State's resident population, have some correlation with the total number of deaths, among other factors.

2. Non-Contiguous US

    A. Death Counts

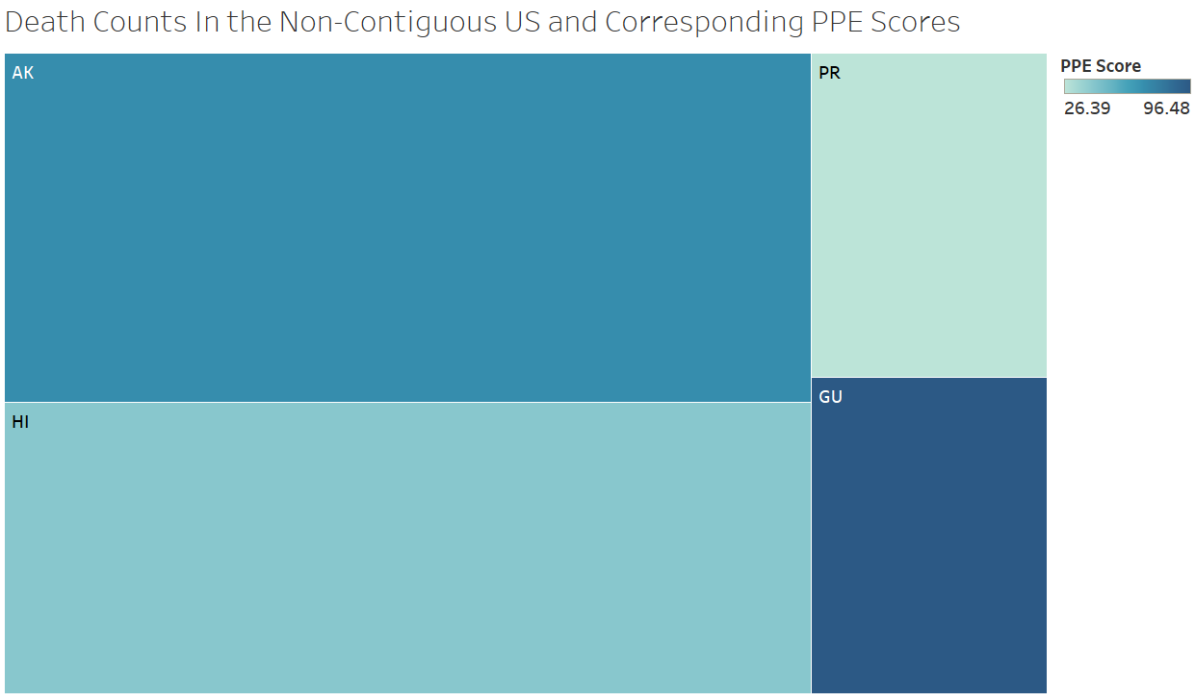

FIG. 6. The treemap above is a sectioned rectangle visualization that takes into account size and color for the total number of deaths. The size factor for how large the rectangles are is defined by the number of total deaths for each state. The color for each rectangle is defined by the PPE Score range, from 26.39 to 98.48.

We analyze the noncontiguous states and territories separately from the mainland states because of their geographical location, different population size and epidemiological dynamics. These states and territories are Alaska, Hawaii, Guam and Puerto Rico. From the size of the rectangle we see that Alaska has the most number of deaths of these noncontiguous regions, then Hawaii, Puerto Rico and lastly Guam. Hawaii is considered to be the richest of these countries, due to its large population, diversity and tourism, and thus was able to procure many PPE supplies from other countries than the US, but deaths were still at a high level, likely due not only to local deaths, but those who traveled to Hawaii and brought COVID-19 with them. Three of the states and territories are islands and thus rely on tourism and shipping from other parts of the world for daily life functions, and so it was inevitable that deaths and cases in all four regions would be higher. Guam is an interesting case because it is located incredibly far from the mainland US, 7,180 miles, and yet it has one of the highest PPE scores of any state. We do not know the motivation of FEMA providing that much PPE to the small semi-isolated island nation

of Guam rather than Puerto Rico, which arguably has a much larger and poorer population, and so the response in this case may not have reflected the relative need.

The non-contiguous case for total cases is much like the non-contiguous case for number of deaths.

3. States With Highest Death Counts

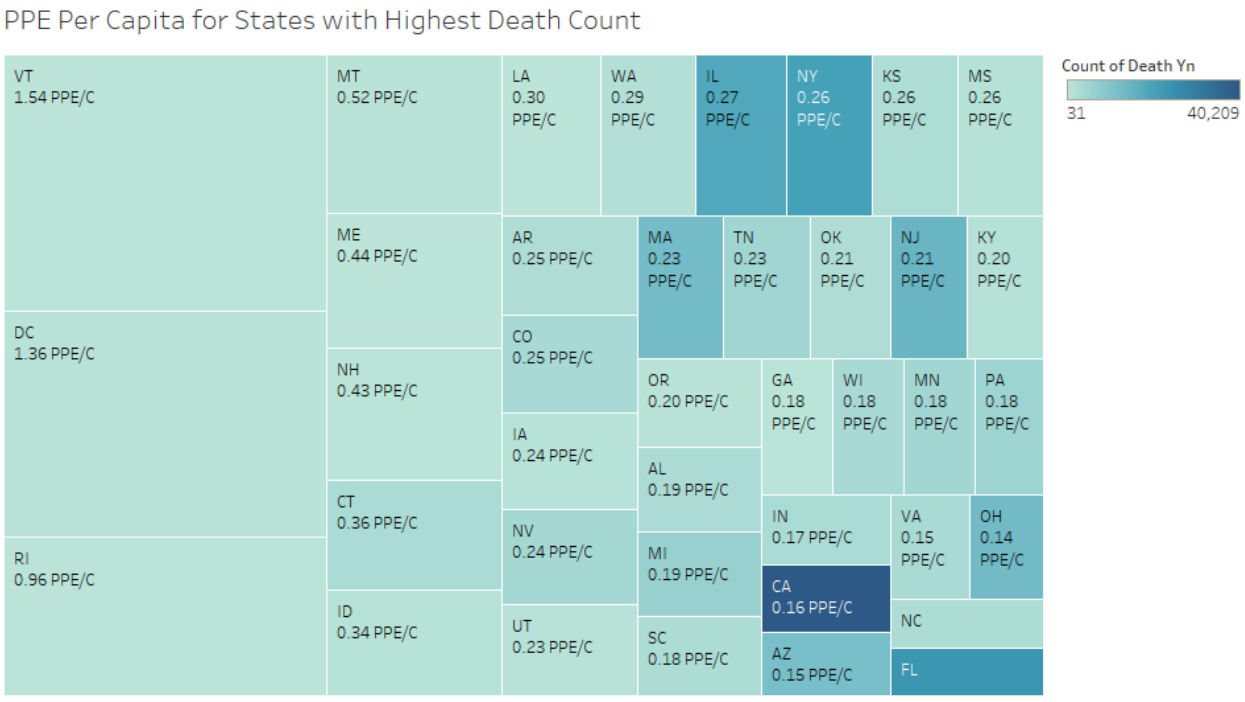

FIG. 7. This treemap is a sectioned rectangle visualization that takes into account size and color for the states with the highest death counts. The size factor for how large the rectangles are is defined by the PPE score for each state. The color for each rectangle is defined by the number of total deaths, from 31 to 40,209.

In FIG. 7, it is immediately visible that the left half when sectioned vertically is a mostly light colored area and consists of states with high numbers of PPE units/capita, while the other half of the rectangle has darker sections and the diversity in color is much higher, and consists of states with lower numbers of PPE units/capita. The States with the darkest blue color are California, Florida, Illinois, New York, Massachusetts, New Jersey, and Ohio. These were all placed on the right side of the rectangle, which indicates that there is a visible immediate association between the lower PPE score and high death counts in States.

V. CASE MONTH BY STATE

1. Death Counts and Case Month

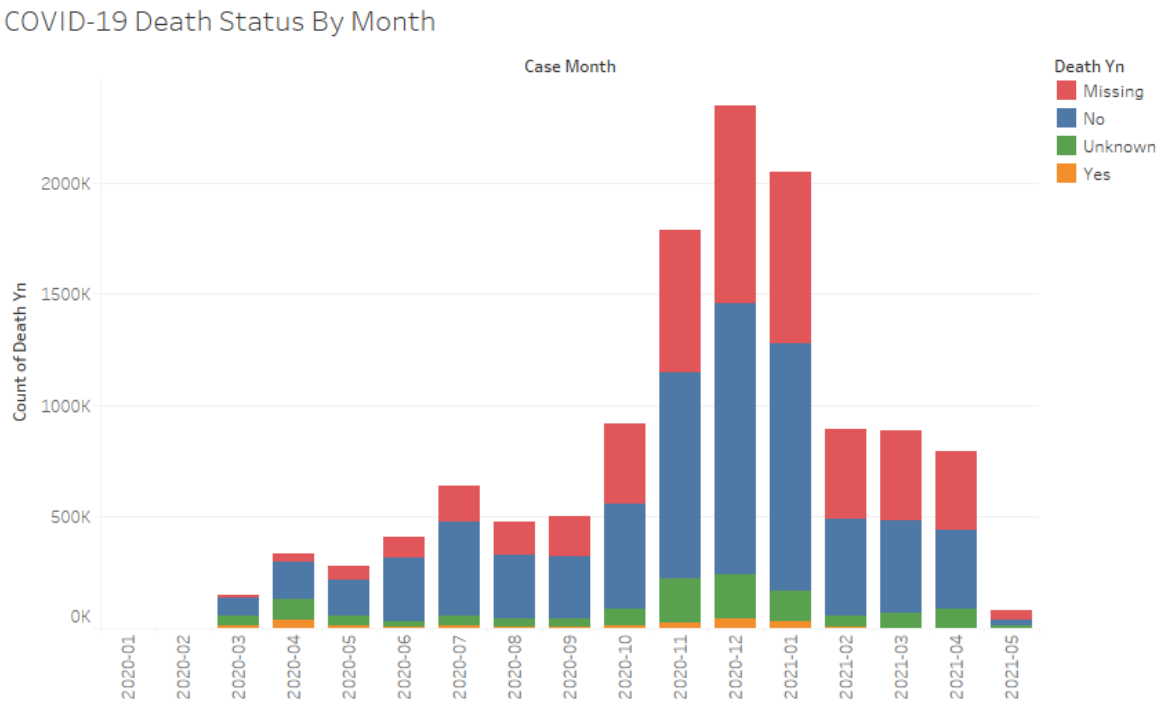

FIG. 8. The stacked bar chart above is a visual representation of the death information by case month overall in the US and reported to the CDC. Each color in a vertical bar represents a different type of death information. The vertical axis consists of the number of cases in which death information was reported by States. The horizontal axis consists of the case months in which cases are reported to the CDC during the COVID-19 pandemic.

In FIG. 8, we investigate four different types of death information: Missing, No, Unknown, and Yes. The red color corresponds to the type “Missing”, which increases in cases dramatically from January 2020 to December 2020, dropping down in level by May 2021. The Missing death information is a gray area because many states try to underreport the number of deaths for various reasons, for example improving the local economy through tourism and spending in shopping malls and restaurants. If people think that it is safe and the threat of

death is low then they will be more likely to engage in normal pre-pandemic activity in the short run. As the pandemic gets worse, another reason why there are so many Missing values could be that the States lost track of paperwork or hospitals' recording systems were faulty; this is plausible because the amount of the deaths in the US was so great that many records could definitely slip through the cracks.

The second largest death information type is "No", colored blue, which indicates that the person in each case has not died of COVID-19 as of yet. The reason why "as of yet" is because since the CDC data is provisional, it can be updated retroactively to correct any errors that were inputted before. As the year passed, the number of people who survived COVID-19 also increased and decreased in the same pattern as for type "Missing".

Now, the "Unknown" death information type, colored in green, is interesting because Unknown cases could happen for a number of reasons. In general, an unknown case means that the States themselves do not know if the patient is alive or has passed. This could mean that the hospital which reported the result had a different system to that of the CDC/State, such as if the hospital is uncertain whether a patient may live or die and thus has a different measure for that. Or it is possible that the situation is similar to the "Missing" type where the hospital lost the record or misreported it so that when the State received the case data it merely slotted the cases which were not there as unknown, and when these records were sent to the CDC they had two categories instead of one for this kind of issue. Finally, an Unknown death could be a death that occurred but was purposely misreported so that the death count for a certain state would be lower than it is in actuality.

The actual number of deaths "Yes" is signified by the color yellow in the stacked bar chart. At the beginning of the pandemic, in March 2020, there were only around ten thousand deaths, but by the next month there was probably almost a ten thousand death increase, just in the first two months after WHO declared COVID-19 a global pandemic. From May until September of 2020, most states began to institute stay-at-home orders, which reduced the death count to a few thousand per month, which was a good trend. However, once important dates started, such as Labor Day, Election Day, Thanksgiving and Christmas, deaths skyrocketed once again. People became tired of staying in and politicians were tired of repeating the same warning messages. As a result, the number of deaths grew very large from November to December, numbering in the tens of thousands per

month, and then after New Years 2021 began to decrease in number. In January 2021 people started getting the vaccine around the world and by the following months until May 2021, deaths from COVID-19 per month grew significantly smaller.

Also for this category we should note that these are just the least amount of deaths that definitively occurred. Many more deaths were uncounted due to miscategorization as “Unknown” or “Missing”, as well as just not reported at all.

2. With PPE Score Quantifier

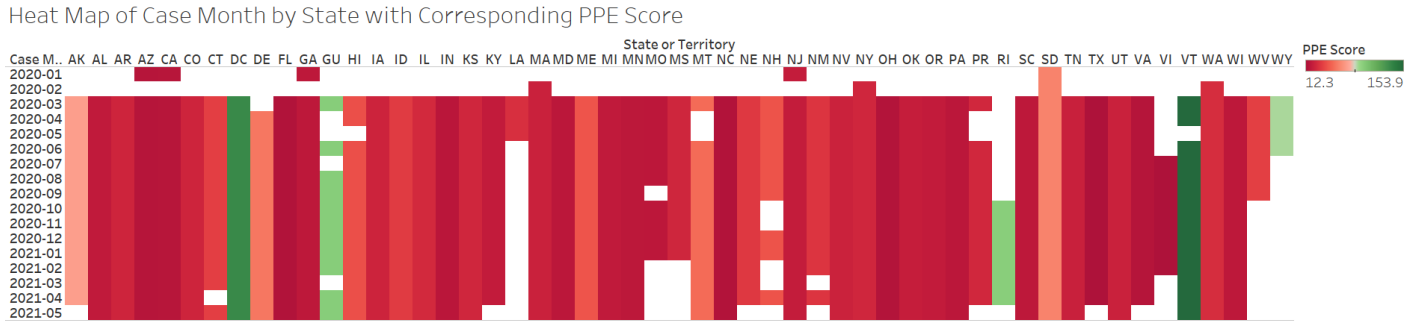

FIG. 9. This heatmap is a data visualization technique that uses color to highlight patterns between date and location. The vertical axis consists of the case months in which cases are reported to the CDC during the COVID-19 pandemic. The horizontal axis includes all 50 States and the four US Territories. The color for each rectangle is defined by the PPE score that ranges from 12.3 to 153.9, with darker green indicating a higher PPE score, light or pale red a middling score, and darker red a low PPE score. Only five out of the fifty four states and territories are green, which means few states received a high amount of PPE relative to their population.

In FIG. 9, the first thing that we notice is that for many states, the reporting of cases to the CDC is not regular. This underreporting is concerning, because any usage of these states’ case information to make predictions or estimate response, as the US government did in order to estimate how much PPE to give each state, would not be accurate. That would mean that any response to the pandemic would underserve the community and would not match their needs. The PPE equipment is crucial to hospitals, medical professionals, front-line workers,

and private citizens to protect themselves, their families, businesses and communities, and underreporting cases can severely impact them in a negative way.

The states/territories which reported the number of cases least frequently were Louisiana, Missouri, Mississippi, New Hampshire, Puerto Rico, Rhode Island, Virgin Islands, West Virginia and Wyoming. That means almost 17% of the states have underreported their COVID-19 data at various times, which has the potential to enormously impact the lives of people who live in those states. The government or other aid organizations would not have enough information to accurately predict not only how many PPE supplies needed to each state, but also how much money needed to fund hospitals treating COVID-19 patients, advisements for public health and safety policy, money to families who have at least one member suffering from COVID-19, and more. These underreporting states mostly have similar ideological beliefs about COVID-19, its origin, protection against it, and impact on people's lives. Many who live in these states, and elected their like-minded officials, have continued to live life as usual, just like they lived before the pandemic, which leads to a greater number of cases in their states and deaths as well.

We also observe that most states started reporting to the CDC starting March 2020, which is consistent with the World Health Organization's announcement that COVID-19 is a global pandemic.

VI. RACE AND ETHNICITY BY STATE WITH DEATH RATE

In analyzing the relationship between the racial makeup of a state and the PPE distributed to it, it is helpful to see the percentage of COVID deaths attributed to each race. As the dataset that contains this information does not include values for the territories, we consider the contiguous and non continuous states together.

1. Overview of the Races

The White population is by far the most common race in the United States at 76.3%, and in most states as well. As expected, this percentage is reflected in the distribution of cases among the races. The plots (FIG 10, FIG 11) of cases by race shows that White people are the most numerous in absolute numbers of cases without

normalization, both in total and in every state. Next in the cases ranking, at less than a quarter of the percentage of the first, is Black; followed by Multiple races, Asian, then American Indian/Alaska Native and Native Hawaiian/Other Pacific Islander. The same information plotted by state indicates a largely similar distribution, with some variation in order for the latter races.

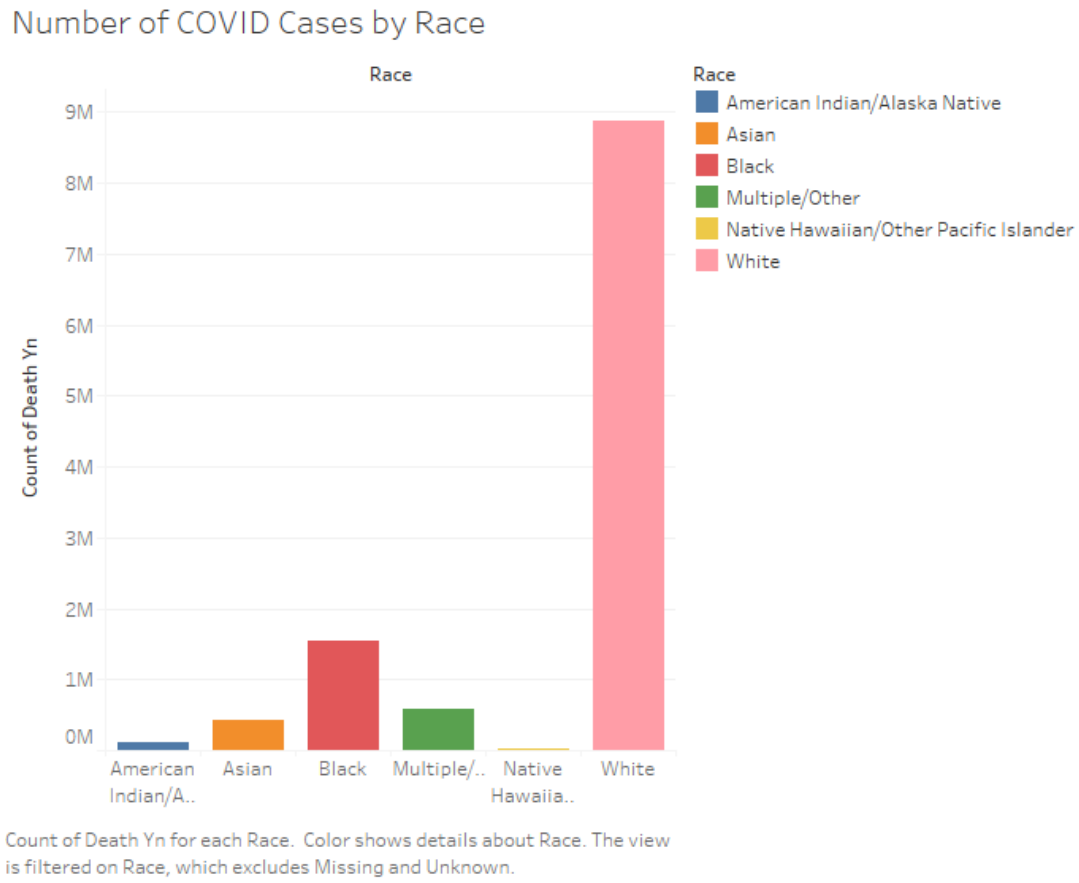

FIG. 10. Number of cases by race. White, in pink, is notably the largest.

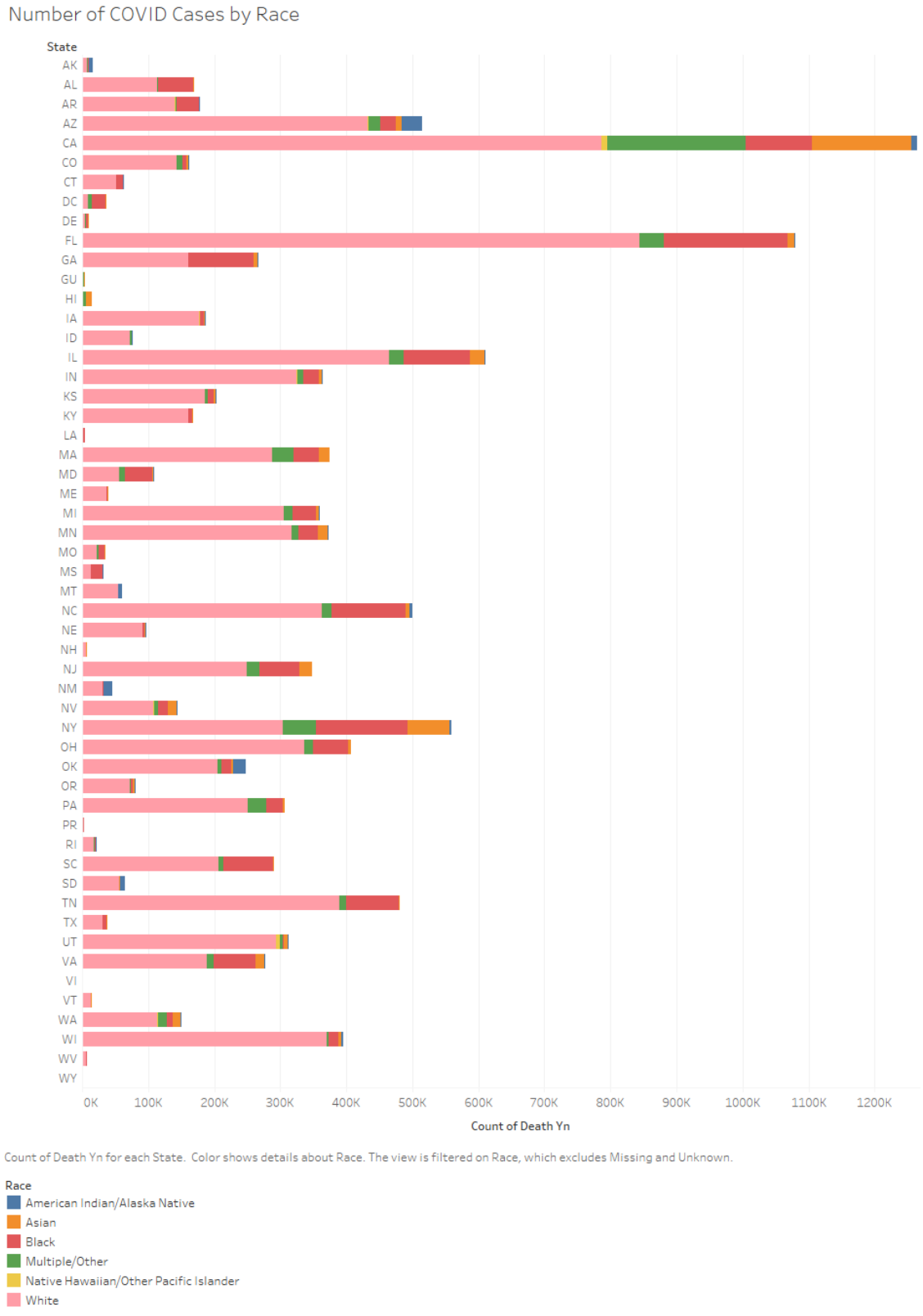

FIGURE 11. Number of cases by state by race. Again, White is the largest in every bar.

2. Cases before scaling

Having considered the proportion of cases for each race, we now focus on the proportion of deaths. We have established that the most common source of cases is from the White race, and we note that the apparently least common source of cases is Native Hawaiian and other Pacific Islander. However, since for the dataset containing case percentages, we unfortunately do not have Native Hawaiian or other Pacific Islander as a unique category, we will use American Indian/Alaska Native, referred to as Native American, as a representative for a race with a very low absolute number of cases.

We map the percentage of total deaths for White and Native American with red being a high percentage, near 100%, and blue being low, near 0% and indicating a negligible percentage. From the maps, Whites seem to have been much more significantly impacted than Native Americans. Despite this, we must recall that we are only considering the absolute percentages of deaths for each race, not adjusted for the vast differences in how much of the total population they account for. To be able to reasonably compare these values and maps, we must account for this population ratio difference.

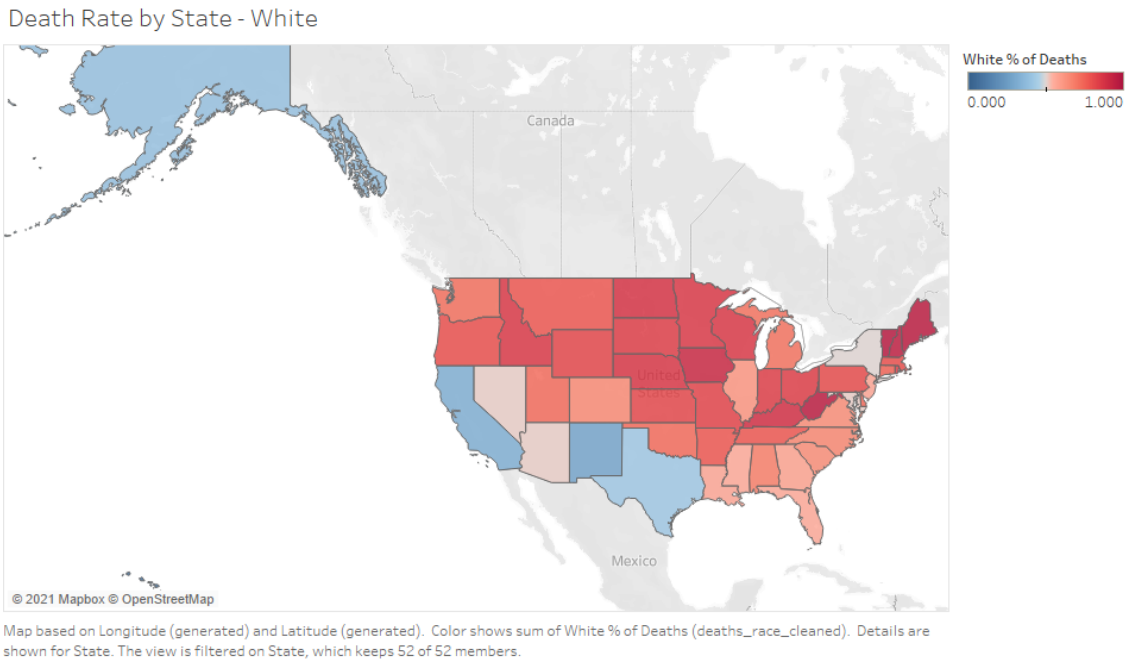

FIG. 12. Percent of total COVID deaths recorded as White, unscaled. Red is near 100% and blue is near 0%.

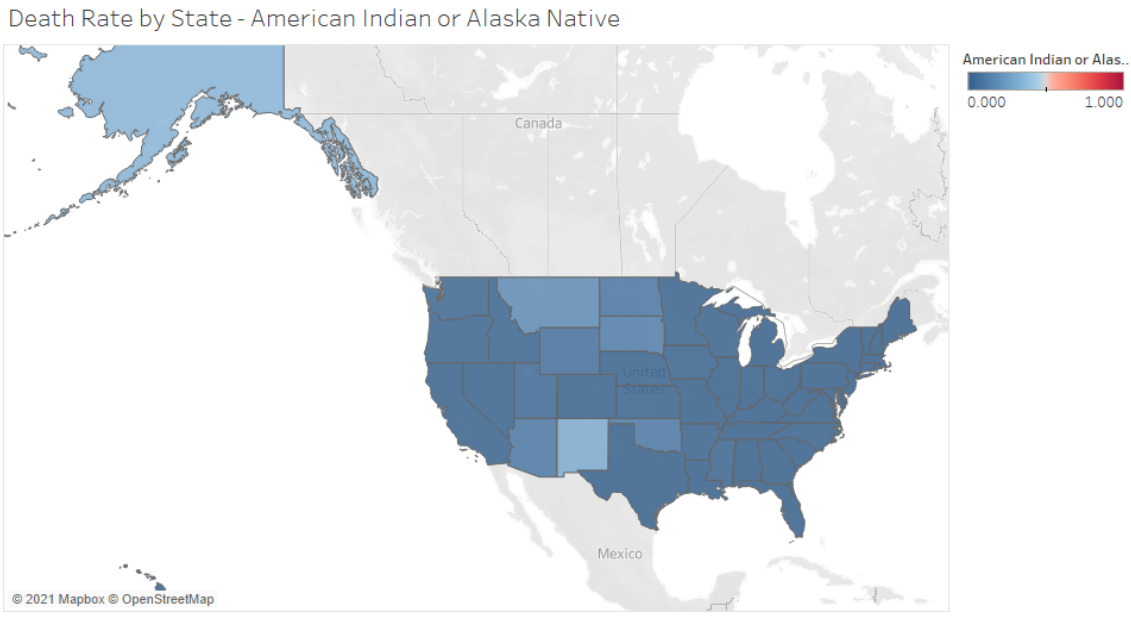

FIG. 13. Percent of total COVID deaths recorded as Native American, unscaled. Red is near 100% and the darkest blue is near 0% and indicates that the percentage is negligible.

3. After Scaling: Overview

The previous plots seem to indicate, at first glance, that Whites are impacted by the virus at an extremely disproportionate rate to the other races. However, as aforementioned, they also make up nearly three quarters of the population. To adjust for this discrepancy such that we can accurately compare how the different races were affected, we normalize the percentages of total cases accounted for by each race by dividing them by the percentages of the total US population that each respective race occupies.

This scaling simplifies as follows: for a given race **R**, we compute

(% of total deaths of **R**) / (**R** % of total population)

= [(**R** deaths) / (total deaths)] / [(**R** population) / (total population)]

= [(**R** deaths) / (**R** population)] × [(total population)] / [(total death)]

= constant × (**R** deaths) / (**R** population)

$\propto$ proportion of affected **R** population

A scaled death rate of 1 indicates that the death proportion and population proportion of a given race in some state means that the death rate is approximately representative of the percentage of the population. A high number indicates disproportionately high death rates, and a lower number similarly indicates disproportionately low rates.

All of the next four plots are on the same scale of 0 to 1.9. We note that those states filled with the darkest blue for any race indicate that the original population ratio of that race was very small, resulting in a near zero scaled death rate.

Comparing the White population to the minority populations, we now see that, while many-- and, in fact, a different set-- of the states are red, they are much lighter, most at the pale red color representing 1, so the White population is affected at most at about a proportionate rate to their representation in the states' population. Not in a single state do we see that Whites die at a disproportionately high rate.

The map for Black deaths does not show the same. While there are a greater number of blue, or less than proportionately affected, states, multiple states, including California, Colorado, New York, New Jersey, Connecticut, and Virginia are marked with darker red. Most notably, Michigan has a very dark, disproportionately high rate of death for Black people.

Although the map for the Asian death rates, scaled, is largely blue, we must consider, as with the Black population, that many states have a very low relative and absolute minority population. With this in mind, we note Nevada and Utah as having a high relative rate of death for Asians. For this race, we include Alaska as of note, since, like Michigan for Black deaths, it has a very high, almost maximum death rate on the scale.

For the Hispanic ethnicity, the numbers are closer to those for the White map, but still show higher rates in states like California and Texas.

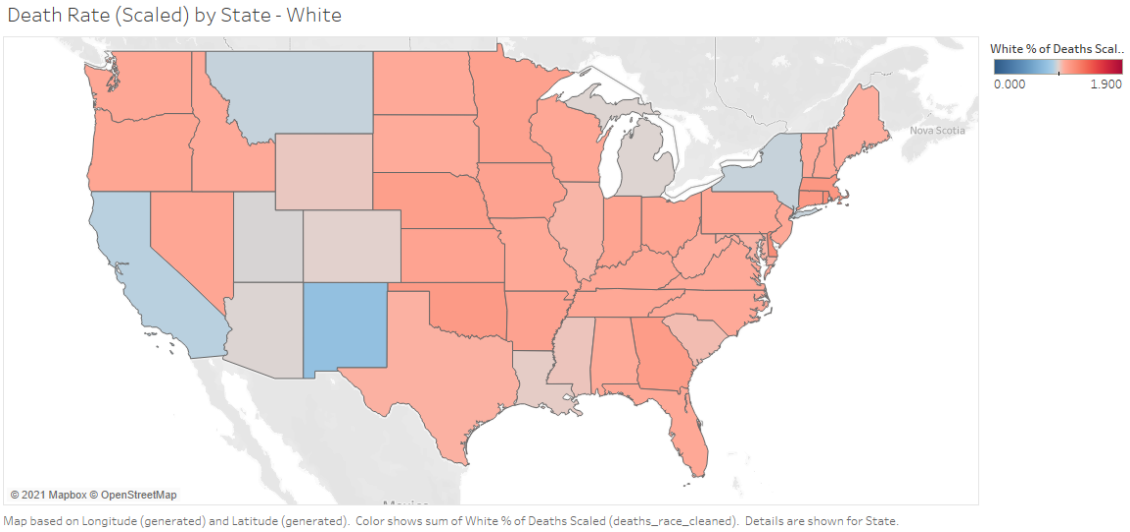

FIG. 14. Percent of total COVID deaths in the contiguous US recorded as White, scaled by percent of total population that is White. Red (1.9) indicates a higher percentage of deaths compared to population representation.

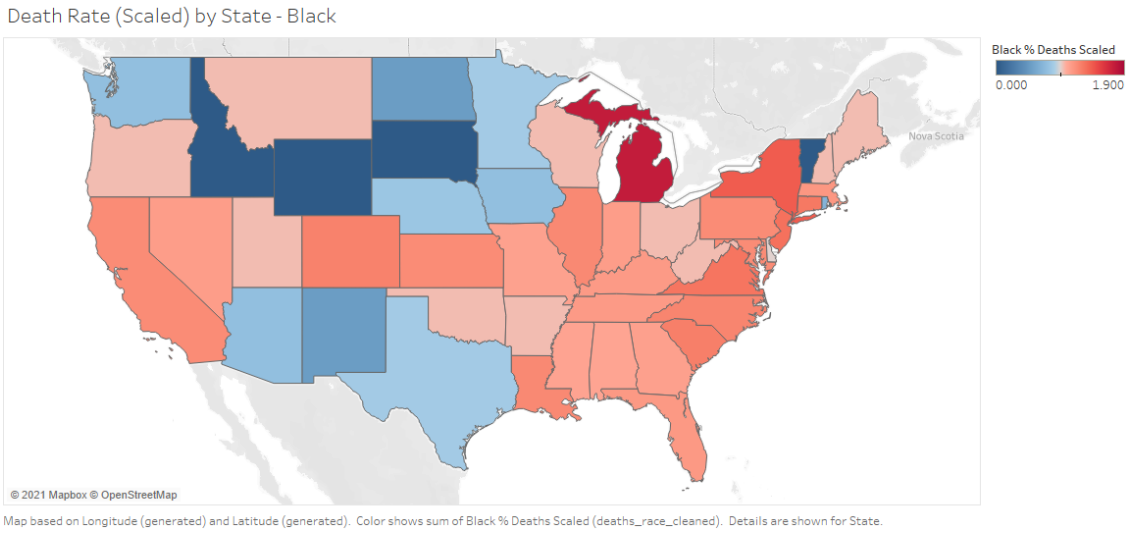

FIG. 15. Percent of total COVID deaths in the contiguous US recorded as Black, scaled by percent of total population that is Black.

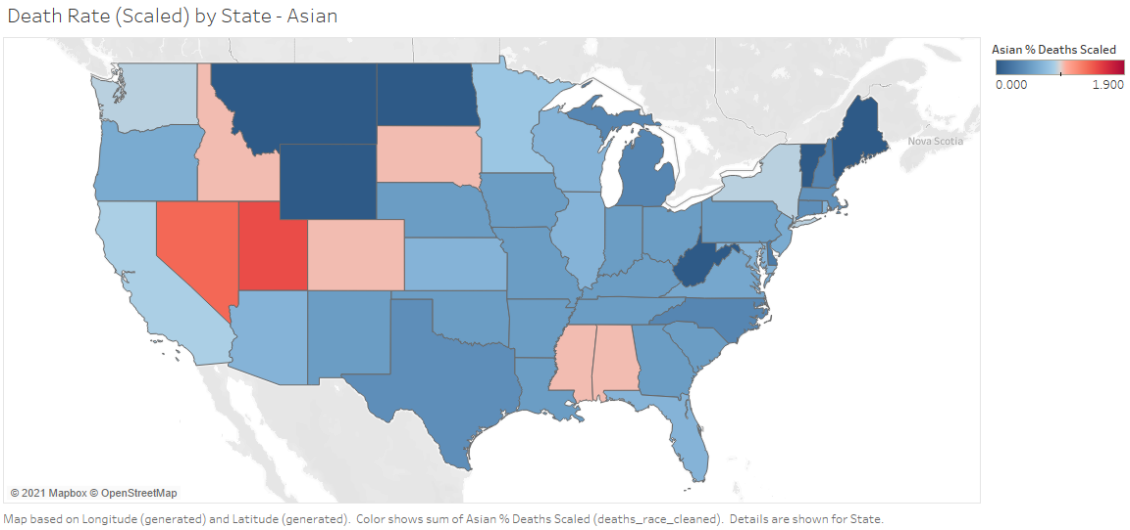

FIG. 16. Percent of total COVID deaths in the contiguous US recorded as Asian, scaled by percent of total population that is Asian.

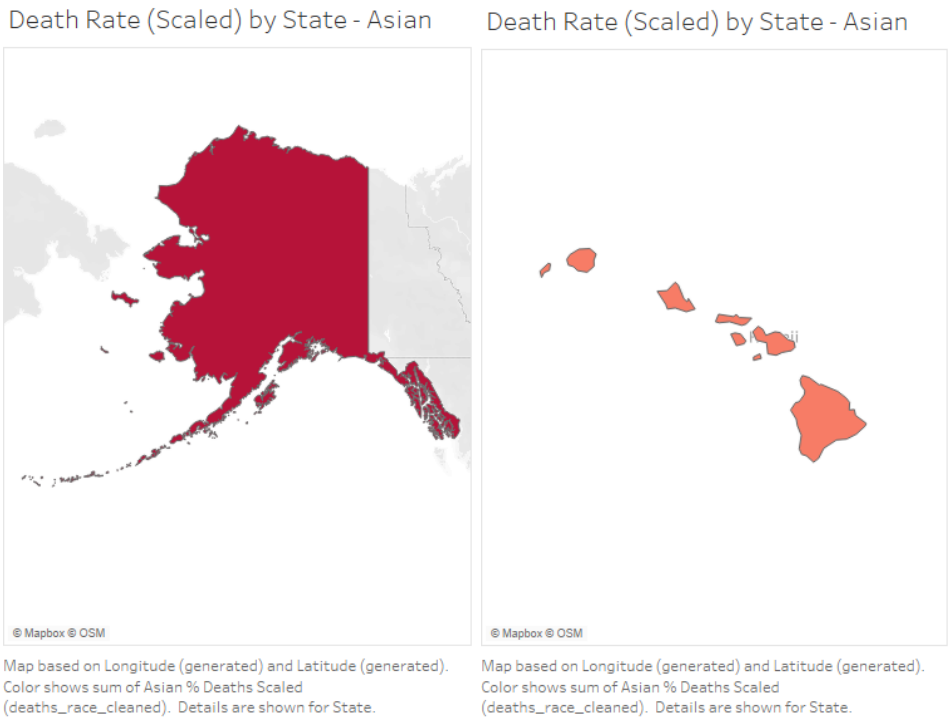

FIG. 17. Percent of total COVID deaths in the non contiguous the US recorded as Asian, scaled by percent of total population that is Asian.

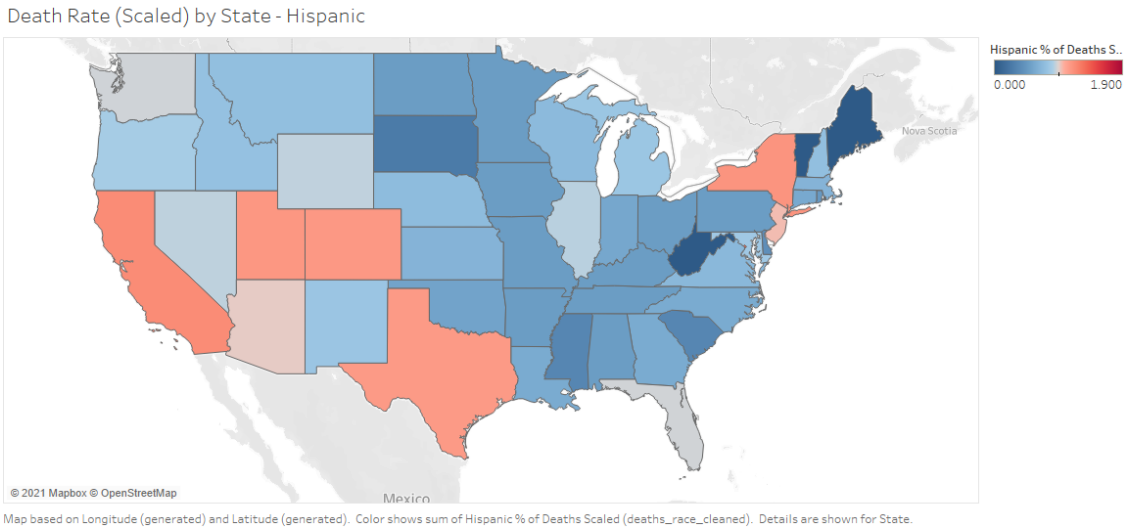

FIG. 18. Percent of total COVID deaths recorded as Hispanic, scaled by percent of total population that is Black.

4. After Scaling: the Extreme Case

Even after the issues of unequal death rates that are apparent in the scaled plots for white versus non-white races, the differences from the unscaled plots for White versus Native American are still more stark. The values range from slightly above zero at blue, which would indicate that the percent of total COVID deaths for the race was zero, to 4 (double the previous maximum of 1.9), which indicates that the race is disproportionately highly affected by COVID compared to their representation in the population. We see that the maximum for the Native American scaled death rate is over twice as high as the maximum of 1.9 for any other race, including White. This was not at all apparent in the unscaled versions of these plots; in fact, it seemed that the exact opposite was true.

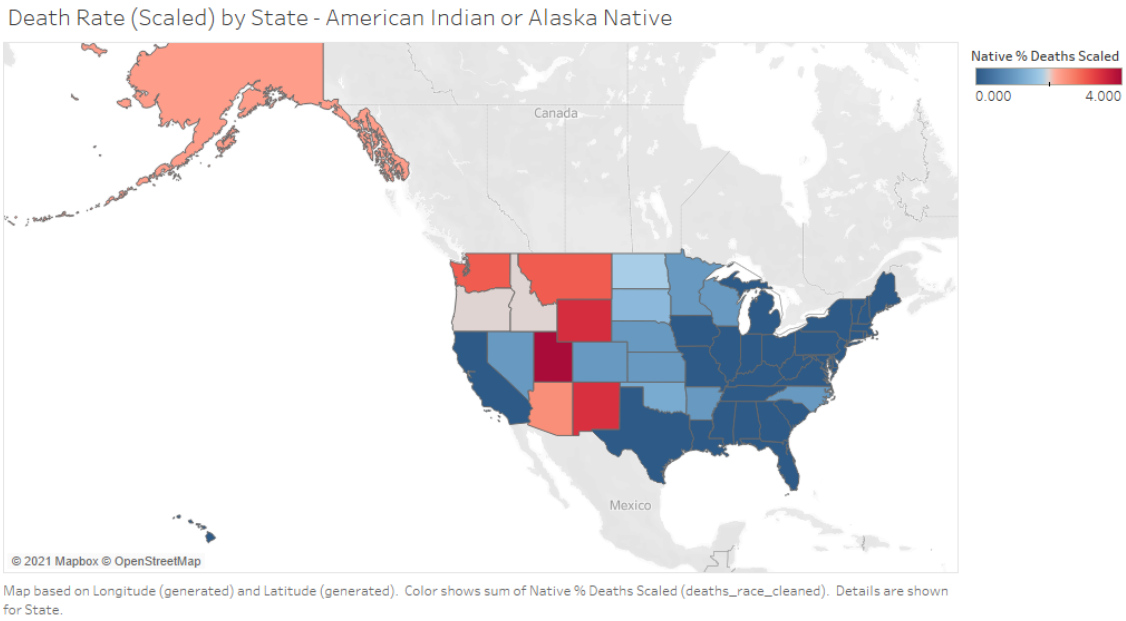

FIG. 19. Percent of total COVID deaths recorded as American Indian/Alaska Native, scaled by percent of total population that is American Indian/Alaska Native. The maximum (red, 4) is more than twice as high as the maximum of any other race. The darkest blue indicates negligible Native population and no scaled value.

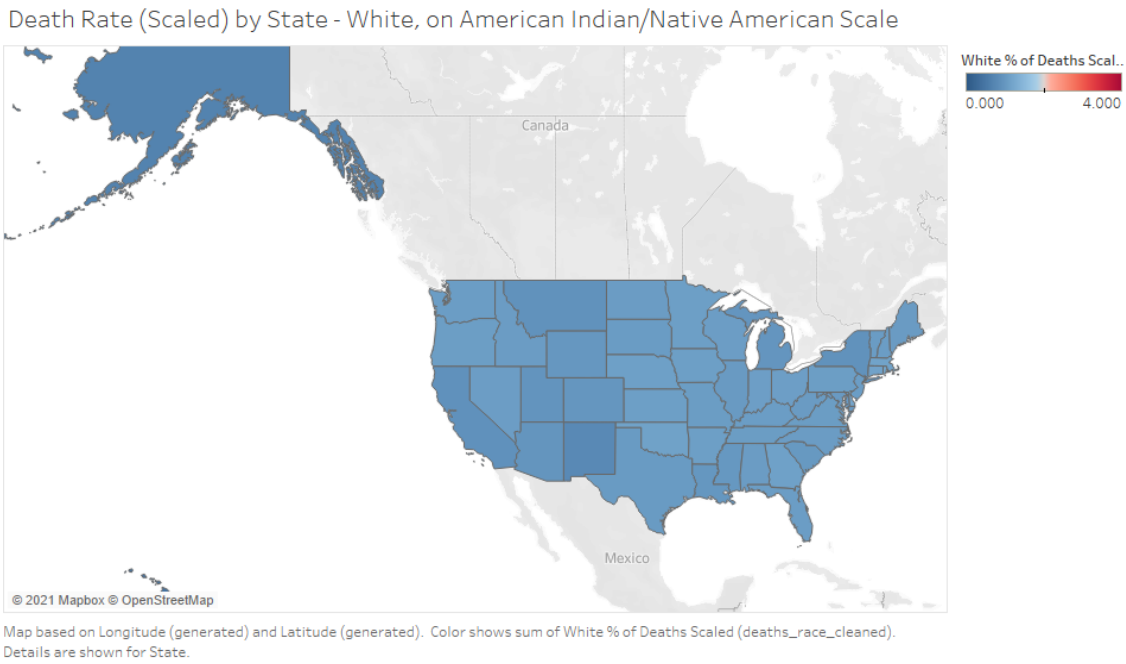

FIG. 20. Percent of total COVID deaths recorded as White, scaled by percent of total population that is White. The maximum (red, 4) is defined by the values from the American Indian/Alaska Native distribution.

Before scaling, the Whites map was more than half red due to a high proportion of the total population, and consequently total COVID cases and deaths being White. The American Indian/Alaska Native map was largely blue, both due to very low proportions of deaths for those races, and the fact that they made up a low absolute proportion of the population.

After scaling, while some states like the Southern and some Eastern ones in dark blue show no value for the scaled death rate of American Indian/Alaska Natives, other states like Washington, Montana, North Dakota, Utah, and New Mexico are notably red due to a disproportionate number of American Indian/Alaska Native cases compared to the proportion of the population that they represent in those states. States like Alaska, Oregon, Idaho, and Arizona also show disproportionate deaths.

We recall FIG. 2, containing the normalized PPE scores associated with each state. Despite this normalization, we still found that not all states had similar PPE scores; in fact, they varied greatly. In that case, we might expect that the states with higher or even average PPE scores would have healthier citizens in terms of COVID, with a more even spread of the negative impact of the virus.

Our states of notably high minority death rates were Michigan, Nevada, Utah, Alaska, Wyoming, New Mexico. Recalling from our exploratory analysis that the mean PPE score is between 0.2 and 0.3, it is clear that all of the selected states but Michigan and Utah have at least average PPE scores, with those like Alaska, Wyoming, Hawaii, and Montana have relatively high PPE scores: Alaska and Wyoming are above the third quartile in score.

However, Alaska and Wyoming were remarkably two of the three worst states for Native American, and Alaska was the worst state for Asians. As such, it is notable that states with such high PPE per capita; i.e. hospital equipment to aid in fighting the virus, would have their minority populations die at such a drastically disproportionate rate, especially considering that states like Utah and Wyoming, to name a few, did not have the same disproportionate rates for White as they did for non-White races and ethnicities.

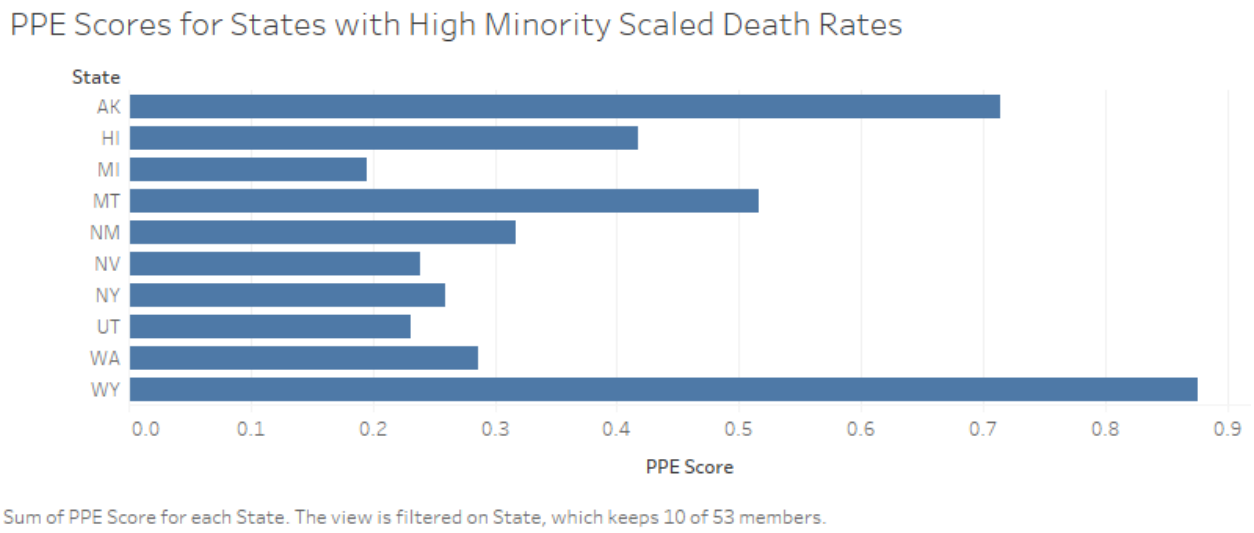

FIG. 21. PPE scores for those states with high minority death rates after scaling.

VII. CASES FOR AGE GROUP BY STATE

One notable quality of the novel Coronavirus is that it is known to particularly affect the elderly population. But when we consider the cases by age in FIG 22, it is clear that, in most states, the majority of the cases are not in the elderly population, but in the young adult and adult 18-49 range rather than the elderly 65 plus range. It is of note that 18-49 range is also much wider than the elderly range, which likely skews the visual.

When we examine the COVID-19 death, rather than cases, we see a vastly different story. Very few of the 18-49 year olds who made up so many of the cases significantly impact this plot; rather, it is largely the 65 and older population that makes up the death count (FIG 23).

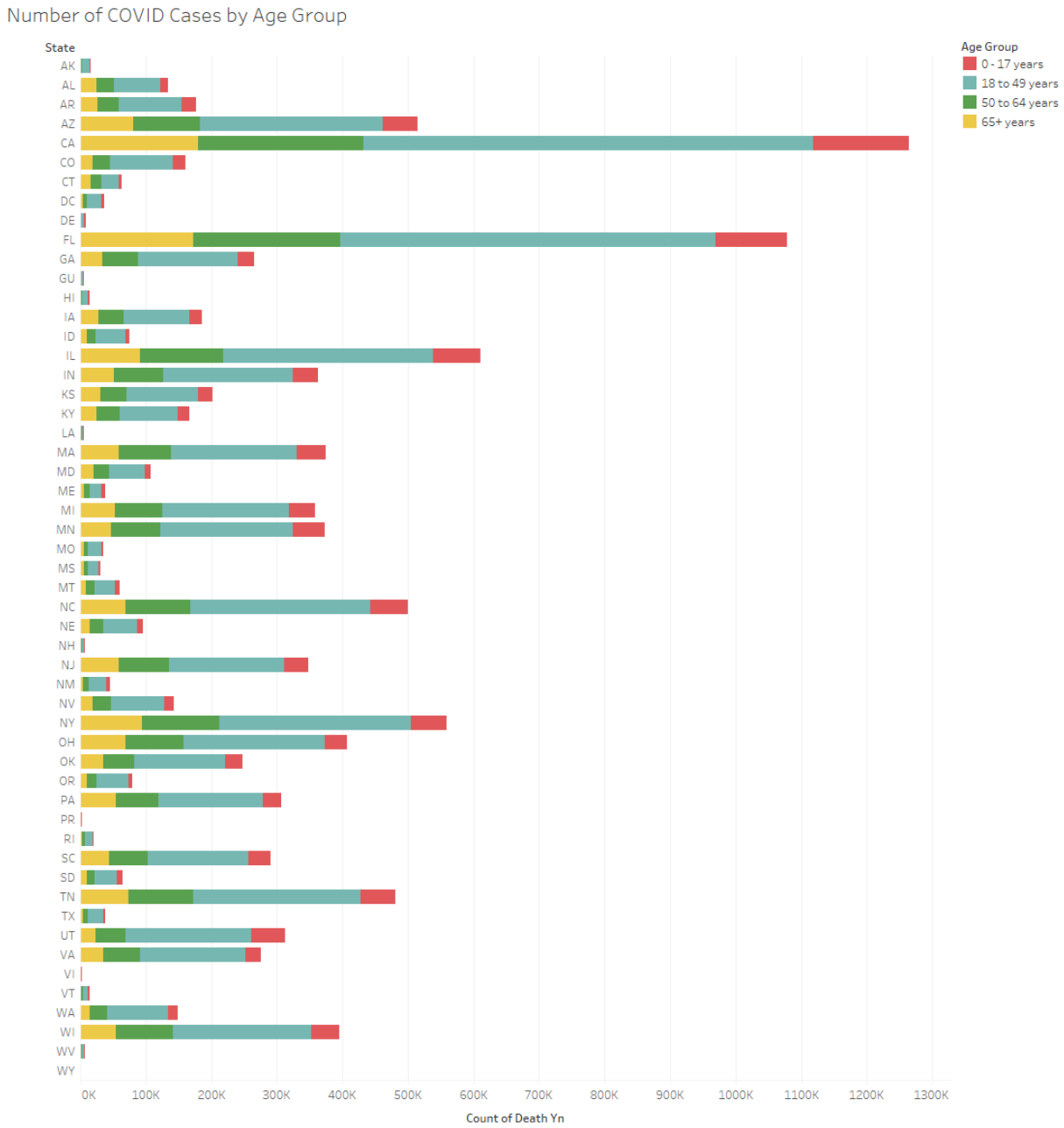

FIG. 22. Number of COVID cases by age group for each state.

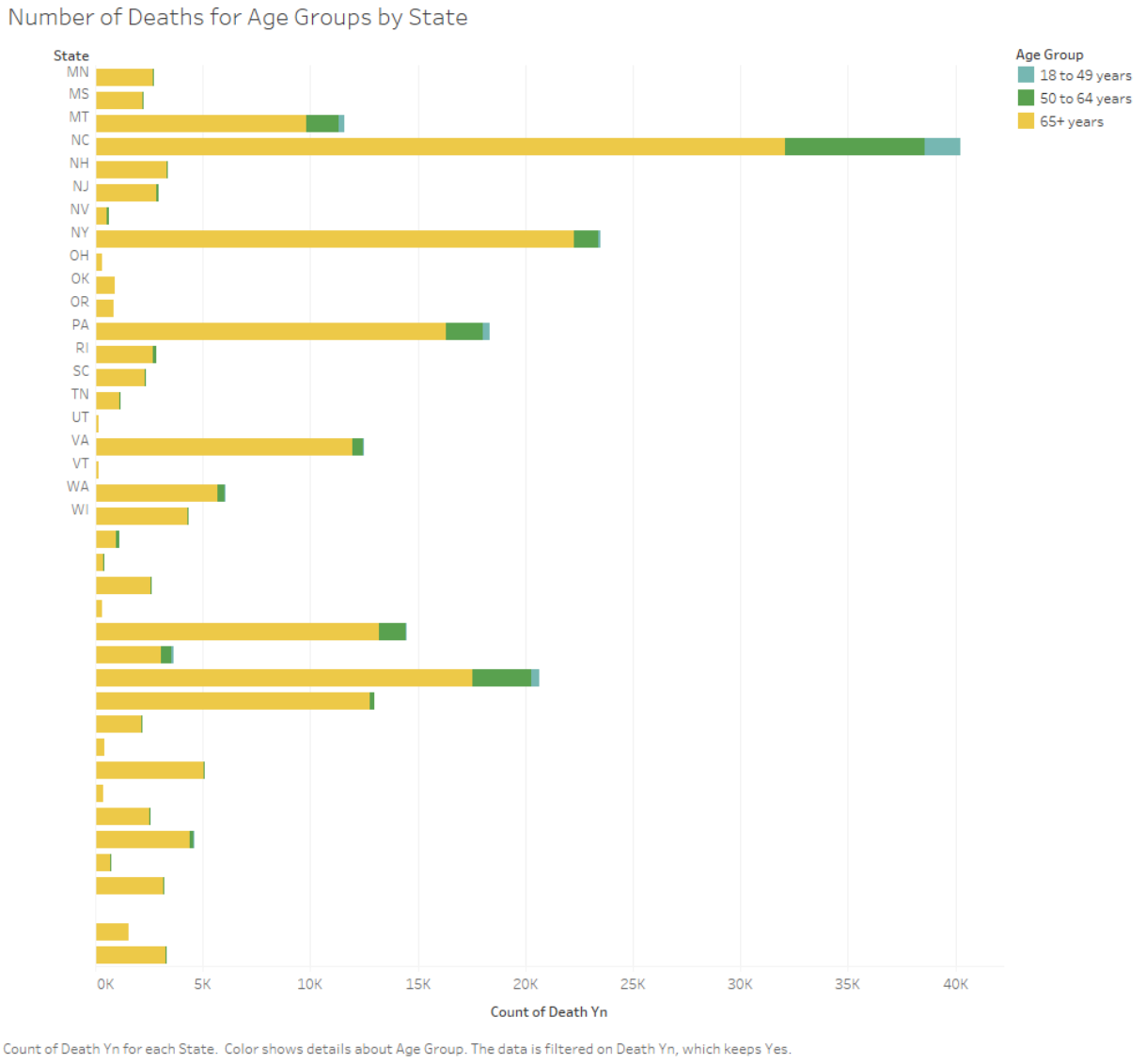

FIG. 23. Number of COVID deaths by age group for each state.

VIII. HOSPITALIZATIONS BY STATE; VENTILATORS AND SURGICAL GOWN PPE

1. For States with Ventilators

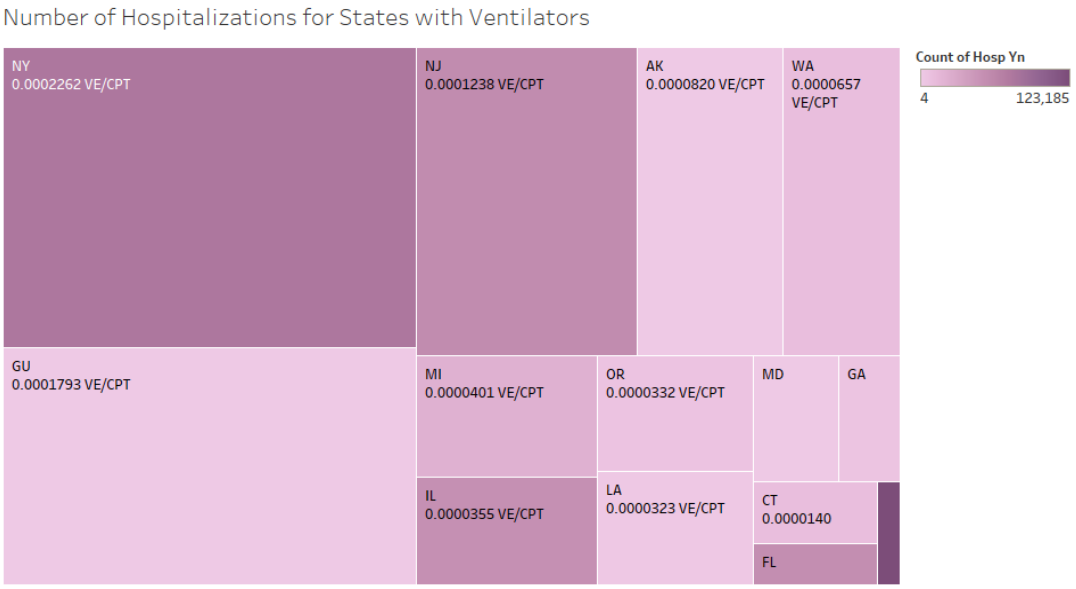

FIG. 24. This treemap is a sectioned rectangle visualization that takes into account size and color for the states who were given ventilators by FEMA and number of hospitalizations. The size factor for how large the rectangles are is defined by the PPE score for each state. The color for each rectangle is defined by the number of hospitalizations, from 4 to 123,185.

From 54 states and territories, FEMA decided to give ventilators to just 14 of them, or almost 26%. One of the biggest issues in the pandemic was that most states had inadequate supply of ventilators, which help a patient breathe if it becomes too hard for them to do so autonomously. COVID-19 is a disease which targets and weakens the lungs, and thus having enough ventilators for everyone hospitalized could and does make the difference between life and death. Many deaths can be prevented with enough ventilators, so having the highest ventilator per capita rate be around 2 for every 10,000 people is absolutely critically low. If it were not for most states obtaining more ventilators in whatever way they could, the loss of life due to COVID-19 would be even more catastrophic than it already has been.

2. Surgical Gowns

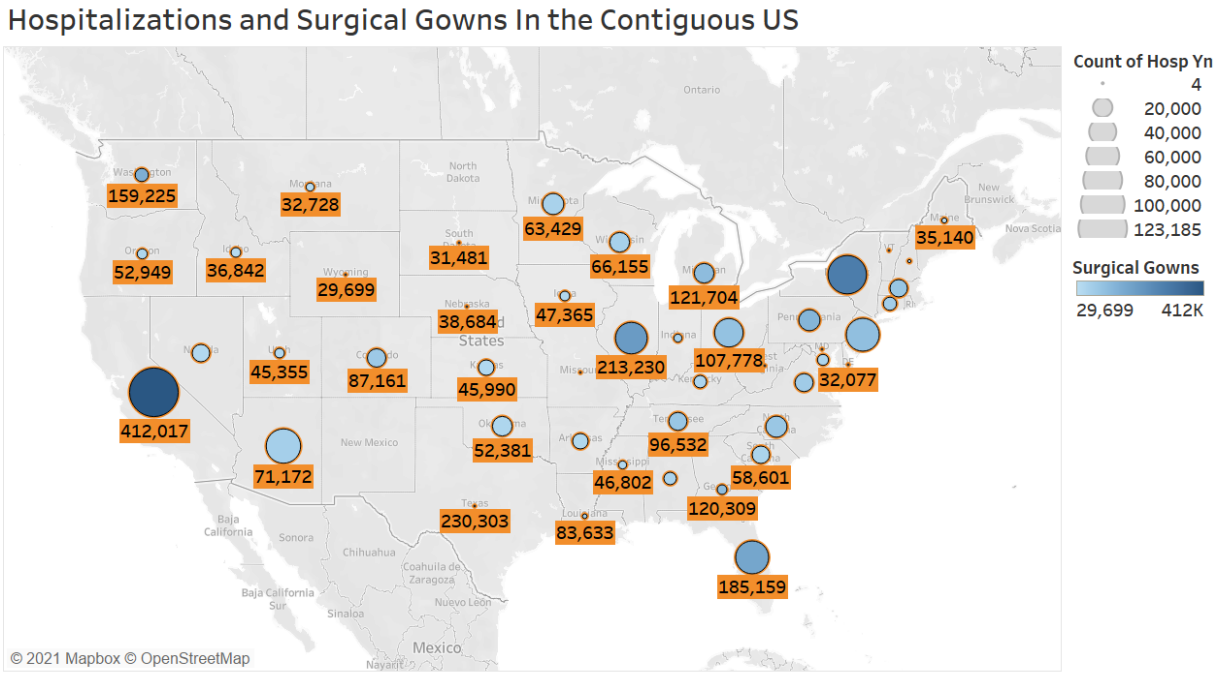

FIG. 25. The map above has three visual components that describe the hospitalizations by State and the number of Surgical Gowns provided by FEMA. The orange highlighted values are the number of surgical gowns provided to the state and a darker colored circle indicates a larger number of surgical gowns relative to other states. The size of the circles is determined by the number of known hospitalizations due to COVID-19 in each state.

In FIG. 25, it is clear that California has both the most number of hospitalizations and the greatest number of surgical gowns provided by the United States government, followed by New York, Illinois and Florida. These states are four of the largest population states in the US, so it seems for surgical gowns FEMA has well equipped the states that need them with an appropriate amount. This is interesting because surgical gowns are not under usual circumstances demanded by the general population, it is doctors, nurses and other medical health professionals who need them. During COVID-19, surgical gowns are especially important to prevent spread of the virus from patient to patient in hospitals and also to protect caregivers and other healthcare workers from contracting the virus in general settings as well as surgical operations.

IX. SYMPTOMS BY STATE WITH PPE SCORE QUANTIFIER

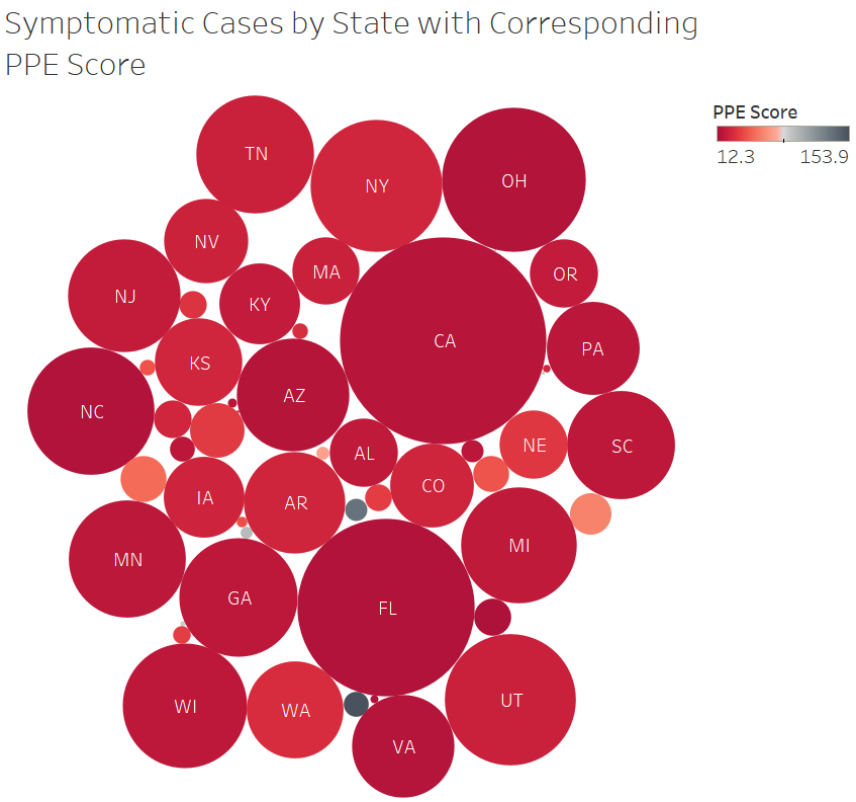

FIG. 26. This packed bubble chart has two visual components that describe the number of cases of people who had symptoms of COVID-19 by State and their corresponding PPE scores. The darker red colored circles indicate a smaller PPE score relative to other states. The size of the circles is determined by the number of cases who exhibited symptoms of COVID-19 in each state.

In FIG. 26, the states with the highest PPE scores, Vermont and Maryland, have the smallest number of symptoms of COVID-19, and most of the remaining states other than California and Florida report a significant amount of symptoms and low PPE scores. This is visible from the size of the circles for states on the outside ring of the bubble chart and the darker red color. The trend appears to be that lighter red/more black circles are of smaller size and bigger circles have darker color, which corresponds to higher PPE values for less symptomatic case states and lower PPE values for more symptomatic case states. Realistically, this trend should be reversed to have a more positive impact and reduce COVID-19 cases and symptoms.

X. CONCLUSION

The goal of this paper was to determine how FEMA governmental aid of personal protective equipment (PPE) to US States and Territories impacted their COVID-19 associated factors, which consist of Deaths and Total Cases, Case Month, Race and Ethicity, Sex, Age Group, Hospitalizations and Symptoms. FEMA allocated surgical masks, surgical gowns, ventilators, coveralls, gloves, face shields and N95 respirators to different states based on an unreleased set of criteria, and sent out these supplies to States and Territories in May 2020, two months after the World Health Organization declared COVID-19 to be a global pandemic. The entire world has been extremely impacted by the COVID-19 pandemic, and fear of the virus ran rampant for months while leaders scrambled to either explain away the dangers of contracting the virus or try to procure much needed defensive techniques to save lives. In the United States we had both types of leaders in every State, and that struggle is felt in many of the policies that were instituted during the last year, such as mask-mandates and stay-at-home orders, as well as mask-ban mandates and opening/reopening starts and stops. We hypothesized earlier that the States with the highest relative levels of PPE would be better prepared to fight the pandemic and mitigate its effects reflected by the COVID-19 related factors.

In order to identify a relationship between PPE supplies to States and Territories and the COVID-19 related factors, we created a variable called PPE Score, which adds the total units of PPE for each state and standardizes this value by the state's resident population. Then we multiplied this proportion by 100 so that we could scale the score from 0 to 200. As a result we were able to connect PPE scores with COVID associated factors. Through exploratory data analysis and summary statistics we identified the distributions of States and Territories with high and low cases as well as PPE scores and also the scaled percentage of deaths by race, which we used to analyze race and ethnicity for COVID-19 related factors.

Next, we analyzed the various COVID-19 associated factors from the CDC dataset and connected them with the PPE Score. For Death Counts and Total Number of Cases, we found that the States of Vermont and Maryland had the highest PPE scores and a very low number of deaths and total cases, while California and Florida had the smallest PPE scores and the greatest number of deaths and cases. For Case Months from January 2020 until May 2021, there were many "Missing" and "Unknown" values compared to "Yes" and "No" values,

which could occur for a number of reasons we discussed, including under-reporting and miscategorization. We examined these underreporting states further in the following heatmap, where only five out of the fifty four states and territories received a high amount of PPE relative to their population.

Additionally, we conducted a scaled and unscaled study of race and ethnicity in relation to death rate. While at first, it appeared that the White race was the hardest hit by the pandemic, analyzing the death rates scaled by population for each rate, by state, showed that it was actually the Native American population that was most negatively affected: nearly twice as badly as other non-White races, and four times as badly as White. While the White unscaled death proportions and population proportions were generally equal for most states, even often with the former lower than the latter, other non-White races were found to die from the virus at disproportionate rates in several of those states where they constituted a significant enough percentage of the total population. In spite of the strong effect of Coronavirus on minority populations in these particular states, we did not find that they had a lower PPE score, or even that non-minority populations were equally badly affected. Particularly in the case of Native Americans, this is deeply troubling, as it points toward a lack of treatment and care for Native Americans despite a higher availability of PPE per capita, leading to significantly and tragically high death rates. This is true of other minority races as well; and, indeed, non-minorities in some cases.

Next we analyzed the cases for age groups by state, and found that the elderly age group of 65 years and older had the highest number of deaths while the younger population of 18-49 year olds suffered the most number of cases but far less deaths than the elderly. This observation fits in with the local media reports of the same trend. We also wanted to see how individual types of PPE, such as surgical gowns and ventilators, would affect the hospitalizations in each state. We discovered that the states that needed the ventilators the most, i.e. the ones with the highest number of hospitalizations, actually were given the least number of ventilators by FEMA, and vice versa. This is incredibly concerning because it shows that FEMA has inadequately responded to the need of the States for ventilators, and in fact only a small proportion of states even got ventilators at all! Conversely, for the surgical gowns and hospitalizations, FEMA distributed the gowns in an accurate and proportioned way, such that every state's needs for gowns were met. This made sense because the general public do not look to surgical gowns as the first line of defense as doctors, nurses and other professionals do. Lastly, for symptoms of COVID-19,

states with the largest PPE scores had the least number of cases with symptoms and states with small PPE scores had the most number of cases with symptoms.

The results of our study have far reaching implications on how countries and states can better mobilize and mitigate the adverse effects of COVID-19 during a major pandemic, as well as how to help the minorities that are hit the hardest. The first line of defense is Personal Protective Equipment, and the states that secured these supplies sooner set the tone for how the virus would ravage their communities. Wearing a mask, being vigilant, having the necessary medical lifesaving technology and protecting our health care workers so they can help us are all extremely important and having these accessible supplies saves millions of lives across the globe every day. From our analysis of the COVID-19 associated factors in relation to PPE score, we have ascertained that FEMA's response to the virus mostly did not reflect the needs of the States, especially in demographic issues of race, ethnicity, and age. In the future, knowing how to use demographics to determine need and how many supplies to send can make or break emergency responses in societies, as well as the societies themselves, around the world.

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