COVID Spread Data Analysis

ATLAS Research Report

Aasish Tammana, Pitu Mirchandani

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Arizona State University, PO Box 876011, Tempe, AZ 85287-6011

atammana@asu.edu

pitu@asu.edu

***Abstract*— The COVID-19 pandemic, which originated in 2019, has had a profound and lasting impact on the world. This research report delves into the period spanning from 2020 to 2023, exploring the dynamics of the pandemic, the measures implemented to mitigate its effects, and their impact on few U.S. states. Concurrently, we conduct an in-depth spatial temporal analysis of COVID-19 case data, examining trends, spikes, and declines to discern patterns and variations across different time periods. One of the central themes of this report is the assessment of strategies employed to reduce the impact of the virus, with a particular focus on COVID-19 vaccinations and non-pharmaceutical interventions such as masking and physical distancing. Spatial-temporal data analysis is utilized to explore the relationship between vaccination rates and the number of COVID-19 cases. We aim to determine whether these measures have contributed to the decrease in cases and evaluate their effectiveness in mitigating the spread of the virus. We examine states such as Arizona, Alabama, and Vermont as case studies, considering the extent to which political factors, social gatherings, and adherence to preventive measures have influenced case numbers.**

***Keywords*— COVID-19, Vaccination, Preventive Measures, Spatial-temporal analysis, Physical Distancing.**

I. Introduction

COVID-19, short for "Coronavirus Disease 2019," is a highly contagious respiratory illness caused by a novel coronavirus known as SARS-CoV-2. This disease was first identified in Wuhan, China, in late 2019 and has since spread globally, leading to a pandemic. COVID-19 has had a profound impact on public health, economies, and daily life around the world **[1]**.

The virus primarily spreads from person to person through respiratory droplets when an infected individual coughs, sneezes, talks, or even breathes near others. It can also spread by touching surfaces contaminated with the virus and touching the face, particularly the eyes, nose, or mouth.

The symptoms of COVID-19 can be moderate or severe, and they normally start 2 to 14 days after exposure. Fever, coughing, shortness of breath, exhaustion, and a loss of taste or smell are typical symptoms. It can be difficult to identify and stop the transmission of the virus since some people may continue to be asymptomatic, or carry the infection but not exhibit any symptoms.

Severe cases of COVID-19 can lead to pneumonia, acute respiratory distress syndrome (ARDS), organ failure and even death, especially in older adults and those with underlying medical conditions. Various public health measures such as the use of masks, social distancing, lockdowns and vaccination campaigns have been implemented around the world to prevent the spread of the virus and reduce the burden on health systems.

Efforts to develop COVID-19 vaccines were accelerated, and several vaccines have been authorized for emergency use in many countries. These vaccines have played a crucial role in reducing the severity of the disease, hospitalizations, and deaths, offering hope for controlling the pandemic.

The COVID-19 pandemic has posed significant challenges to societies, healthcare systems, and economies, while also highlighting the importance of global collaboration in addressing public health crises. Ongoing research and public health efforts continue to evolve in the fight against COVID-19 as we work toward a future with fewer cases and a return to normalcy.

II. Background

This research report focuses on the evolution of the pandemic in various U.S. states from 2020 to 2023, with a particular emphasis on the interplay between vaccination campaigns, physical distancing measures, and their effects on spread of the virus.

The first cases were reported in the United States in January of 2020. Over the subsequent years, the virus spread rapidly across the nation, affecting each state differently. This research delves into the trends and dynamics of COVID-19 cases in three specific states: Arizona, Alabama, and Vermont, which offer unique insights due to varying approaches to mitigating the virus's impact.

As of the latest available data in September 2023, the population of the United States is estimated to be approximately 335.4 million people, according to the most recent figures from Census Bureau **[2]**.

A. Covid Cases in the US

In the United States of America, between January 3, 2020, and September 13, 2023, a total of 103,436,829 confirmed cases of COVID-19 were reported to the World Health Organization (WHO), resulting in 1,127,152 reported deaths. As of June 2, 2023, the country has administered a significant number of COVID-19 vaccine doses, with a total of 668,882,018 doses given. These statistics reflect the nation's ongoing efforts to manage and mitigate the impact of the pandemic through vaccination and public health measures **[3]**.

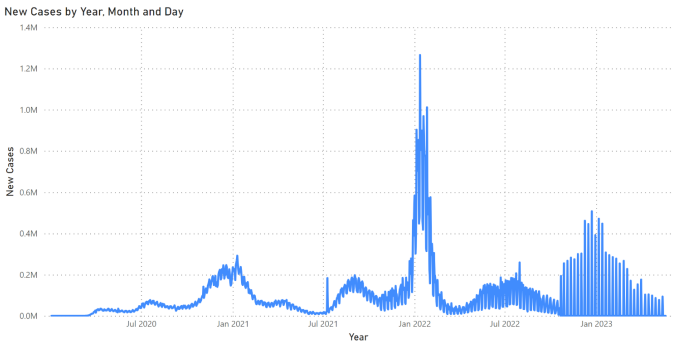


Fig. 1 Trend line indicating new cases by Date

In general, during the initial wave of the pandemic, the United States experienced its first peak in COVID-19 cases in the spring and early summer of 2020. The country saw subsequent waves of cases during the fall and winter of 2020-2021.

B. Hospitalisations in the US

The highest peak of hospitalisations were in December 2020 and January 2021, consistent with the highest peak in reported cases**[3]**.

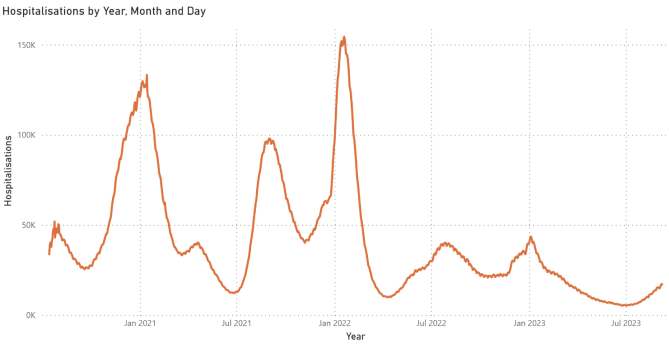


Fig. 2 Trend line indicating new hospitalisations by Date

C. Deaths in the US

COVID-19 has led to a significant number of deaths worldwide. The pandemic has affected nearly every country, with varying levels of impact and mortality rates**[3]**.

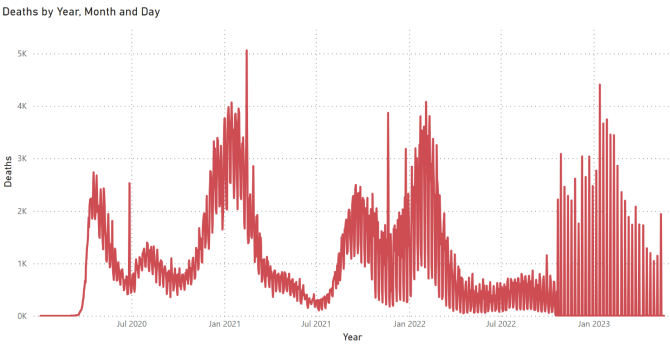


Fig. 3 Trend line indicating new deaths by Date

D. Vaccinations in the US

Vaccination campaigns have played a crucial role in reducing COVID-19-related deaths. Vaccines have been shown to be highly effective in preventing severe illness and death, particularly among vaccinated populations.

According to CDC, As of the latest available data (May 11th 2023), COVID-19 vaccination efforts in

the United States have made significant progress **[4]**. Over 81% of the total population has received at least one dose of a vaccine, with even higher percentages in older age groups, such as 95% among those aged 65 and above. Moreover, nearly 70% of the population has completed their primary vaccine series, indicating a substantial level of protection. Booster doses, which provide added immunity, have been administered to 17% of the total population, with the highest uptake among individuals over 65, reaching 43%. These statistics highlight the nation's commitment to combatting the pandemic, with a strong focus on increasing vaccine coverage across different age groups**[3]**.

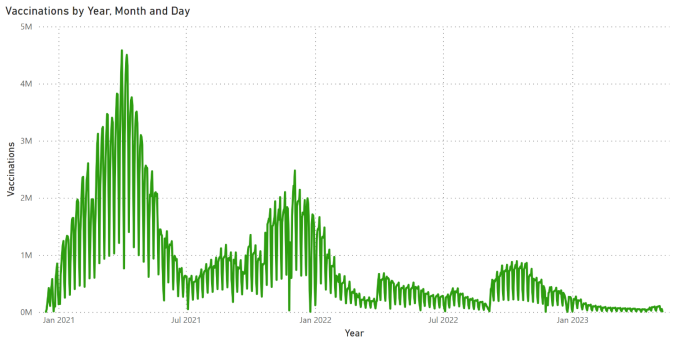


Fig. 4 Trend line indicating new vaccinations by Date

III. Trend Analysis - US

A. *Covid Cases v/s Vaccinations in the US*

In the analysis of the data on the number of COVID-19 cases (7-day rolling average) and the number of vaccinations by month and year, several key patterns have emerged.

Initially, from January 2020 to April 2021, there was a dramatic surge in cases, coinciding with the onset of the pandemic, while vaccinations gradually rolled out. During this period, there appeared to be an inverse relationship between the number of cases and vaccinations, indicating the effectiveness of vaccination efforts in curbing the spread of the virus.

Subsequently, from mid-2021 to mid-2022, both variables exhibited fluctuations, with less clear trends. However, It is evident that, as the vaccination efforts dropped from April to July 2021, the cases surged and led to a second peak in cases around Jan 2022.

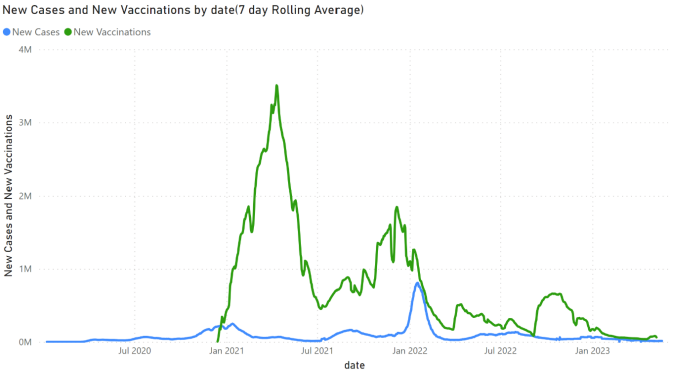


Fig. 5 New Cases and New vaccinations by Date (7 day Rolling Average)

Finally, from mid-2022 to May 2023, the number of cases and vaccinations reached relatively stable levels. As vaccination efforts reached the entirety of the population, the cases reduced and reached a stable level. It's essential to note that while these observations highlight correlations, causation is complex, influenced by various factors, including public health measures and the emergence of new variants **[3]**.

B. *Hospitalisations v/s Deaths in the US*

The data analysis of COVID-19 hospitalizations and deaths spanning from 2020 to 2023 reveals a discernible pattern. Hospitalizations exhibit fluctuations but consistently correlate with subsequent changes in deaths, albeit with a noticeable time delay. Notably, the surge in hospitalizations during the latter part of 2020, particularly in November and December, is mirrored by a sharp increase in deaths **[3]**.

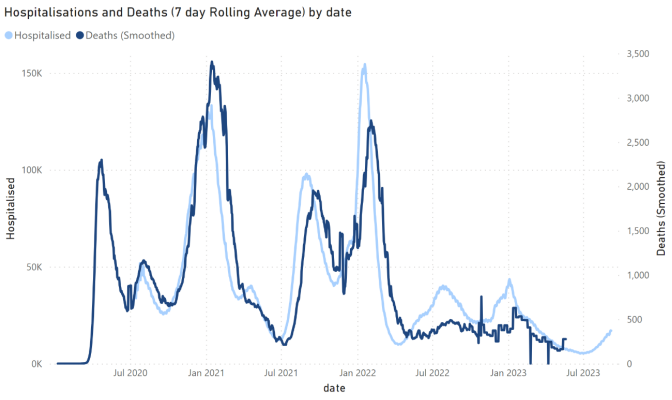


Fig. 6 Hospitalisations and New deaths (7 day Rolling Average) by Date

In 2021, a similar trend unfolds, with hospitalizations peaking in early months and a corresponding rise in deaths, although the latter lags behind. The data for 2022 demonstrates a gradual decline in both hospitalizations and deaths compared to the previous year. However, the analysis highlights the influence of various factors, such as vaccination campaigns and emerging variants, on these patterns. It is important to acknowledge that the incomplete data for June and July 2023 precludes a comprehensive assessment of the most recent trends.

C. Masking Policy in the US

The relationship between the facial covering policy and the number of COVID-19 cases within the United States reveals a notable correlation. In the early months of 2020, when no facial covering policy was in place, cases remained relatively low, but as awareness of the pandemic grew, the number of cases began to rise. The implementation of a recommended policy in March 2020 did not immediately curb the upward trend in cases. However, a significant shift occurred in April 2020 when facial coverings were mandated outside the home at all times, leading to a noticeable decrease in case numbers. **[5]**

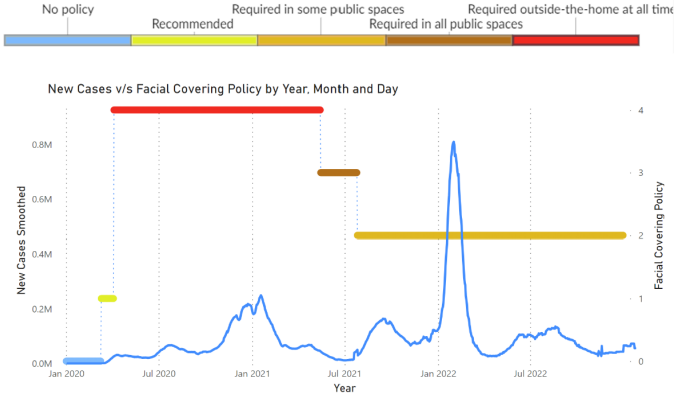


Fig. 7 Masking Policy by Date

This trend continued throughout the year, even during the fall and winter months. In May 2021, a slight policy relaxation to require facial coverings in all shared/public spaces outside the home or in situations when social distancing was not possible did not significantly impact case numbers. Subsequently, as the policy was further relaxed to only require facial coverings in some specified shared/public spaces or situations when social distancing was not possible from August 2021 onwards, case numbers varied without showing a clear trend. It's important to note that while there is a correlation between stricter facial covering policies and reduced case numbers, other factors like vaccination rates, public compliance, and the emergence of new variants also play significant roles in shaping the COVID-19 landscape. Furthermore, regional variations in policies at state and local levels further influence these dynamics.

IV. US State Trends

A. Total Cases by State in the US

In analyzing the total COVID-19 cases by state in the United States, several noteworthy trends and patterns emerge. First and foremost, there is considerable variation in the total number of cases, with populous states like California, Florida, and Texas reporting the highest figures, reflecting the influence of population density and other factors on virus transmission. Regional differences are also apparent, Southern states, such as Florida, Texas, consistently reporting higher numbers, likely due to factors like climate and population density **[6]**.

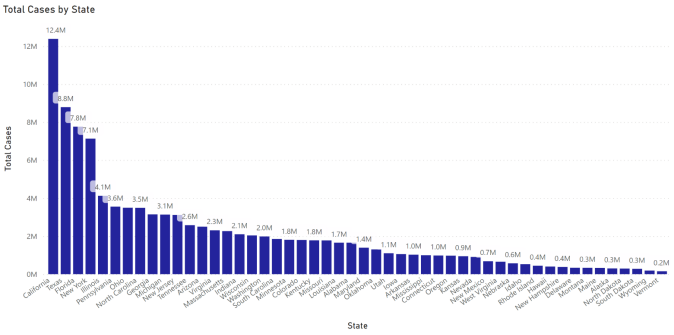


Fig. 8 Total Cases by State

The impact of the pandemic has varied across regions, with the Northeastern states initially hit hard, while some Midwestern states experienced surges at different times. Additionally, states with smaller populations generally reported lower cases, often attributed to lower population density and geographical isolation. The influence of vaccination rates, urbanization, policies, and seasonal

fluctuations on these patterns is evident but complex.

B. Arizona

1) *Cases*: Arizona, a populous state in the southwestern United States, has reported a substantial total of 2,514,694 COVID-19 cases as of 27th September 2023. The state's high case count can be attributed to factors like population density, a warm climate attracting visitors, and urban centers like Phoenix **[7]**.

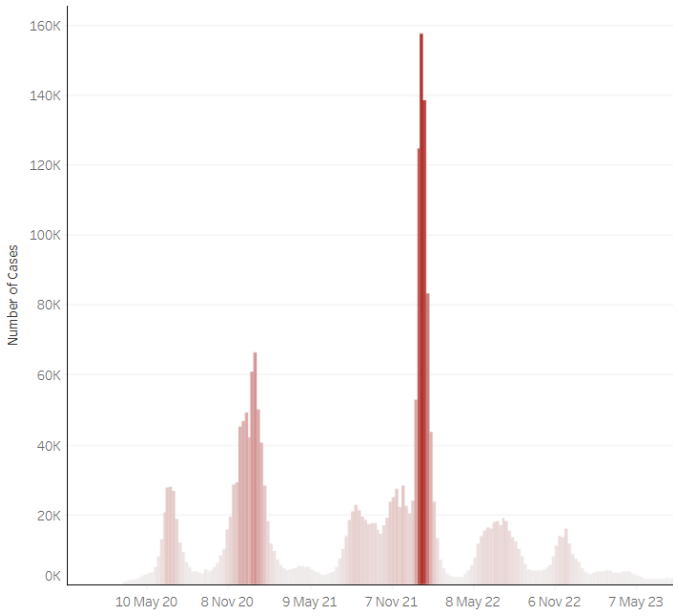


Fig. 9 Total Cases by Date in Arizona

Throughout the pandemic, Arizona experienced multiple waves of COVID-19 cases, with varying degrees of severity, often influenced by the presence or absence of strict mitigation measures.

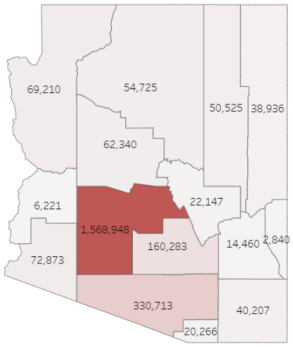


Fig. 10 Total Cases by County in Arizona

2) *Hospitalisations*: Arizona saw surges in COVID-19 hospitalizations at various points during the pandemic. These surges often correlated with spikes in cases and strained healthcare resources.

There were a total of 143,439 hospitalisations which accounted for about 6% of the population in the state. Within Arizona, Maricopa County was the most affected with 89,177 which is itself 62% of the hospitalisations **[7]**.

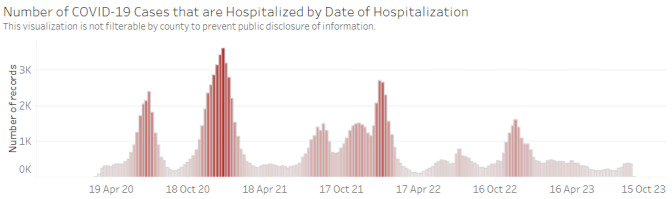


Fig. 11 Hospitalisations in Arizona

3) *Deaths*: According to the Arizona Department of Health Services, there were totally 33,774 deaths reported due to covid-19 and factors such as the prevalence of the virus, healthcare capacity, and the effectiveness of public health measures. Maricopa again registered the highest number of deaths i.e. 19,197 which is about 56%. This is closely followed by Pima County with 4400 deaths. This makes it evident that the precautions taken in Pima county were more stringent than Maricopa county **[7]**.

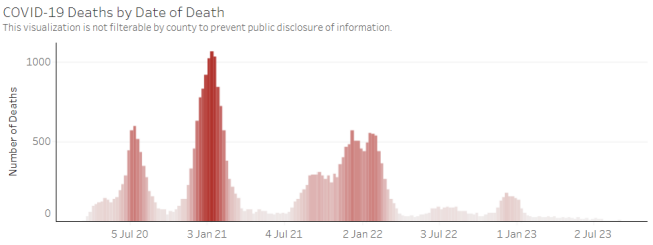


Fig. 12 Deaths in Arizona

4) *Vaccination*: According to the Arizona Department of Health Services, there were totally 14,227,494 doses of the vaccine administered within Arizona and 77.1% of the people are vaccinated **[7]**.

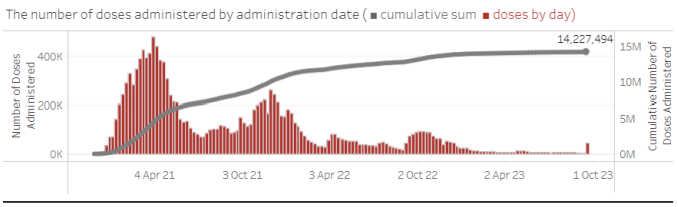


Fig. 13 Vaccinations in Arizona

C. Alabama

1) *Cases*: As of July 1st 2022, the estimated population of Alabama was around 5.04 million people.As of May 10th 2023, there have been a total of 1,659,936 reported cases of COVID-19 in Alabama.

   On average, the number of reported COVID-19 cases in Alabama was the highest during January 2022 compared to other months in 2022 **[8]**.

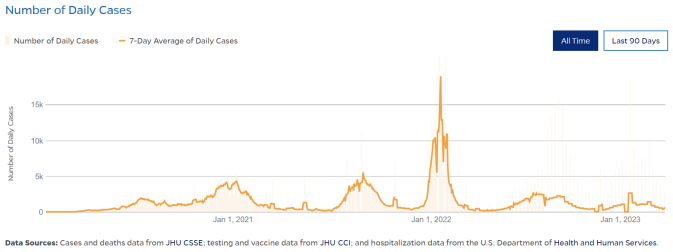


Fig. 14 Total Cases by Date in Alabama

2) *Hospitalisations*: Alabama saw surges in COVID-19 hospitalizations at various points during the pandemic, very similar to Arizona **[8]**.

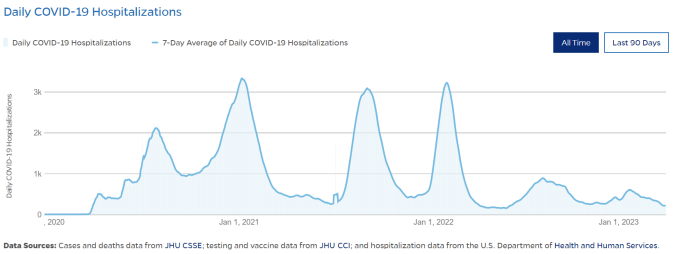


Fig. 15 Hospitalisations in Alabama

3) *Deaths*: The number of reported COVID-19 deaths in Alabama was the highest during January 2021 compared to other months. There was a similar rise in deaths around November 2021 **[8]**.

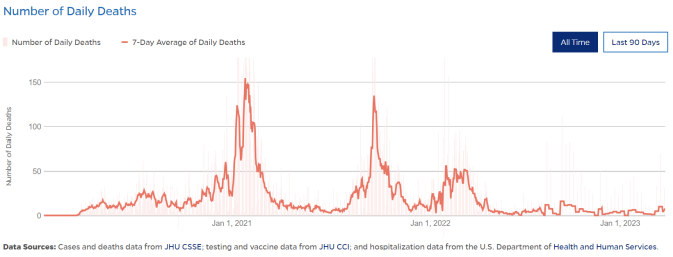


Fig. 16 Deaths in Alabama

4) Vaccinations: In Alabama, 3,193,141 people or 65% of the population have received at least one dose. Overall, 2,611,593 people or 53% of Alabama's population have been fully vaccinated **[8]**.

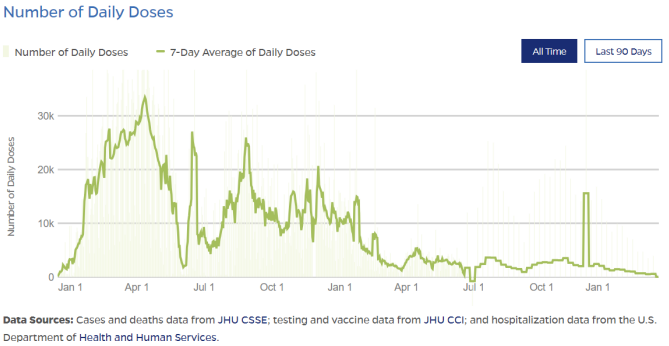


Fig. 17 Vaccinations in Alabama

D. Vermont

1) *Cases*: As of July 1st 2022, the estimated population of Vermont was around 647 thousand people. Since the beginning of the pandemic, a total of 153,198 cases have been reported, As of March 23rd 2023 **[9]**.

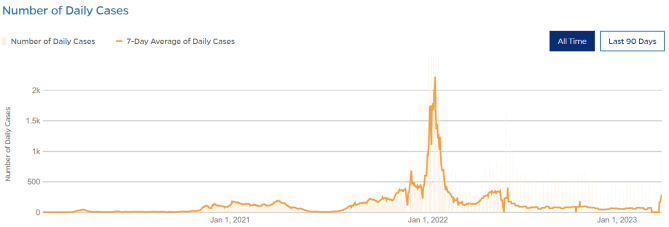


Fig. 18 Total Cases by Date in Vermont

2) *Hospitalisations*: Similar to the other states, Vermont as well saw fluctuations in COVID-19 cases. However, the most significant impact occurred around the month of January in 2022 where Vermont experienced the highest number of hospitalisations on an average **[9]**.

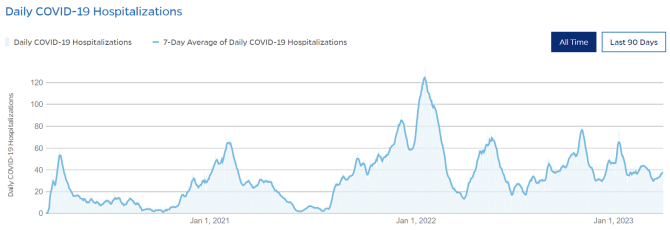


Fig. 19 Hospitalisations in Vermont

3) *Deaths*: Being a less densely populated state, vermont saw a relatively low number of covid deaths throughout the pandemic. This clearly shows the relationship between population density and deaths **[9]**.

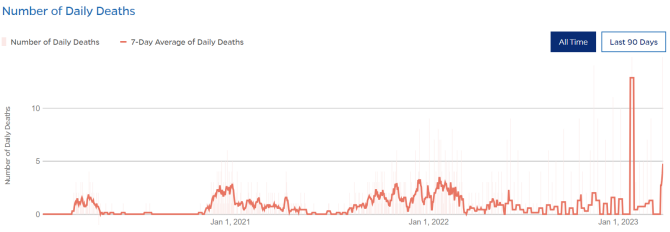


Fig. 20 Deaths in Vermont

4) Vaccinations: As per the latest available information, Vermont has a full vaccination record for 95% of the population. This was majorly completed in the initial months of 2021. The total number of doses administered is about 1,762,563. Additionally, about 35% of the population has received the booster dose as well **[9]**.

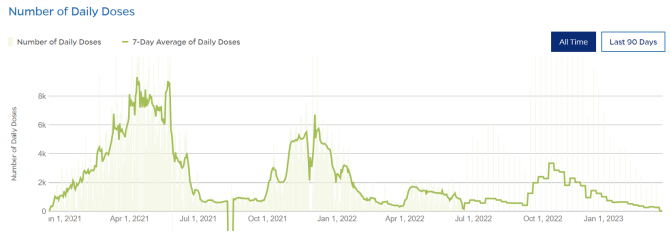


Fig. 21 Vaccinations in Vermont

V. Demographic Statistics of various states

This part of the report concentrates on the age, gender, ethnicity related statistics for Covid - 19 related deaths within the US. All demographic data represented here is collected as of 09/27/2023.

A) Covid -19 deaths by Sex and State

The bar chart illustrates the COVID-19 related fatalities across three U.S. states—Alabama, Arizona, and Vermont

In Alabama, the chart indicates a significant difference in the number of deaths between genders, with the male population experiencing approximately 12.07 thousand deaths compared to 10.37 thousand in the female population. Arizona presents a more pronounced difference, where the male death toll is notably higher, reaching about 18.39 thousand, while the female fatality count stands at 12.98 thousand. In contrast, Vermont shows a minimal gender gap in COVID-19 deaths, with the male population accounting for 590 deaths and the female population 520 **[10]**.

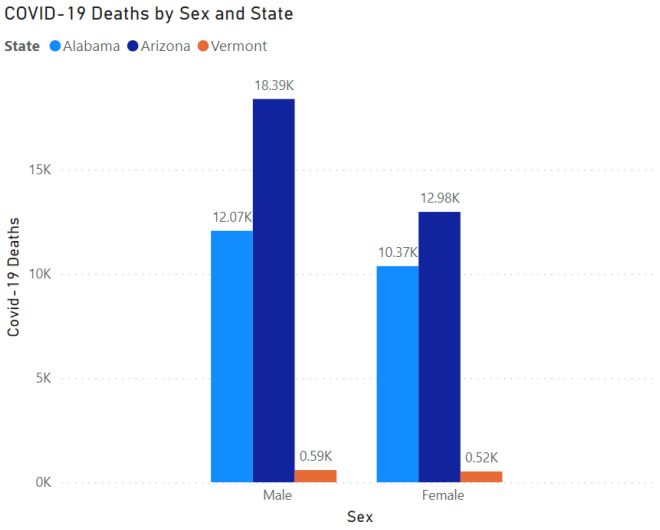


Fig. 22 Covid-19 Deaths by Gender and State

The data suggests a pattern where the male population in Alabama and Arizona is more severely affected by COVID-19 in terms of mortality rates. Meanwhile, Vermont's overall lower numbers, which are reflective of its smaller population, exhibit a comparatively balanced impact between genders.

B) Covid -19 deaths by Age Group, Sex and State

The bar chart presents a clear trend of COVID-19 deaths across different age groups in the United States. The fatalities are lowest among the youngest, with those aged 5-14 years having the fewest deaths. As age increases, there is a notable rise in mortality; the 35-44 age group sees a slight increase, with deaths becoming significantly higher in the 55-64 bracket **[10]**.

The data shows a sharp increase in deaths among those 65 years and older, with the highest numbers in the 75-84 and 85+ age groups, indicating the virus's severe impact on the elderly. This trend highlights the necessity for prioritized healthcare and protective measures for older adults.

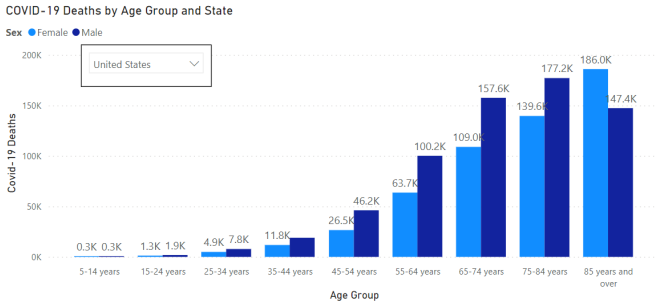


Fig. 23 Covid-19 Deaths in US by Age Group, Gender

1) Arizona: The bar chart details COVID-19 deaths by age group and sex in Arizona, indicating a similar age-related increase in mortality. Notably, the age groups of 65-74 and 75-84 years show a substantial increase in deaths, Especially the males **[10]**.

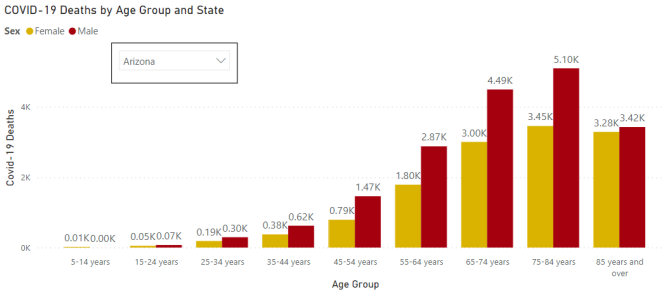


Fig. 24 Covid-19 Deaths in Arizona by Age Group, Gender

2) Alabama: Alabama's data shows a different distribution. While the trend of increasing deaths with age still holds, the mortality rate for those 85 and over does not peak as it does nationally and in Arizona, but rather shows a slight dip compared to the 75-84 age group. This could suggest varying factors at play in Alabama, such as differences in healthcare access, population demographics, or the management of the pandemic among the most senior citizens **[10]**.

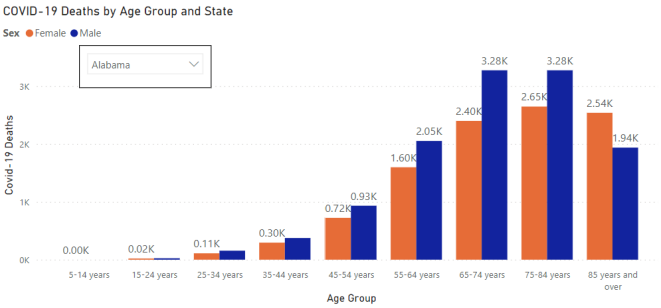


Fig. 25 Covid-19 Deaths in Alabama by Age Group, Gender

3) Vermont: This trend mirrors the national observation that the oldest demographic is the most affected, but the sharp increase in Vermont suggests a particular vulnerability or possibly a higher proportion of elderly in the state's population.

When comparing Vermont to Alabama and Arizona, we see Vermont's total numbers are lower, likely reflecting its smaller population size. Despite this, the relative impact on the oldest age group is significant, emphasizing the universal susceptibility of the elderly to COVID-19, regardless of state size **[10]**.

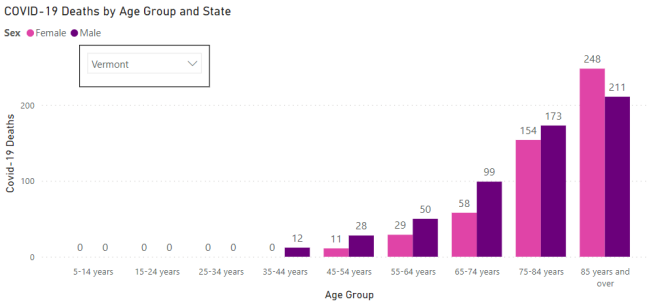
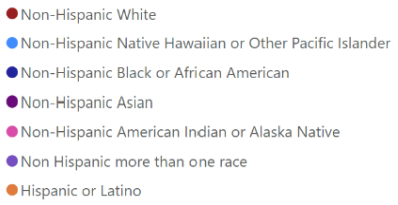


Fig. 26 Covid-19 Deaths in Vermont by Age Group, Gender

C) Covid -19 deaths by Race / Ethnicity and State

The donut chart provides a breakdown of COVID-19 deaths in the United States by race/ethnicity. The largest segment, accounting for 66.98% of the deaths, is attributed to the Non-Hispanic White population, followed by Hispanic or Latino individuals at 14.72%. The Non-Hispanic Black or African American group represents 13.53% of the fatalities **[11]**.

Below is the legend for the various donut charts depicted in this segment of the report:



Smaller proportions of the deaths are seen among Non-Hispanic Asian (3.15%), Non-Hispanic American Indian or Alaska Native (1.04%), and Non-Hispanic Native Hawaiian or Other Pacific Islander populations (0.2%).

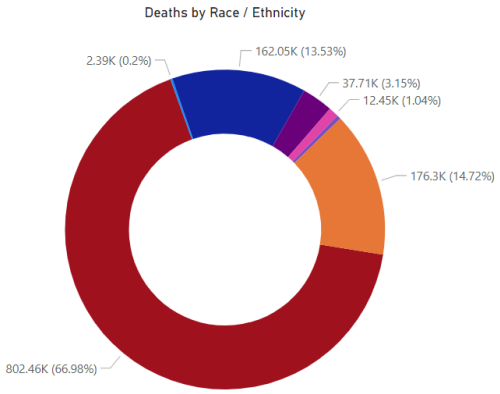


Fig. 27 Covid-19 Deaths in US by Race / Ethnicity

1) Arizona: The Non-Hispanic White category comprises the majority with 58.89% of the deaths. The Hispanic or Latino population follows at 26.92%, indicating a significant impact on this community. Other groups, including Non-Hispanic Black or African American (7.78%), Non-Hispanic American Indian or Alaska Native (3.46%), reflect smaller percentages of the total deaths **[11]**.

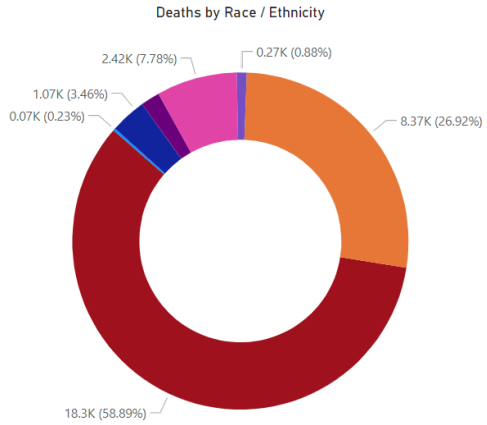


Fig. 28 Covid-19 Deaths in Arizona by Race / Ethnicity

2) Alabama: Here, the distribution of COVID-19 deaths by race/ethnicity shows a higher percentage of Non-Hispanic White individuals affected (71.08%) compared to the national average (66.98%) and Arizona (58.89%). Conversely, the Hispanic or Latino population in Alabama accounts for a smaller share of deaths (1.73%) than in Arizona (26.92%) **[11]**.

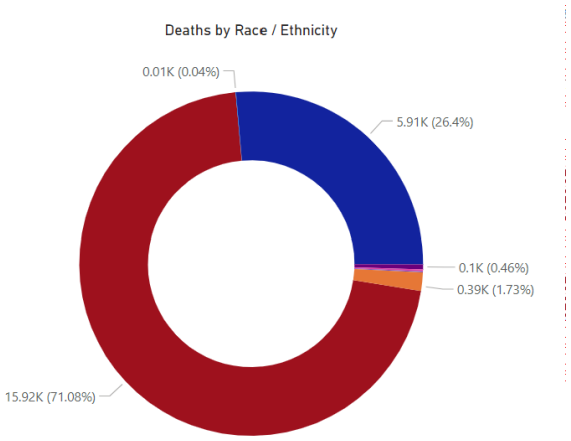


Fig. 29 Covid-19 Deaths in Alabama by Race / Ethnicity

3) Vermont: The racial/ethnic distribution of COVID-19 deaths in Vermont is markedly different from Alabama, Arizona, and the national average. In Vermont, a significant majority of the deaths are Non-Hispanic White population, accounting to the entirety.

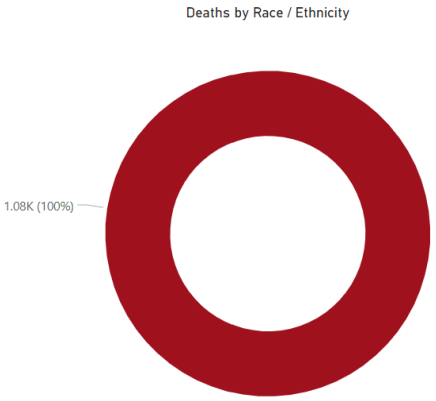


Fig. 30 Covid-19 Deaths in Vermont by Race / Ethnicity

The shares of the Hispanic or Latino, and Non-Hispanic Black or African American populations are extremely smaller in

Vermont compared to these other regions. This contrast may reflect Vermont's demographic composition, which differs substantially from the more diverse states of Alabama and Arizona, as well as the overall national demographics [11].

The data suggests that racial/ethnic disparities in COVID-19 deaths are influenced by state-specific demographics and could also indicate varying levels of vulnerability or exposure among these groups.

VI. Critical Hospital Staffing Shortage

This part of the report concentrates on the Number of hospitals reporting a critical staffing shortage in the US.

Data is categorised into 3 types:

- Staffing Shortage
- No Staffing Shortage
- No Reports

When we say shortage, it represents the number of hospitals which reported a shortage and not how much shortage.

A. USA: In analyzing the staffing shortage data in hospitals from January 2020 to October 2023, several significant insights have emerged. The most notable finding is that the highest shortages occurred in December 2020, with 37,456 hospitals reporting critical staffing shortages, closely followed by November 2020, with 32,529 hospitals reporting shortages. This indicates a particularly challenging period for hospital staffing **[12]**.

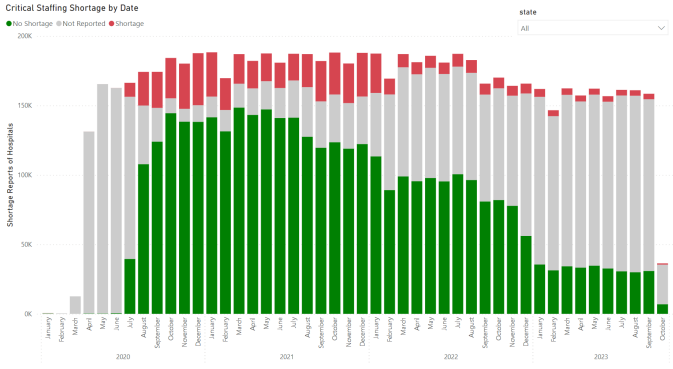


Fig. 31 Hospital Staffing shortage in USA

Notably, there was a substantial drop in shortages starting in February 2022, and this trend continued into 2022 and 2023.

B. Alabama: From July 2020 to December 2020, the number of hospitals reporting a staffing shortage gradually increased. In 2021, the situation improved, with "No Shortage" hospitals consistently outnumbering those reporting shortages **[12]**.

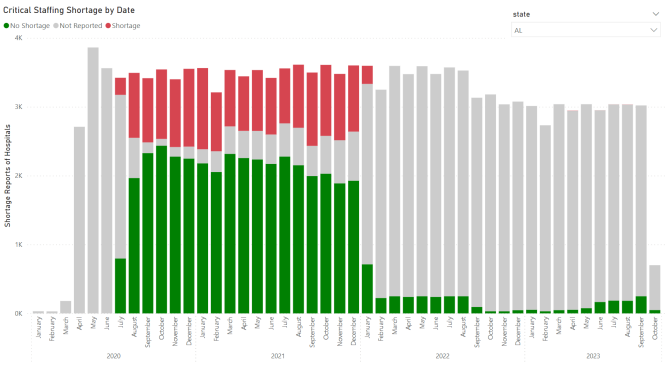


Fig. 32 Hospital Staffing shortage in Alabama

C. Arizona: Notably, in the initial months of the COVID-19 pandemic, there were a substantial number of hospitals not reporting their staffing shortage status. As time progressed, a pattern emerged with a higher number of hospitals reporting both shortages and no shortages, while the count of unreported hospitals decreased.

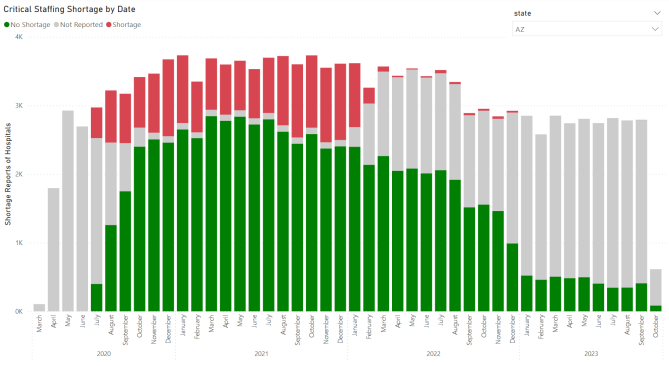


Fig. 33 Hospital Staffing shortage in Arizona

In July and August 2020, there was a notable increase in hospitals reporting shortages, likely reflecting the impact of the pandemic. In the subsequent months, this trend continued with the majority of hospitals reporting shortages or no shortages. By March 2022, the situation

improved, with a significant decrease in shortages **[12]**.

D. *Vermont:* Surprisingly, from July 2020 to October 2022, there was a consistent number of hospitals reporting shortages, with varying levels of shortage and no shortage. In the later months of 2022 and early 2023, the staffing situation began to improve, with a significant reduction in reported shortages and a substantial increase in hospitals without shortages **[12]**.

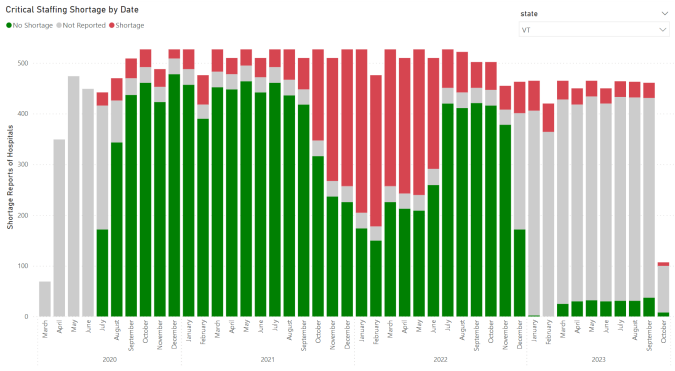


Fig. 34 Hospital Staffing shortage in Vermont

VII. Comparative Analysis

A. *Total Cases:*

- Case Trends: Each state's peaks and troughs varied based on local factors such as population density, climate, urbanization, and local policies.
- Population Density: Heavily populated states like Arizona reported higher case counts, while Vermont, with a smaller population, had fewer cases.
- Local Policies and Climate: States like Arizona and Alabama may have experienced higher cases due to warm climates that attract visitors year-round, as well as varying strictness in mitigation measures.
- Vaccination and Public Health Measures: The overall efforts of vaccination and public health measures have been effective in managing the pandemic's impact, though the degree of effectiveness varied.

Region	Total Cases	Population (2023 est.)	Notable Trends
United States	103.43M	336M	Multiple waves, significant peaks in early 2020 and late 2020/2021.
Arizona	2.51M	7.45M	Multiple waves influenced by mitigation measures, high cases probably due to population density, climate, and urban centers.
Alabama	1.66M	5.04M	Highest average cases reported in January 2022.
Vermont	153k	647k	Lower cases likely due to lower population density and effective containment measures.

Table. 1 Total Cases

In conclusion, while there is a general synchronicity in the trends with the national data, especially in terms of waves of cases, local discrepancies are apparent. These could be due to a combination of factors like state-specific policies, population density, and climate. States with higher populations and urban centers reported more cases, while states with smaller populations like Vermont reported fewer cases.

B. *Total Hospitalizations:*

- Surges in Hospitalizations: All regions show a pattern of increased hospitalizations correlating with national case surges, particularly in the early pandemic months. The stress on hospitals was nationwide, with peaks often coinciding with the winter months, likely due to seasonal effects.
- Staffing Shortages: The reported staffing shortages were highest during the peak hospitalization periods, suggesting a direct link between the number of hospitalizations and the ability of hospitals to adequately staff their facilities.
- Regional Variations: There is a notable variation between states in both

hospitalizations and staffing shortages. While national trends give a general picture of the pandemic's impact, state-level data show how local factors, such as population density and healthcare infrastructure, influenced the pandemic's impact.

- Improvements Over Time: All regions showed improvement in staffing shortages as the pandemic progressed, indicating an adaptation of the healthcare system over time, possibly due to policy changes, vaccination rollouts, and improved protocols.

Region	Total Hospitalizations	Population (2023 est.)	Notable Trends
United States	47M	336M	Multiple waves, significant peaks in early 2020 and late 2020/2021.
Arizona	143k	7.45M	Multiple waves influenced by mitigation measures, high cases probably due to population density. Maricopa County (62%)
Alabama	121k	5.04M	Highest average cases reported in January 2022.
Vermont	6.7k	647k	Lower cases likely due to lower population density and effective containment measures.

Table. 2 Total Hospitalizations

This analysis suggests that the healthcare system's response evolved over time and varied by region, with significant strains occurring during the peak periods of case surges.

C. Total Deaths:

- Overall Death Trends: The analysis suggests that the number of deaths in the U.S. has seen significant peaks and troughs, indicative of the various waves of the pandemic.

  In Arizona, Maricopa County has reported the highest number of deaths, suggesting that urban centers with higher population densities have been more impacted.

  Alabama saw its highest number of deaths in January 2021, indicating a severe wave of COVID-19 during that period.

  Vermont, with its lower population density, experienced fewer deaths, which could be correlated with its ability to better manage the spread of the virus.

- Death Rates Relative to Case Numbers: By comparing the death counts to the case numbers, we can infer the fatality rates. We could calculate the case fatality rate (CFR) by dividing the number of deaths by the number of confirmed cases.

$$CFR = (Number\ of\ Confirmed\ Cases/Number\ of\ Deaths)\times 100$$

Region	Total Cases	Total Deaths	CFR (%)
United States	103.43M	1.12M	1.09
Arizona	2.51M	33.7k	1.34
Alabama	1.66M	22.6k	1.36
Vermont	153k	1,073	0.70

Table. 3 Total Deaths

D. Total Vaccinations:

- Correlation with Case Reduction: The vaccination campaigns seem to have a direct correlation with case reductions, especially in states with higher vaccination rates like Vermont. In contrast, Alabama's lower vaccination rates may have contributed to

higher cases and a severe wave in January 2022.

The U.S. shows strong vaccination efforts with 81% having at least one dose, which has helped reduce severe COVID-19 cases, particularly among the elderly. Arizona's 77.1% vaccination rate hasn't fully prevented infection surges, possibly due to high population density and climate. Alabama lags with a 65% initial vaccination rate, correlating with higher case rates.Vermont's 84% full vaccination rate, including 54% with boosters, reflects its success in controlling the virus's spread.

Region	Total Doses	% (One Dose)	% Fully Vaccinated	Notable Trends
United States	676M	81%	70%	High coverage in older age groups, with 95% of those 65+ having at least one dose.
Arizona	14.2M	77.1%	65%	High vaccination rate, with a focus on increasing coverage across age groups.
Alabama	7M	65%	53%	Slower vaccine rollout possibly contributing to higher case rates in Jan 2022.
Vermont	1.6M	95%	86%	Swift and extensive vaccination efforts, leading to effective virus containment.

Table. 4 Total Vaccinations

E. Masking Policies and COVID-19 Case Numbers:

To investigate the potential temporal association between the implementation of facial covering policies and the evolution of COVID-19 case numbers, we conducted a cross-correlation analysis. This statistical technique is utilized to evaluate the extent to which two time-series data sets are correlated at different time lags.

Our analysis focused on a dataset spanning Jan 2020 until May 2023, which included the following variables: 'Facial Covering Policy'—a numerical indicator of the stringency of mask mandates, and 'New Cases (7-day Rolling Average)'—a smoothed representation of COVID-19 incidence.

To prepare the data for analysis, we removed instances with missing values in these key variables, ensuring a robust dataset for our correlation calculations.

We performed a forward-lag cross-correlation, examining lags of up to 12 months to capture the potential delayed effects of masking policies. This approach allowed us to explore not only the immediate impact of such interventions but also their extended influence over the subsequent year.

- Findings - Our cross-correlation analysis revealed a spectrum of correlation coefficients at different lags, ranging from -0.011 to 0.178. The most notable peak in the correlation coefficient was observed at a 7-month lag, with a value of 0.1787. This suggests a modestly positive correlation between the stringency of masking policies and a reduction in COVID-19 cases observed 7 months later.

Lag (In Months)	Correlation coefficient
1	0.001845
2	-0.00114
3	-0.00863
4	-0.00713
5	0.008847
6	0.143322
7	0.178689
8	0.127413
9	0.123272
10	0.000947
11	-0.01114
12	0.086421

Table. 5 Correlation between Masking policy and Case numbers

- Interpretation - Although there was no direct relation between the two, We can say the data sheds some light towards a delayed correlation. While the correlation coefficient of 0.1787 does not indicate a strong linear relationship either, it is significant enough to suggest that the impact of masking policies may not be immediate but could manifest over a more extended period. This delayed effect could be attributable to various factors such as the incubation period of the virus, the time required for policy adoption and behavioral change, and the indirect effects of such policies on transmission dynamics. However, it is crucial to acknowledge that correlation does not imply causation.

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