Maryland Department of Health's Recommended COVID-19 Response

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Executive Summary

As the COVID-19 pandemic escalates, we analyzed Maryland's data to determine how the Maryland Department of Health (DoH) should distribute resources in combating the outbreak. We examined which populations are most vulnerable to COVID-19, which counties are facing higher cases and deaths, and what factors contribute most to the number of fatalities. Our findings helped shape recommendations for the Maryland DoH to provide the most support to at-risk groups and geographic areas in terms of prevention, contact tracing, testing, hospitalizations, and vaccine distribution. In order to prioritize resource distribution within the high-risk groups, further analysis is needed to determine which counties have the fewest resources available and how that may relate to their COVID-19 case/death counts.

Problem Statement

I. Background

In 2020, the COVID-19 pandemic has spread rapidly across the United States. According to the Johns Hopkins University Coronavirus Resource Center, Maryland had 228,471 cases and 5,064 deaths as of December 12, 2020.[1] The Maryland state government has implemented measures in four areas: testing, hospital capacity, supply of personal protective equipment (PPE), and contact tracing.[2] The government has tested over 4 million individuals, expanded staffing support in hospitals and alternative site care capacities, distributed over 78 million PPE units, and entered 97,000 contact tracing cases.[2] Maryland has launched the MD COVID Alert app, which notifies individuals if they came into close proximity with people who have tested positive.[3] Maryland has also issued guidelines for wearing masks, social distancing, and avoiding non-essential travel.[4] With the recent breakthroughs and approvals in vaccines, the state has unveiled the "Maryland COVID-19 Vaccination Plan." Phase I will focus on distributing vaccines to healthcare workers, nursing-home residents, and essential workers, and Phase II will shift towards vaccinating the general public.[5] As the COVID-19 pandemic escalates in severity, however, the Maryland DoH still has much more challenges to overcome.

II. Industry

Policymakers, organizations, and individuals in the United States are managing the effects of COVID-19 in different ways. From a policy perspective, 43 states issued state-wide stay-at-home and social distancing orders to combat disease spread.[6] 31 states mandated the wearing of face coverings in public spaces.[7] The closure of non-essential businesses demonstrated the eagerness of some states to get the virus back under control. Equally important to policies have been medical interventions: more resources have been dedicated to testing, hospital capacity, new/existing treatments, and the number of health workers in most states. Likewise, insurance benefits have been expanded to cover COVID-related costs.

Despite implementing a combination of policy and medical interventions, no state has successfully solved how to prevent COVID-19 deaths, hospitalizations, and cases. There are three reasons why these problems have persisted nationwide: First, public health is underfunded and poorly equipped. The third coronavirus relief bill granted the Center for Disease Control (CDC) $4.3 billion to allocate to federal, state, and local health departments. This pales in comparison to the pandemic's projected $16 trillion financial impact. Furthermore, only 2.5 cents for each dollar of U.S. health spending goes towards public health.[8,9,10,11] The country's

public health system is ill-equipped to implement effective disease prevention strategies. Second, there is a lack of top-down coordination.[12] The government lacks a universal, coordinated strategy for federal, state, and local agencies to follow. The private sector has struggled with shifting production, research, and distribution capabilities to goods and services that improve health outcomes. This has led to shortages of and over-paying for ventilators and PPE. Third, the idea of individual freedom generally takes precedence over collectivism and government intervention. While countries like China, Vietnam, and South Korea, have been able to mitigate pandemic spread, the U.S. still struggles to balance individualism and collectivism.

Lack of public-health funding, a coordinated and enforced strategy, and ideological beliefs have led to a desperate situation in the U.S., and it is likely to get worse if changes aren't made. In Maryland alone, the model projects that total deaths will double from ~5,000 as of 12/13/2020 to ~10,000 by 4/1/2021.[13] If mandates ease, that number is expected to reach ~13,000. The model also predicts hospital capacity to reach 88% by 1/26/2021, which could strain the system and affect quality of care. Economic ramifications will likely total more than the $2 billion, which Maryland estimated in August 2020 when cases and deaths plateaued.[14]

III. Stakeholders

Key stakeholders in the pandemic are the American people and, because this is a Maryland-centric analysis, those of Maryland. Nationwide, statewide, and county-level health departments are leading coronavirus efforts; the Maryland DoH provides a wealth of information.[15] Local (county) health departments, such as that of Baltimore City, are involved but do not provide as much information as the Maryland DoH does.[16,17]

Although this is not an exhaustive list, other key stakeholders include hospitals and front-line health workers, who have seen a surge in COVID-19 cases and a sharp drop in available ICU beds; local businesses, whose bottom lines have been impacted by lockdown restrictions; employed people, many of whom have laid off, furloughed, or told to work from home; and students and the education system, which have transitioned remote learning.

The most significant stakeholder in our analysis, however, is the Maryland DoH, as our analysis will impact resource distribution to help contain the spread of the coronavirus. As the pandemic slows and vaccines roll out, we hope to return to a "new normal," a life similar to - but not the same as - the one led prior to the COVID-19 outbreak. We hope that hospitals and medical workers will no longer be overwhelmed, that local businesses will eventually conduct business as normal, and that students will return to schools and employees to workplaces.

IV. Business Question

How should the Maryland Department of Health optimize its distribution of resources to protect both vulnerable populations and the most severely affected areas?

Data Analysis, Interpretation, and Findings

I. COVID-19 Cases and Deaths Over Time By County

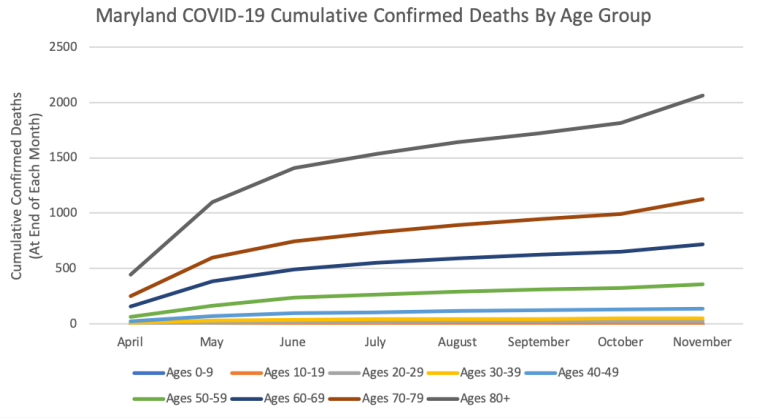
In order to show a "story" and illustrate how the COVID-19 clusters may have changed over time, cluster analyses were conducted for three dates: April 3, August 4, and December 4, 2020. (April 3 is the earliest date with available data, August 4 is the "midpoint," and December 4 is the most recent date from when we completed our analysis). There were three clusters (high cases/deaths, very high cases/deaths, and low cases/deaths) that appeared for each date.

		MASTER INTERPRETATION			OVERALL
County	MASTER CLUSTER (Apr/Aug/Dec)	3-Apr-20	4-Aug-20	4-Dec-20	
Anne_Arundel	111	high cases, high deaths	high cases, high deaths	high cases, high deaths	started with high cases and deaths
Baltimore	111	high cases, high deaths	high cases, high deaths	high cases, high deaths	and continued with high cases/deaths up to present
Baltimore_City	111	high cases, high deaths	high cases, high deaths	high cases, high deaths	
Carroll	123	high cases, high deaths	low cases, low deaths	low cases, low deaths	started with high cases and deaths
Howard	123	high cases, high deaths	low cases, low deaths	low cases, low deaths	got it relatively under control by the midway point and had lower cases/deaths
Allegany	223	low cases, low deaths	low cases, low deaths	low cases, low deaths	started with low cases and deaths
Calvert	223	low cases, low deaths	low cases, low deaths	low cases, low deaths	maintained low case and death counts
Caroline	223	low cases, low deaths	low cases, low deaths	low cases, low deaths	
Cecil	223	low cases, low deaths	low cases, low deaths	low cases, low deaths	
Charles	223	low cases, low deaths	low cases, low deaths	low cases, low deaths	
Dorchester	223	low cases, low deaths	low cases, low deaths	low cases, low deaths	
Frederick	223	low cases, low deaths	low cases, low deaths	low cases, low deaths	
Garrett	223	low cases, low deaths	low cases, low deaths	low cases, low deaths	
Harford	223	low cases, low deaths	low cases, low deaths	low cases, low deaths	
Kent	223	low cases, low deaths	low cases, low deaths	low cases, low deaths	
Queen_Annes	223	low cases, low deaths	low cases, low deaths	low cases, low deaths	
Somerset	223	low cases, low deaths	low cases, low deaths	low cases, low deaths	
St_Marys	223	low cases, low deaths	low cases, low deaths	low cases, low deaths	
Talbot	223	low cases, low deaths	low cases, low deaths	low cases, low deaths	
Washington	223	low cases, low deaths	low cases, low deaths	low cases, low deaths	
Wicomico	223	low cases, low deaths	low cases, low deaths	low cases, low deaths	
Worcester	223	low cases, low deaths	low cases, low deaths	low cases, low deaths	
Unknown	223	low cases, low deaths	low cases, low deaths	low cases, low deaths	
Montgomery	332	very high cases, very high deaths	very high cases, very high deaths	very high cases, very high deaths	started with the highest case/death counts
Prince_Georges	332	very high cases, very high deaths	very high cases, very high deaths	very high cases, very high deaths	and continued to have the highest case/death counts

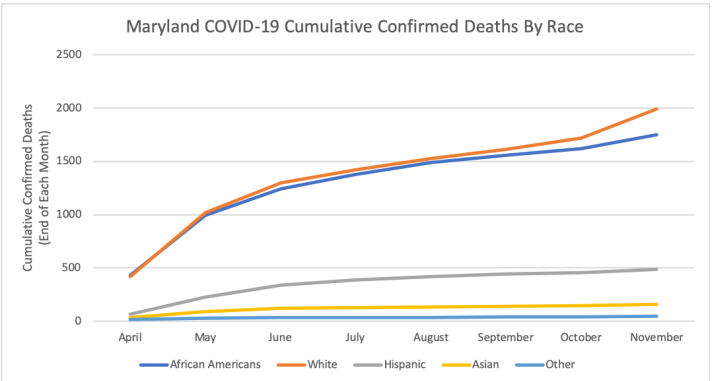
The image shows the results of the cluster analyses conducted for each date and the overall interpretation for trends in COVID-19 cases/deaths over time. The cluster groups were:

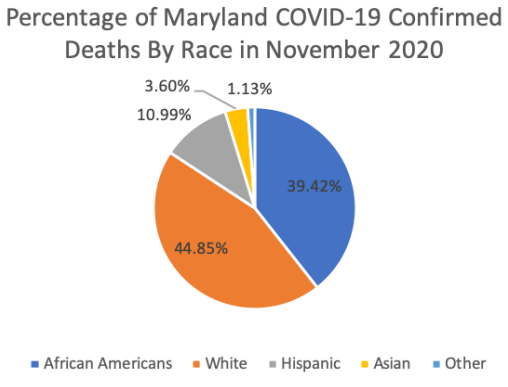
1. Cluster 111: High cases/deaths on all three dates
2. Cluster 123: High cases/deaths on April 3; low cases/deaths on August 4 and December 4
3. Cluster 223: Low cases/deaths on all three dates
4. Cluster 332: Very high cases/deaths on all three dates

II. At-Risk Population Groups



The graph demonstrates that confirmed deaths are higher for older individuals, and that gap has widened during the pandemic. The U.S. Census Bureau[18] estimates that individuals over 65 account for only 15.9% of the population, but the graph shows that people ages 60+ represent 87% of Maryland's cumulative confirmed COVID-19 deaths.





The line graph illustrates racial discrepancies. In November, whites and African-Americans had around 2,000 confirmed deaths. Hispanics, Asians, and other races had below 500 deaths. The U.S. Census Bureau[18] estimates that whites make up 58.5% of the population, African-Americans 31.1%, Hispanics 10.6%, and Asians 6.7% (Hispanics may be double-counted in the data if they have reported being part of multiple races). The pie chart shows that African Americans and Hispanics account for larger percentages of COVID-19 confirmed deaths than their percentages of the total population, which means that they could be more at risk.

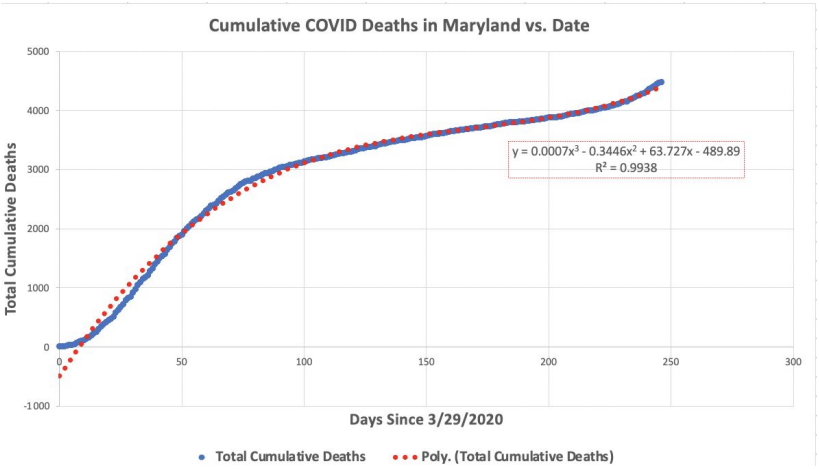
III. Predictors and Problem Scope

Hospitalizations are the primary driver for COVID-19 deaths in Maryland. Thus, the Maryland DoH should focus on disease prevention and the quality of hospital care. The inverse relationship between deaths and testing signals that testing alone is not a solution. Likewise, the rolling average percent positive trend suggests that disease prevalence is increasing at a faster rate than deaths. This could also mean that the disease is becoming less viral.

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	**155.6687532**	15.30644135	10.170147	**1.904E-20**
Daily Total Tests	**0.001196659**	0.000294253	4.0667627	**6.46E-05**
Total Cases	**-0.023330713**	0.000341452	-68.32786	**9.6E-160**
Total Hospitalizations	**0.353647773**	0.005607283	63.069359	**8.35E-152**
Rolling Average % Positive	**-20.64741629**	0.535708629	-38.54225	**4.98E-105**
Total Cases Age >60	**0.042615389**	0.004148986	10.271279	**9.197E-21**

Predict Total Number of Deaths by a Certain Date (R Square = 0.9996)

Total Deaths = 155.6687532 + 0.001196659(Daily Total Tests) - 0.023330713(Total Cases) + 0.353647773(Total Hospitalizations) - 20.64741629(Rolling Average % Positive) + 0.042615389(Total Cases Age >60)



Since 3/29/2020, total cumulative deaths can be fit using a 'poly^3' fitting equation. The fitting model predicts that by 12/30/2020, 5,556 deaths will have occurred (10% more than the ~5,000 on 11/30/2020). Although deaths plateaued during summer months, the model suggests deaths will occur at an increasing rate starting in November and into the spring.

Recommendations

I. Distribution of Resources

Our data analysis generates recommendations for how the Maryland DoH should distribute resources in the COVID-19 pandemic response, particularly in terms of prevention, contact tracing, testing, hospitalizations, and vaccine distribution.

II. Short-Term and Long-Term Responses

In the short-term, the Maryland DoH should prioritize distributing resources to protect more at-risk populations and the counties most severely impacted by the pandemic. Building upon our initial data analysis about COVID-19's toll in cases and deaths, the state should determine which locations have the largest vulnerable populations and the least financial and public health resources. Supporting the highest-risk and most resource-constrained counties could help minimize COVID-19's impact. When expanding hospital capacity, contact tracing, personal protective equipment (PPE), and testing supply, the Maryland DoH should increase coordination with county governments to better understand the situation in different counties and

adapt to their unique challenges. This requires streamlined communication with hospitals, nursing homes, long-term care facilities, and testing centers. With limited resources to combat the COVID-19 pandemic, the Maryland DoH's optimal response is to provide resources to the areas that are most at risk. In the long-term, once the needs of high-risk groups are filled, the government should address the needs of those who are not part of vulnerable populations.

In order to implement these responses, however, the government may need to increase funding, especially to accommodate for increased demand in healthcare supplies and contact tracing efforts. The Maryland DoH can also distribute PPE, vaccines, and testing kits through hospitals, doctor's offices, clinics like Urgent Care, and county governments. If cases and deaths decrease enough for a return to normal, the state could loosen lockdown restrictions.

III. Importance and Impact

If the COVID-19 pandemic is not contained and vulnerable populations do not receive support or care first, followed by the general population, COVID-19 cases will surge, as will the death toll. The existing lockdown and travel restrictions will likely persist. Crucial medical supply shortages may become pertinent issues as cases and deaths rise, and the shortage of healthcare professionals may become an even larger issue than the lack of PPE.[19] Our data analysis projected that deaths will occur at an increasing rate over winter 2020 and into spring 2021. The U.S. Center for Disease Control agrees, forecasting that reported COVID-19 deaths will increase such that "332,000 to 362,000 COVID-19 deaths will be reported by [January 2, 2021]," a number larger than the number of Americans who died in World War I.[20,21]

The economic ramifications of an uncontained and undeterred COVID-19 pandemic are shocking: Research conducted by the USC Center for Risk and Economic Analysis of Terrorism Events (CREATE) shows that the United States could lose $3-4 trillion in GDP over the next two years, just from the business closures and partial reopenings that occurred during the pandemic.[22] This does not take into consideration productivity lost as a result of people contracting the virus, workdays taken off to care for others, and job losses that could affect millions of people.

IV. Implementation Specifics

The implementation timeline will follow the state's vaccine rollout plan. Maryland will receive 155,000 doses and plans to administer those vaccines through December 2020 and January 2021.[23] Only a portion of high-risk groups, like frontline medical professionals, long-term care facility workers, and first responders, will be vaccinated; the population at large will still be susceptible. Until high-risk demographics and counties are vaccinated, it is critical that they are prioritized for resource distribution to mitigate deaths and hospitalizations.

After the initial vaccine rollout, the timeline continues until herd immunity is reached; the goal is fall 2021.[23] Throughout the nine month timeline, the state should continue to expand its medical supply stockpile, expand testing, and enforce mask-wearing. Implementation risks include funding, vaccine supply chain, and individual choices/behavioral economics.

There are four metrics the Maryland DoH should monitor to evaluate efficacy. The first is case-fatality rate (CFR), divided by the aforementioned demographic subgroups. While the CFR has been decreasing overall, it is important to monitor CFR for disparities and to ensure that high-risk groups are no longer as vulnerable. The second is R0, which measures how many people will contract the disease from one infected person. An effective implementation means that R0 should decrease, which can be measured via contact-tracing and testing data. The third is hospital capacity. The analysis showed that hospitalizations and deaths follow similar trends. It is important to measure percent of available beds to see if: 1) hospitalizations are declining, and 2)

there is capacity to meet demand. The final metric is the percent of the population that is vaccinated. While it is unlikely that Maryland will enter a full lockdown, herd immunity is critical for disease prevention. Because of the vaccine's >90% efficacy, epidemiological models indicate that 60-70% of the state's population will need to be vaccinated.[24]

V. Adapting COVID-19 Response to Future Disease Outbreaks

Response can be thought of as a four-step process: preparation, assessment, intervention, and assurance. The Maryland DoH needs to proactively prepare for a future outbreak. This means investing more in local public health departments, training health workers in pandemic procedures, building a stockpile of PPE, and developing a scalable plan for testing and containment. After the MERS outbreak, countries like South Korea followed these adaptations and were better-equipped to handle COVID-19.[25]

Next, the Maryland DoH should quickly assess the situation. This encompasses disease dynamics, capabilities, and health capacity. They should also assess what resources and information it needs from federal and local agencies. Once the problem is defined, there needs to be quick and aggressive intervention. Action items include policy recommendations, health services, or education. The last step is assuring that health outcomes are improved. KPI monitoring and ensuring that service delivery occurs are critical. This approach will allow the Maryland DoH to be flexible during future outbreaks.

Appendix

Here is the final GitHub repository.

Cluster Analyses

Data Sources

Data (Cases by County and Confirmed Deaths by County) was downloaded from the Maryland Open Data Portal.

Python

This Python Google Colaboratory file shows the data cleaning used for the December 4 dataset, as well as scatter plots for each of the chosen dates. Excel was used for all cluster analyses. Data cleaning for the other two dates' datasets were also conducted in Microsoft Excel.

Excel

To conduct the data cleaning in Excel:

1. Download data from the Maryland Open Data Portal.
2. Transpose the data such that the counties are the rows and the columns are the case/death counts.
3. Choose the three desired dates for data analysis.
    a. April 3 is the earliest date for which there is data for both cases by county and confirmed deaths by county.
    b. The data was downloaded on December 4, which is the most recent date in the dataset.
    c. August 4 is the date that was "in the middle" of April 3 and December 4.
4. Delete all dates that are not required for data analysis.
    a. This will have to be done twice, once for the April 3 dataset and once for the August 4 dataset.
5. For the April 3 dataset:
    a. Calculate standard deviation and mean for each variable (the case count and death count).
    b. Calculate the z values for each of the variables using the STANDARDIZE function.
    c. Create another table with the columns "anchor," "county #," "county name," and the z value. Pull the county name and z variables using VLOOKUP. Use three anchors.
    d. Add three columns to step 4a's table. Name these "dist 2_1," "dist 2_2," and "dist 2_3."
    e. Use the SUMXMY2 function to pull values for each of the "dist 2_x" columns.
    f. Add another column and call it "min dist^2" (minimum distance squared). Input numbers in this column by using the MIN function, with the values coming from one row of the "dist 2_x" columns.
    g. Create a new column at the end called "anchor" and use the MATCH function to see which anchor it corresponds with.
    h. Calculate the sum of the minimum distance squared by using the SUM function for all the values in the "min dist^2" column.
    i. Run a cluster using the Solver add-in.

        i. Make sure the solving method is “Evolutionary.”
6. Repeat step 4 and its constituent substeps for the August 4 dataset.
7. To interpret the clusters:
    a. Make a worksheet containing the cluster anchors for all three datasets and interpret the results for each anchor/cluster. Name it the “anchors + clusters” worksheet.
    b. Compile a list of clusters and which county falls into which cluster for each date. Add in the anchor number and the corresponding interpretation for each cluster. Name this worksheet “interpretation.”
    c. Make a master table to visualize which county belongs to which cluster for each group of data. Create a “Master Cluster” column that combines the three anchor numbers for each colony, and use Conditional Formatting and a 3-point color scale to visualize which counties share similar clustering tendencies across the three data groups.
    d. Add in the corresponding interpretations from the “interpretation” worksheet. Name these as the “Master Interpretation” columns, and label each column according to its date.
    e. Consolidate the interpretations into a new “Overall” column that summarizes the interpretations across dates for easy trend viewing.

Pivot Table Graphs

Data Sources

The following datasets were downloaded from the Maryland Open Data Portal

- MD COVID-19 - Confirmed Deaths by Race and Ethnicity Distribution
- MD COVID-19 - Confirmed Deaths by Gender Distribution
- MD COVID-19 - Confirmed Deaths by Age Distribution

Python

The Python Google Colaboratory file replicates the Excel analysis described below.

Excel

1. Use VLOOKUP to combine the race, gender, and age data based on the date.
2. Age Line Graph:
    a. Identify the confirmed deaths for each age group at the end of each month (April to November 2020) and create a new table with that information.
    b. Insert a line graph based on that table.
    c. Rename the title “Maryland COVID-19 Cumulative Confirmed Deaths By Age Group.”
    d. Rename the y-axis “Cumulative Confirmed Deaths (At End of Each Month).”
3. Replicate the steps above for the race and gender line graphs.
4. Race Pie Chart:
    a. Use a formula to calculate the percentage of confirmed deaths that each group had at the end of November.
    b. Insert a pie chart based on that table.
    c. Rename the graph to “Percentage of Maryland COVID-19 Confirmed Deaths By Race in November 2020.”

Multiple Linear Regression

Data Sources

The following data sources were used from the Maryland Open Data Portal

- Maryland's Confirmed COVID-19 Deaths by Date
- Maryland's Confirmed COVID-19 Hospitalizations by Date
- Maryland's Confirmed COVID-19 Testing by Date
- Maryland's Confirmed COVID-19 Total Cases State-wide by Date
- Maryland's Confirmed COVID-19 Total Hospitalizations State-wide by Date

Python

This Python Google Colab Notebook provides instructions for calculating weekly rolling averages for deaths, hospitalizations, and tests in Maryland.

Excel

1. Use VLOOKUP to merge deaths, hospitalizations, testing, and cases workbooks into one worksheet (use dates as the unique identifier).
2. Standardize the worksheet dates by including data from 3/29/2020-11/30/2020.
3. Use the Data Analysis tool to perform a Regression analysis with 'Total Deaths' as the dependent variable and 'Daily Total Tests,' 'Total Cases,' 'Total Hospitalizations,' 'Rolling Average % Positive,' and 'Total Cases Age > 60'
4. Create a new worksheet with a column as 'Total Deaths' and 'Days Since 3/29/2020', and insert a scatter plot.
5. Insert a best-fit line and pick a polynomial raised to the 3rd power.

Citations

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