Introduction

World Health Organization has declared COVID19 a pandemic since March 11, 2020, and since the outbreak, more than 13 million people have been infected around the world. There have been many studies on the effect of different indices and factors on the COVID19 numbers in different countries. But to the best of author's knowledge, there has not been any study on the response of countries based on their GDP, hospital beds, age over 65, diabetes prevalence, etc.

In addition, in another part of this report, the effect of women leadership representation on COVOID response was studied based on ministerial percentage, women political score and whether the current leader is female or not. Unfortunately, only a mere 10 percent of total world leaders are women which makes it difficult for any statistical analysis.

Methodology

Data Source

The data in this report has been collected from three different sources.

The women leadership data have been downloaded from Council Foreign Relations (https://www.cfr.org/article/womens-power-index). The dataset contains excellent information about percentage of ministerial positions held by women, percentage of seats held by women in the national legislature, political score of women in that country.

The COVID data have been downloaded from HDX (https://data.humdata.org/dataset/total-covid-19-tests-performed-by-country). The dataset contains information about daily new cases, deaths, tests and also other information such as GDP, number of hospital beds, handwash stations, percentage of population over 65 and 70, etc.

Last, health expenditure data by country have been downloaded from WHO (https://apps.who.int/nha/database/Select/Indicators/en). The dataset has the health expenditure information since 2000 (% of GDP).

Data Wrangling and Exploratory Data Analysis

COVID dataset columns were reduced from 34 to 21 after removing irrelevant columns. Negative values were replaced by zero and 'World' row was removed. The shape of the dataset decreased to 28243, 21. Figure 1 shows the daily new deaths per million for 10 sample countries from January to June. There is a high variation among the total cases and total deaths of countries around the world.

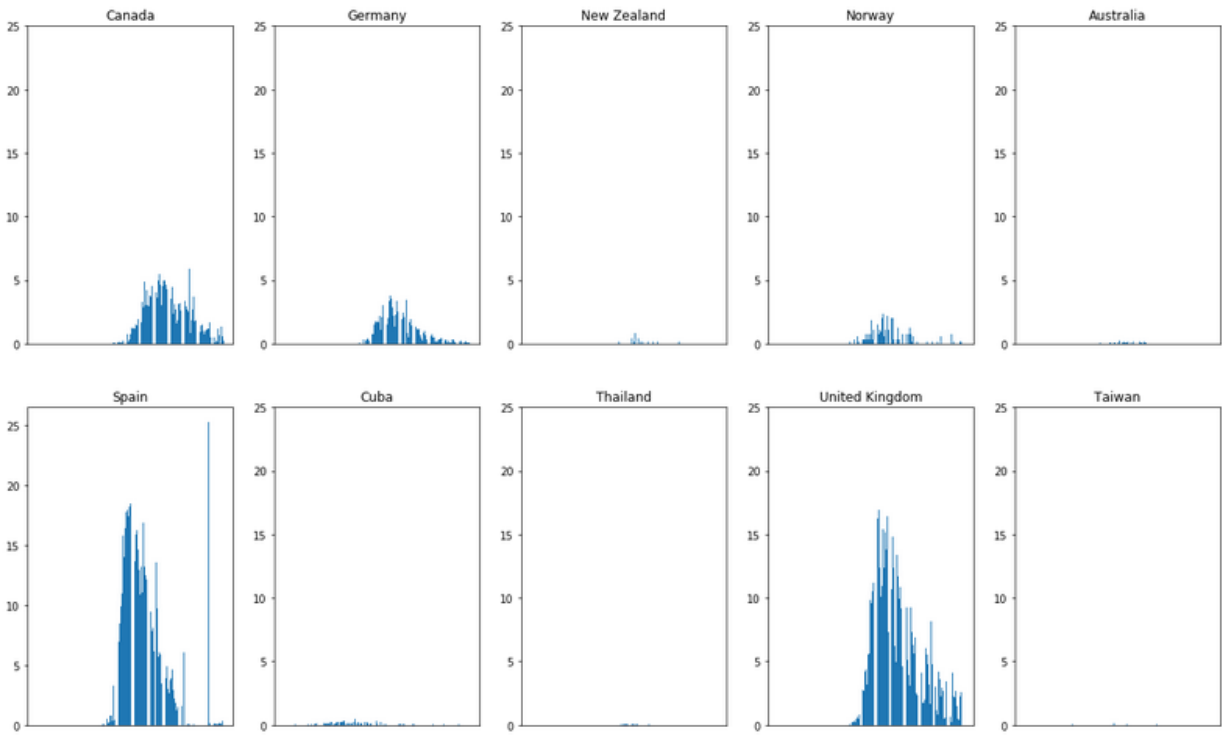

Figure 1 Daily new cases for 10 sample countries from January to July. Cuba, Thailand, and Taiwan total cases are extremely small.

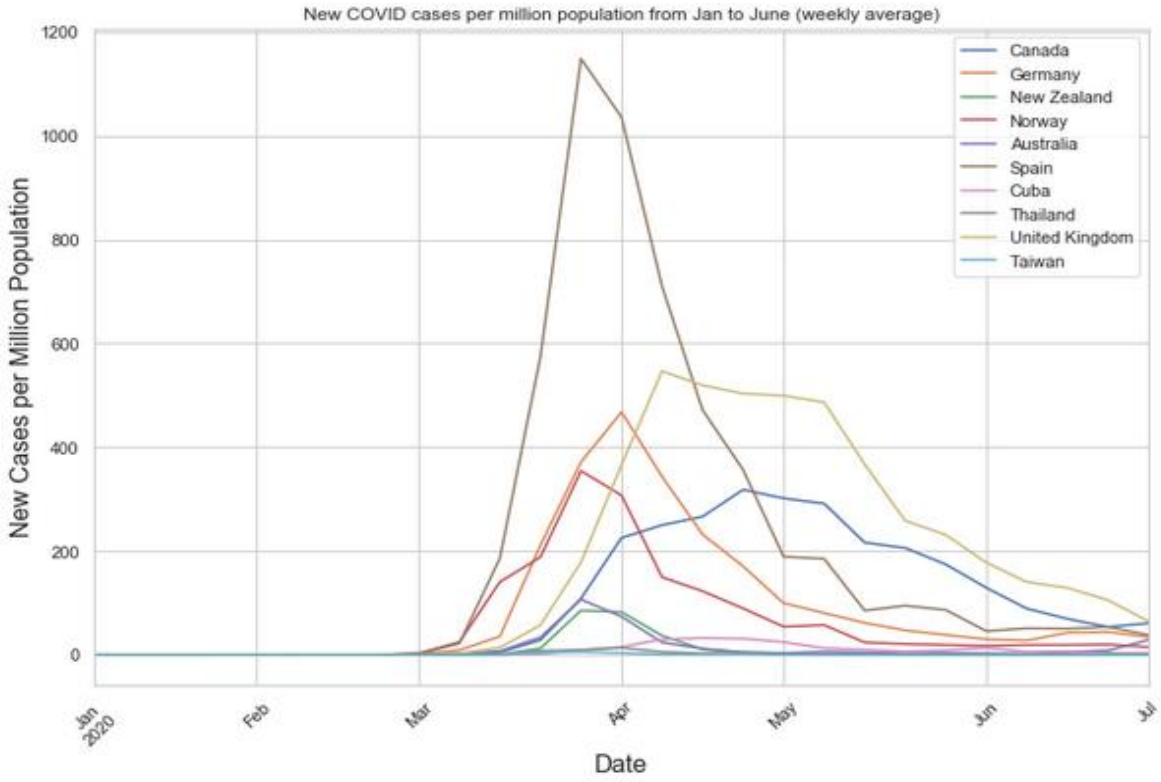

Figure 2 Weekly new cases per million for 10 sample countries from January to July.

Even though there are some missing values (e.g. diabetes prevalence, hospitals bed, etc.) in the dataset, they were still included in the final dataset for significance study. Also, the daily numbers were summed to calculate the weekly numbers to smoothen the curves and reduce the effect of weekends identified new cases and deaths. Figure 9 shows the relationship between total cases and deaths and age. Even though they seem to have a linear relationship, R square is for both plots are less than 0.2.

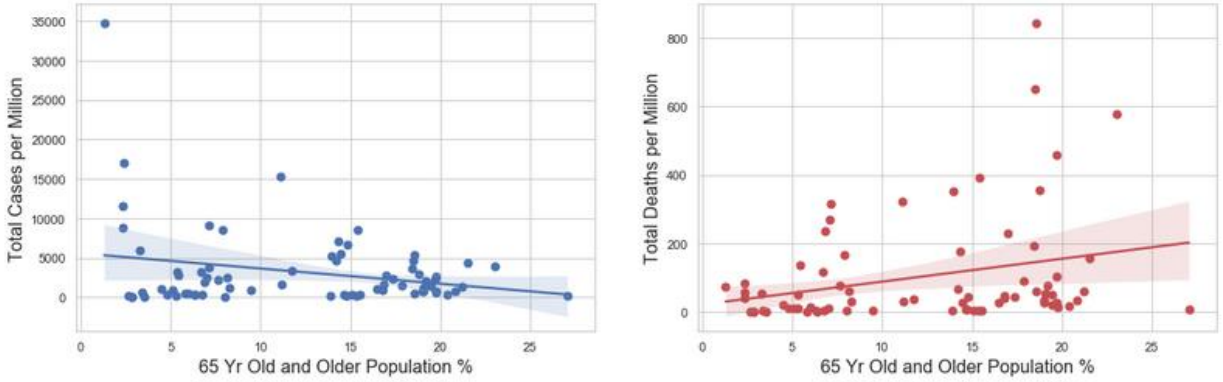

Figure 3 Relationship between different parameters and total cases and deaths. R squared for total cases and deaths are 0.2 and 0.08 respectively. As a result, there is not a strong relationship between population over 65 and total tests and total deaths.

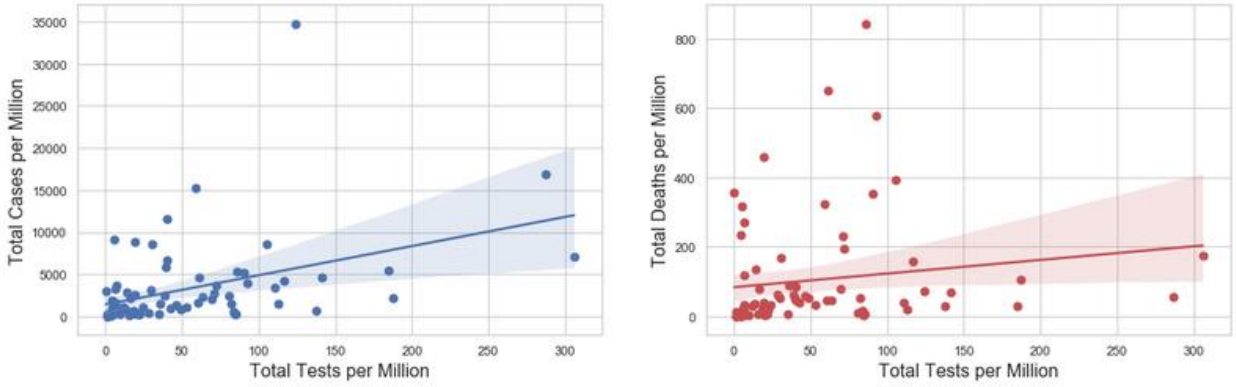

Figure 4 Relationship between different total tests and total cases and deaths. R squared for total cases and deaths are 0.2 and 0.026 respectively. As a result, there is not a strong linear relationship between total tests and total cases and deaths.

Female leadership dataset comprises of 194 different countries and 17 rows. Irrelevant data such as ‘Names of elected and appointed female heads of state or governments since 1946’, ‘Number of elected and appointed female heads of state or governments since 1946’ ‘Region’ and ‘Subregion’ data were removed from the dataset. After removing irrelevant columns, dataset sized was reduced to five columns of location, current head (female or male), ministerial percentage, seats percent and political score. The political parity score (a number between 0 and 100, 100 being the best) is an aggregate of women’s representation across five indicators of political participation: heads of state or government, national cabinets, national legislatures, national legislature candidates, and local legislatures. The index measures women’s descriptive representation, which refers to the numerical presence of women rather than women’s impact or policy preferences.

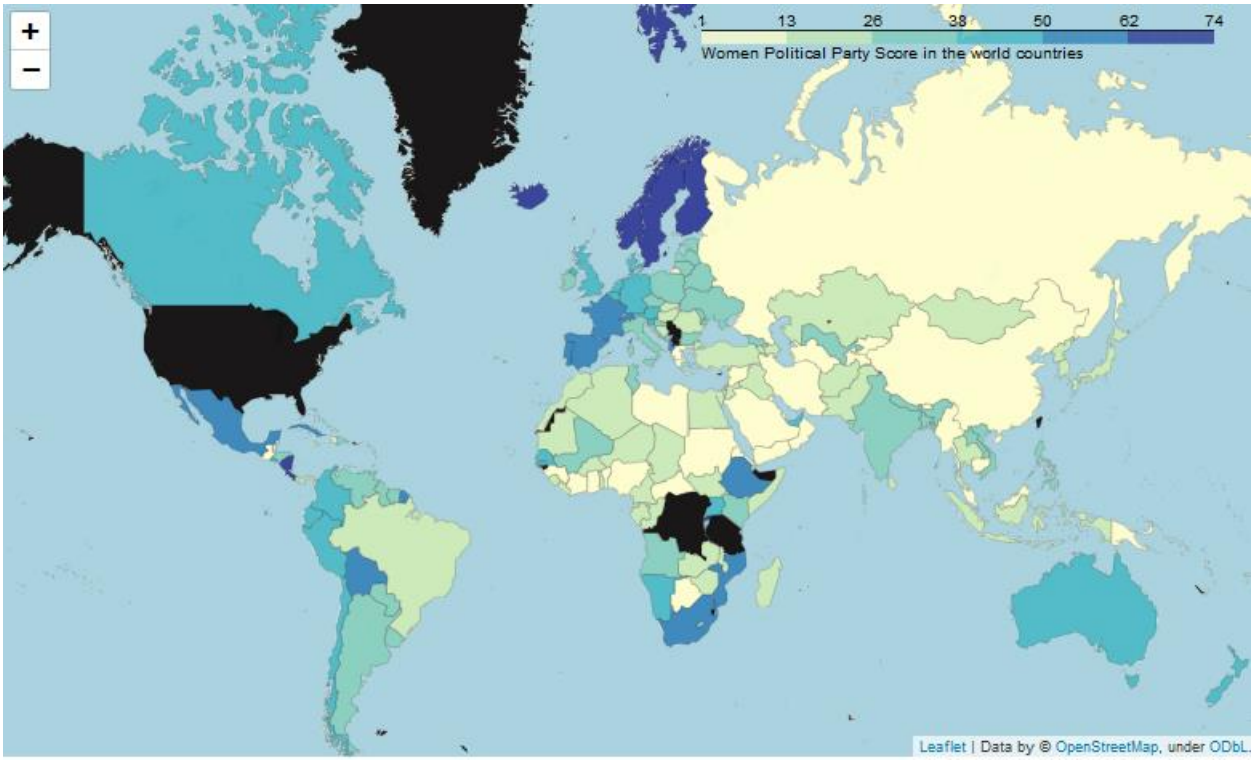

Figure 5 Political score of countries in the world (higher the score, better the women representation)

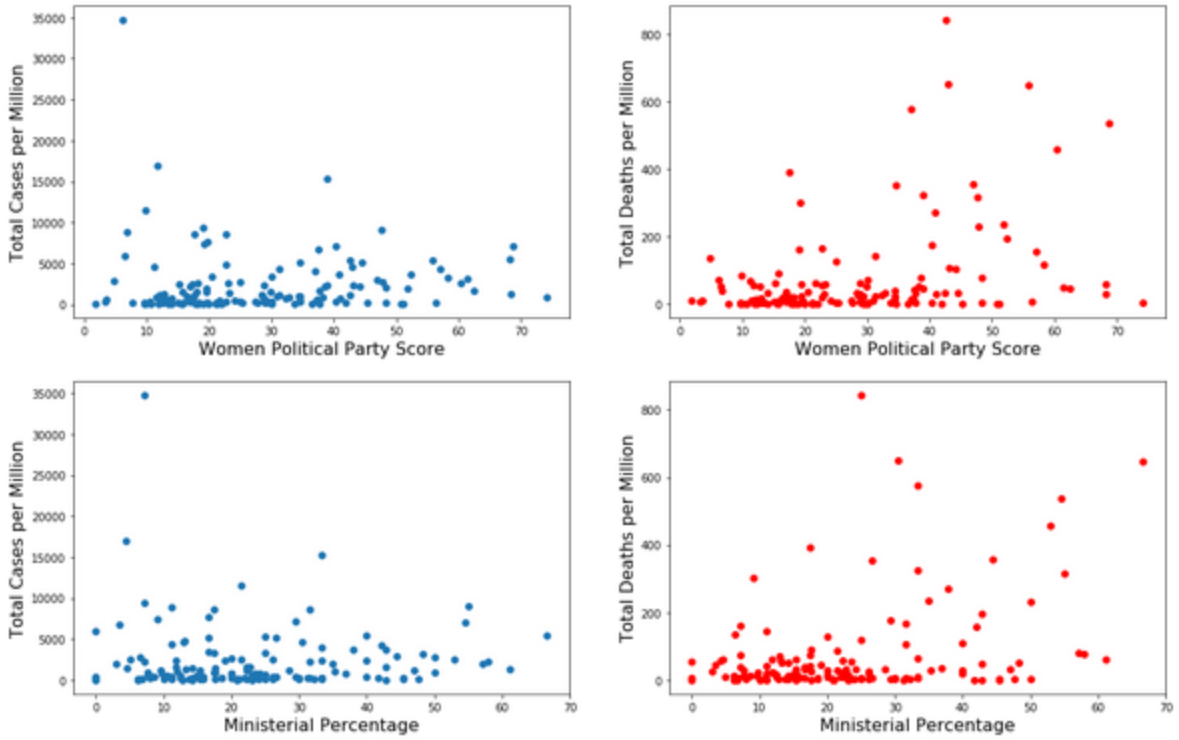

Figure 6 Relationship between women political leadership representation and total cases and deaths. There is no relationship between political party score and ministerial percentage.

Figure 11 shows total cases and deaths versus different women representation numbers (political score and ministerial percentage). No visual relationships were observed between these parameters.

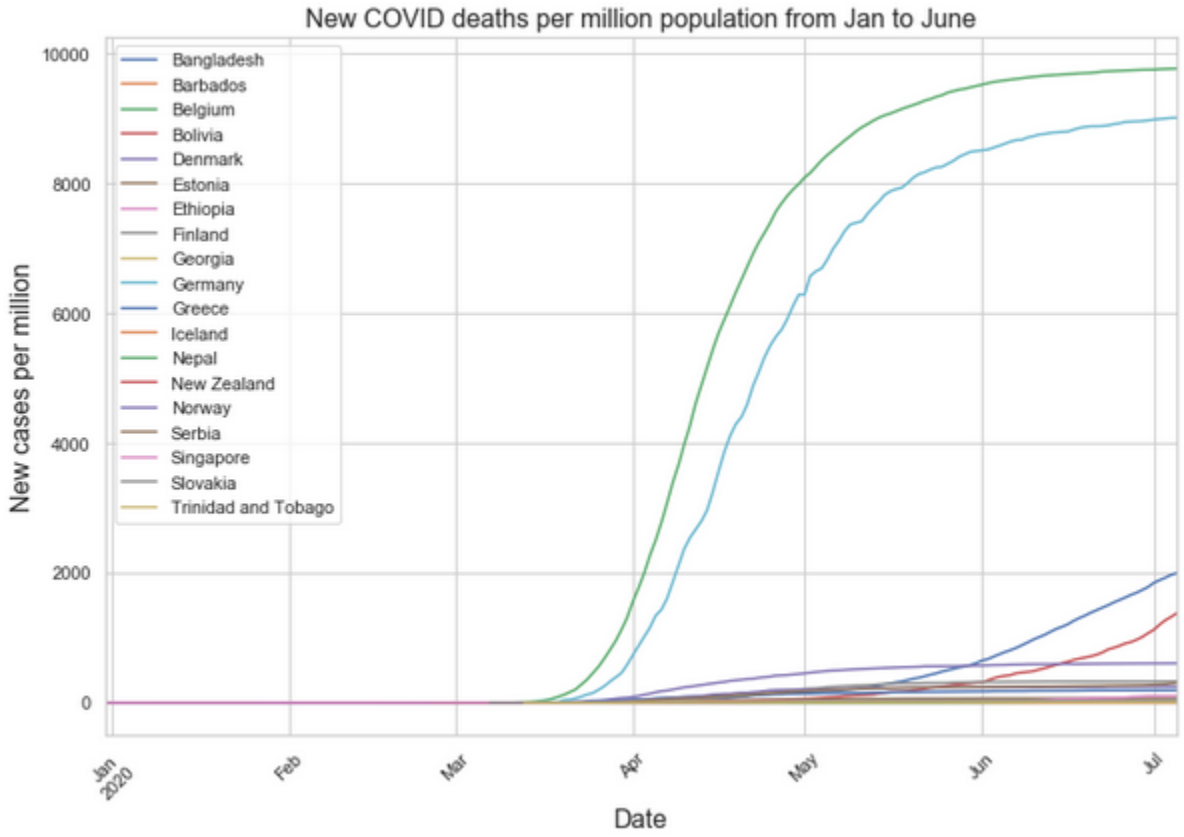

Figure 7 Female led countries' new cases per million from January to July 2020.

Last, only country and health expenditure columns were included in the final health data. Figure 1 shows the data distribution for the health expenditure before removing outliers. Outliers for the health data were identified according to interquartile proximity rule and removed from the dataset. There are several countries with high percentage of health expenditure mostly because of an ongoing war or natural disasters, etc. 37 countries with health expenditure higher than the upper range were removed from the dataset.

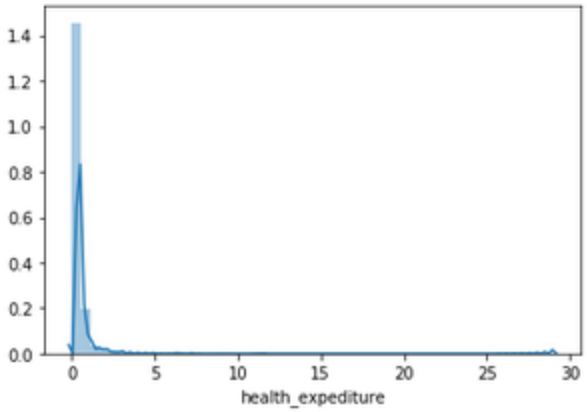

Figure 8 Distribution of health expenditure of 170 countries in the WHO health expenditure data.

In our final dataset, only health data from 2017 were included. Table 1 shows the statistics for the health data. Unfortunately, only 71 countries have available data for 2017.

Table 1 Statistical summary of the health data after removing 37 countries.

Count	133
Mean	0.257513
Standard Deviation	0.148878
Min	0.000662
25%	0.152129
50%	0.249299
75%	0.343456
Max	0.671331

Most countries health expenditure did not see a significant increase from 2000 to 2017 (if not decreased). Table 1 shows that most countries health expenditure have been less than 0.34% of their GDP. I decided to only include the health data from 2017 in the final dataset (fina_data).

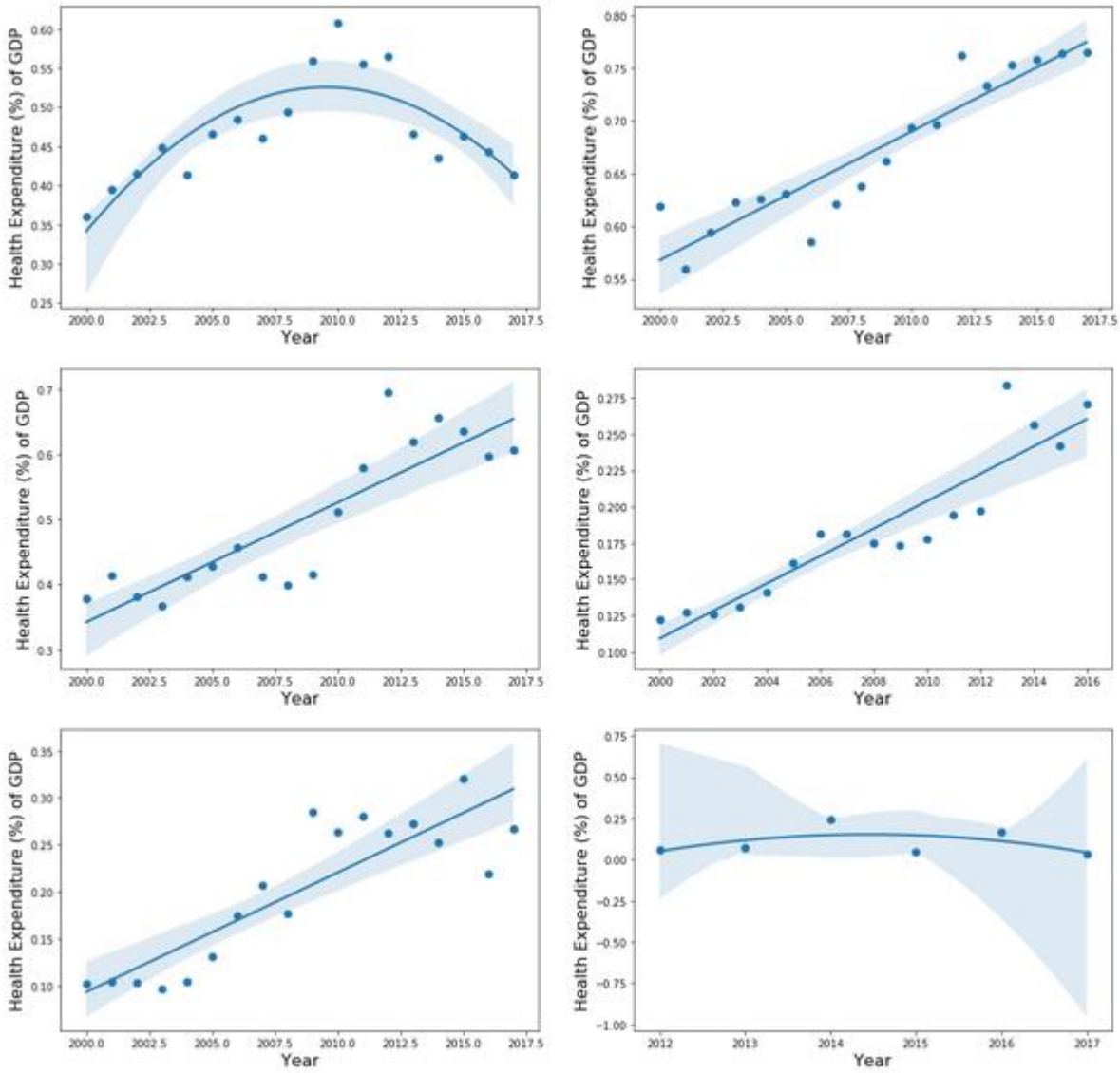

Figure 9 Health expenditure (% of GDP) for six sample countries (2000-2017)

Feature Engineering

In order to evaluate a country's response to COVID, we need to define features that truly represent the data. for example, new cases by itself is not a good feature since it is correlated with the number of tests.

Number of deaths per million can be one of the indicators but still need other features. In addition to number of deaths per million, number of days until the total cases have been increased 10 times also shows how fast a country reacted to the COVID outbreak. Peak mortality also indicates how well a

country can flatten the curve. Other features are peak mortality, days that the country cases surpassed its hospital capacity, early and current accelerations. Some of these features were taken from a Toward Data Science article (see References).

We can say countries with lower early mortality, longer Days until 10x, smaller early and current accelerations.

Early Mortality:

Weekly Number of Deaths 14 days after the Outbreak, divided by the number of Confirmed Cases, in the week of the Outbreak. This feature still may be affected by the total number of tests (as we will see later). In addition, there are more than 50 countries that did not reach 5 per million thresholds for the outbreak. These countries were removed from the final dataset.

Days until 10x:

The number of days it takes from the Outbreak (5 per million total cases) to multiplying the Confirmed Cases by 10. In other words, the time frame from rate 5 per million to 50 per million.

Peak Mortality:

Number of Deaths in the peak week, divided by the number of weekly Confirmed Cases, 14 days before (mortality_rate).

Peak Hospital Occupancy

Average of total cases in the peak week with two weeks before and after to the hospital_beds_per_million assuming only 10% of hospital beds are dedicated to COVID patients.

Days with Maxed Hospital Capacity:

Number of days that a country's total cases has reached their hospital_per_thousands but assuming only 10% of hospital beds are dedicated to COVID patients.

To calculate the number of days (instead of weeks), first the number of recovered cases need to be estimated. Since I didn't have any data on recovered cases, I estimated the number of the recovered cases by the difference between the new cases and new deaths 14 days before (ignoring those in intenstive hospital care for a long period of time) and assuming only 1 in every 5 new cases are hospitalized. And I calculated the number of the hospital beds capacity every day from 10% of hospital beds as hospital_load = hospital_beds_per_thousands*100 - (total_cases_per_million - total_deaths_per_million + total_recovered_cases_per_million)/5. If negative, one day would be counted as hospital overload.

Early Acceleration:

If deltaW0W1 the percentage increase of Confirmed Cases from the week of the Outbreak to the week after, and deltaW1W2 the percentage increase from the 1st to the 2nd week after the Outbreak, then the acceleration is: early_acc = deltaW1W2 / deltaW0W1.

When early acceleration feature was calculated, it was noticed that some of the countries have negative values. This is because the confirmed cases for the second week of outbreak was less than the first week (e.g. New Zealand). As a result, the negative value was replaced with zero.

Final Dataset

All these features were computed using Python and merged with the other two datasets (health and women leadership) and named final_data. Since there is a weak relationship between total tests and total cases and deaths, only countries with nonzero total number of tests were included in the final dataset. In addition, total cases and deaths were plotted against different features and visual outliers were removed from the dataset.

Table 2 Outliers for the final dataset based on the defined features

Feature	Outlier	Countries Removed
mortality_rate	>0.8	Bahamas, Belize, Nicaragua, Sao Tome and Principe, Tajikistan, Chile
Early_mortality	>2	San Marino
Early_acc	>10	Liechtenstein, Albania

As mentioned earlier, countries with no outbreak (less than 5 per million) also were removed from the final dataset.

Statistical Tests

In this report, two statistical tests were used to study the significance of the paired groups: normal paired t test and Welch's t test. In addition, Pearson's correlation coefficients between different features and total_deaths and their significance were also calculated for different features.

Since t test assumes a normality in the data distribution, the normality was tested Shapiro method. All features are lognormal as shown in Figure 13. The test failed to reject H_0 using Shapiro, and therefore, the final_data sample (as well male and female leaders) looked normal.

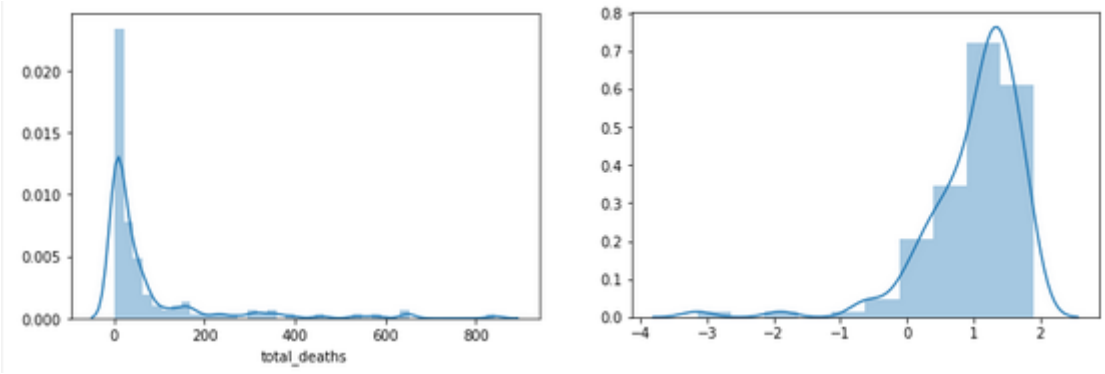

Figure 10 Distribution for final_data on normal (left) and log(x) scale (right).

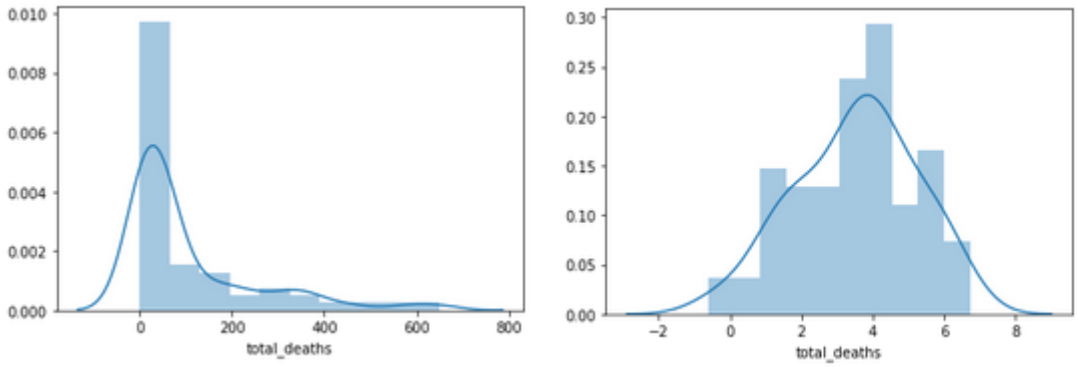

Figure 13 Distribution for countries with male leaders on normal (left) and log(x) scale (right).

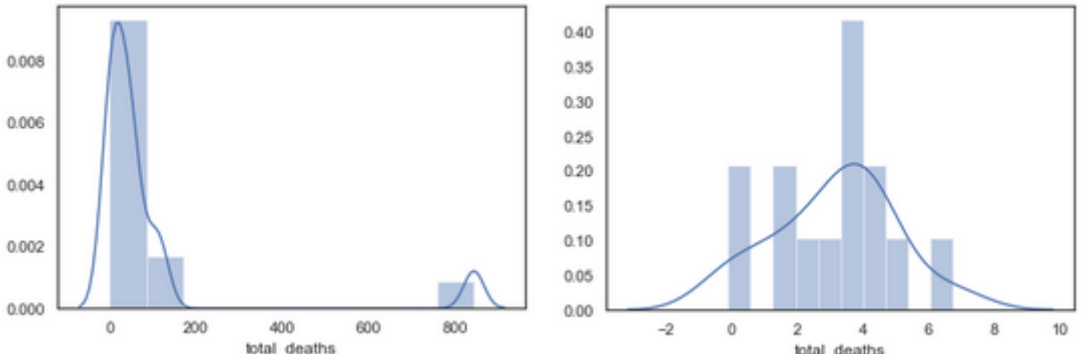

Figure 12 Distribution for countries with female leaders on normal (left) and log(x) scale (right).

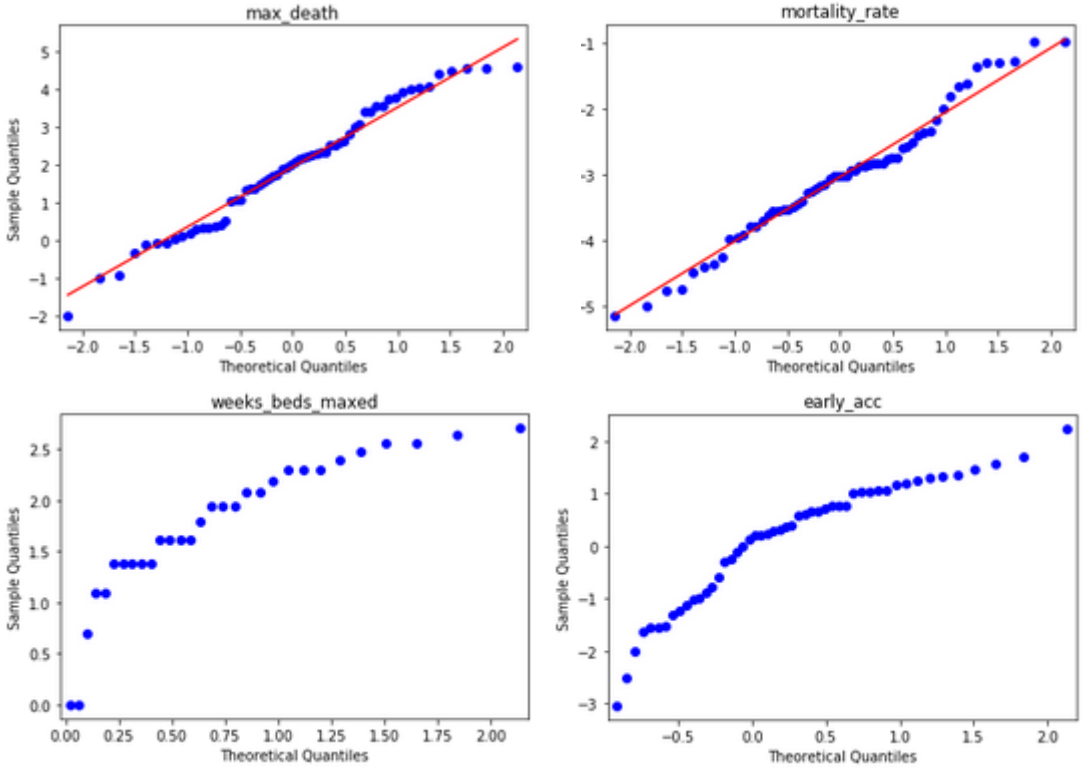

Figure 11 Normality assumption for different features.

Results and Discussion

After removing outliers from the dataset, different features were plotted against women leadership representation and shown in Figures 6 to 8. As we can see, there is only a relationship between total cases and total deaths with total tests. R square values are low ranging from 0 to 0.15 which means that there is not a strong relationship between women political representation and our features. Figure 14 shows some of our defined features versus political score and ministerial representation.

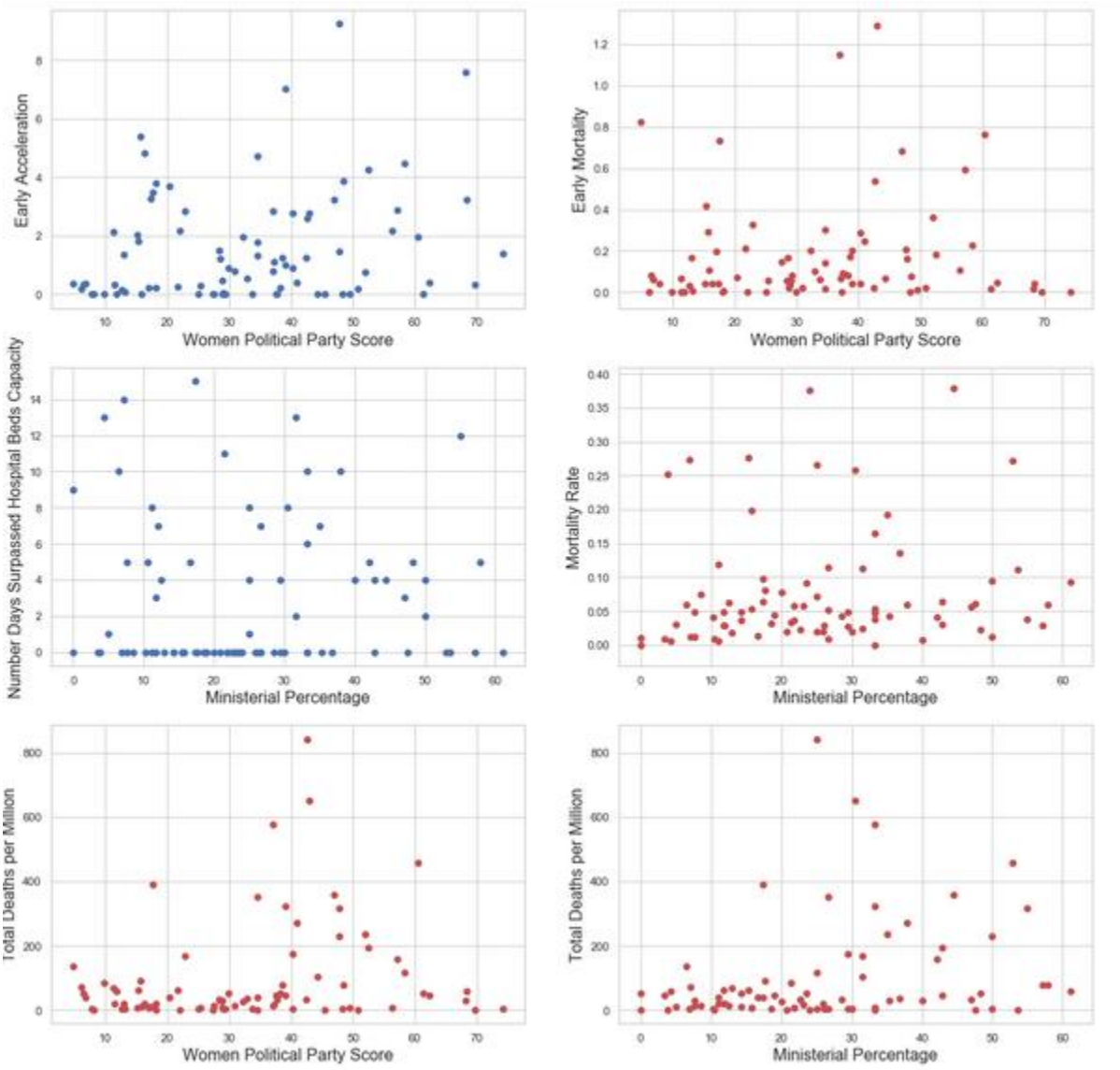

Figure 14 Relationship between different features and women leadership representation. No relationship was observed. R square values for linear, polynomial, and logarithmic (or exponential) fit were less than 0.15.

Figure 15 shows the top 10 largest Pearson coefficients for different features in the final dataset. Using the table of critical values for Pearson coefficient and degree of freedom of 72 (size – 2), the cut-off for 0.05 significance level (or 95 percent critical value) is 0.195. As a result, days_maxed_beds, early_mortality, gdp_per_capita, age_over_65 and early_acc are all significantly correlated with total_deaths.

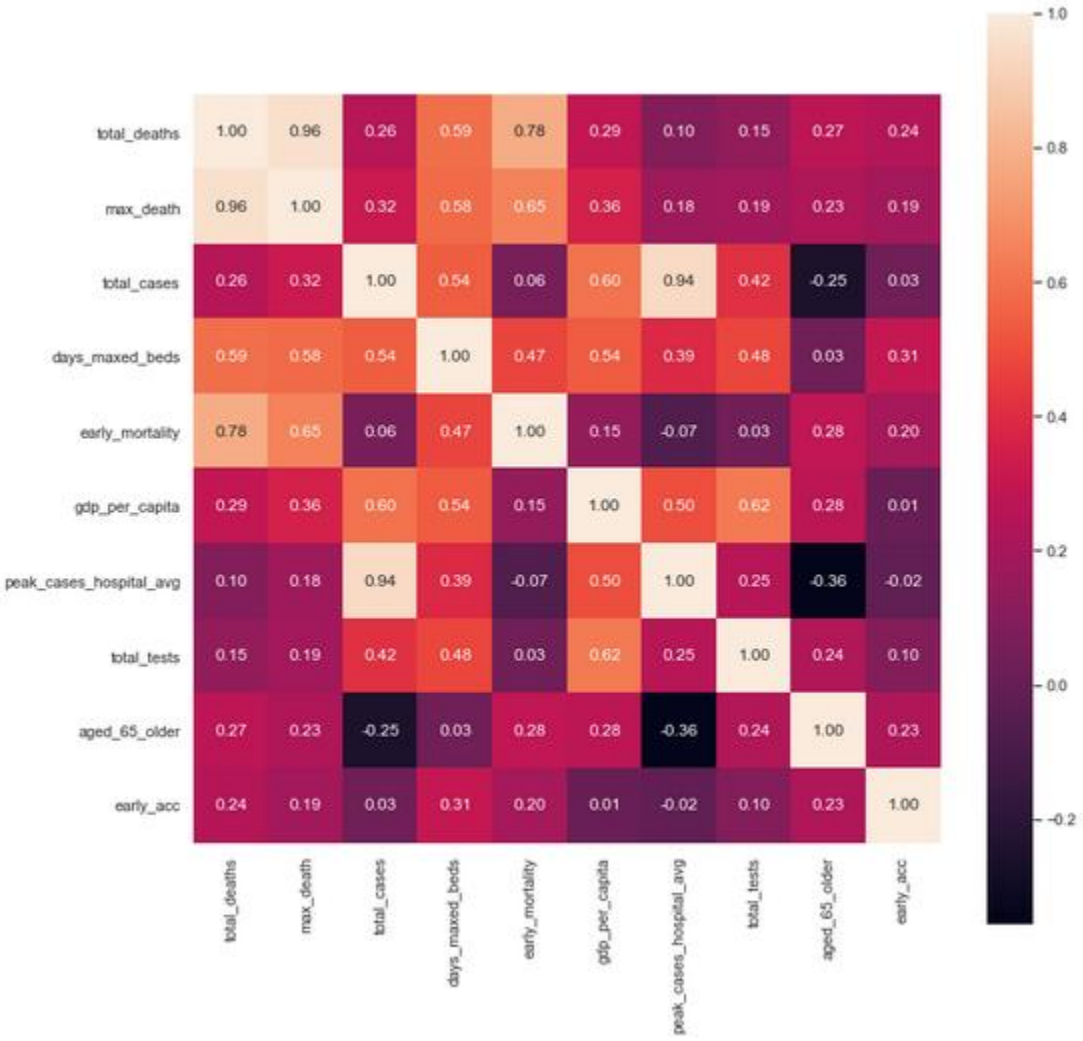

Figure 15 Top 10 Pearson coefficient for based on total_deaths for the final_data.

Finally, Table 3 and 4 show the statistical values (for features with significant Pearson's coefficients) for countries with female and male leaders in the final dataset. Except days_maxed_beds, median for all other features for countries with female leaders are lower than their male counterparts. Since equal variance assumption does not hold, Welch's t test was conducted. The results showed that, with 95 percent confidence interval, there is not enough evidence to suggest that there is a significant difference between these two groups.

Table 3 Statistical summary for countries with male leaders.

	total_cases	total_deaths	aged_65_older	early_mortality	gdp_per_capita	early_acc	days_maxed_beds
count	60.0000	60.000000	60.000000	60.000000	60.000000	60.000000	60.000000
mean	3526.7974	105.827117	11.781883	0.195506	27962.189183	1.554178	37.283333
std	5493.275220	148.304260	6.688278	0.276045	21900.846062	1.736600	37.993350
min	46.963000	0.537000	1.307000	0.000000	0.000000	0.000000	0.000000
25%	474.103250	10.974000	6.217000	0.040347	11974.715500	0.213244	0.000000
50%	1566.062500	39.850000	11.465500	0.082509	24410.771000	1.172466	30.500000
75%	4068.684500	141.212750	18.456250	0.208107	38121.949500	2.320881	77.000000
max	34743.462000	651.059000	27.049000	1.290231	116935.600000	9.251373	101.000000

Table 4 Statistical summary for countries with female leaders.

	total_cases	total_deaths	aged_65_older	early_mortality	gdp_per_capita	early_acc	days_maxed_beds
count	14.000000	14.000000	14.000000	14.000000	14.000000	14.000000	14.000000
mean	1821.520429	95.716786	14.247929	0.097660	27866.991500	2.374186	47.214286
std	1773.963493	218.245200	6.243641	0.148951	19776.998388	2.638941	37.860429
min	50.848000	0.896000	3.526000	0.000000	1729.927000	0.000000	0.000000
25%	385.553000	6.876500	8.635750	0.017051	8676.592000	0.250432	6.750000
50%	1405.270000	37.142000	16.071500	0.031434	29818.202000	1.127482	49.500000
75%	2298.514750	57.528500	19.231750	0.143516	42140.362250	4.162206	82.250000
max	5450.544000	843.084000	21.228000	0.539311	64800.057000	7.575773	106.000000

Table 5 Welch’s t test for countries with male and female leaders.

Feature	T test	P value	Null Hypothesis
'mortality_rate'	0.47743347270096936	0.6384737026484493	Accept
'early_acc'	-0.26177834184507875	0.7964854340077215	Accept
'max_death'	0.5091168486428339	0.6167242320422257	Accept
'early_mortality'	1.6831262542345369	0.10706209422083189	Accept
'total_tests'	-0.6021973212450671	0.5542267865555421	Accept
'peak_cases_hospital_avg'	-0.1707662771429982	0.865802542871926	Accept
'total_cases'	0.9033041416839234	0.376468383645011	Accept
'total_deaths'	0.9211741948927772	0.3689387979775094	Accept

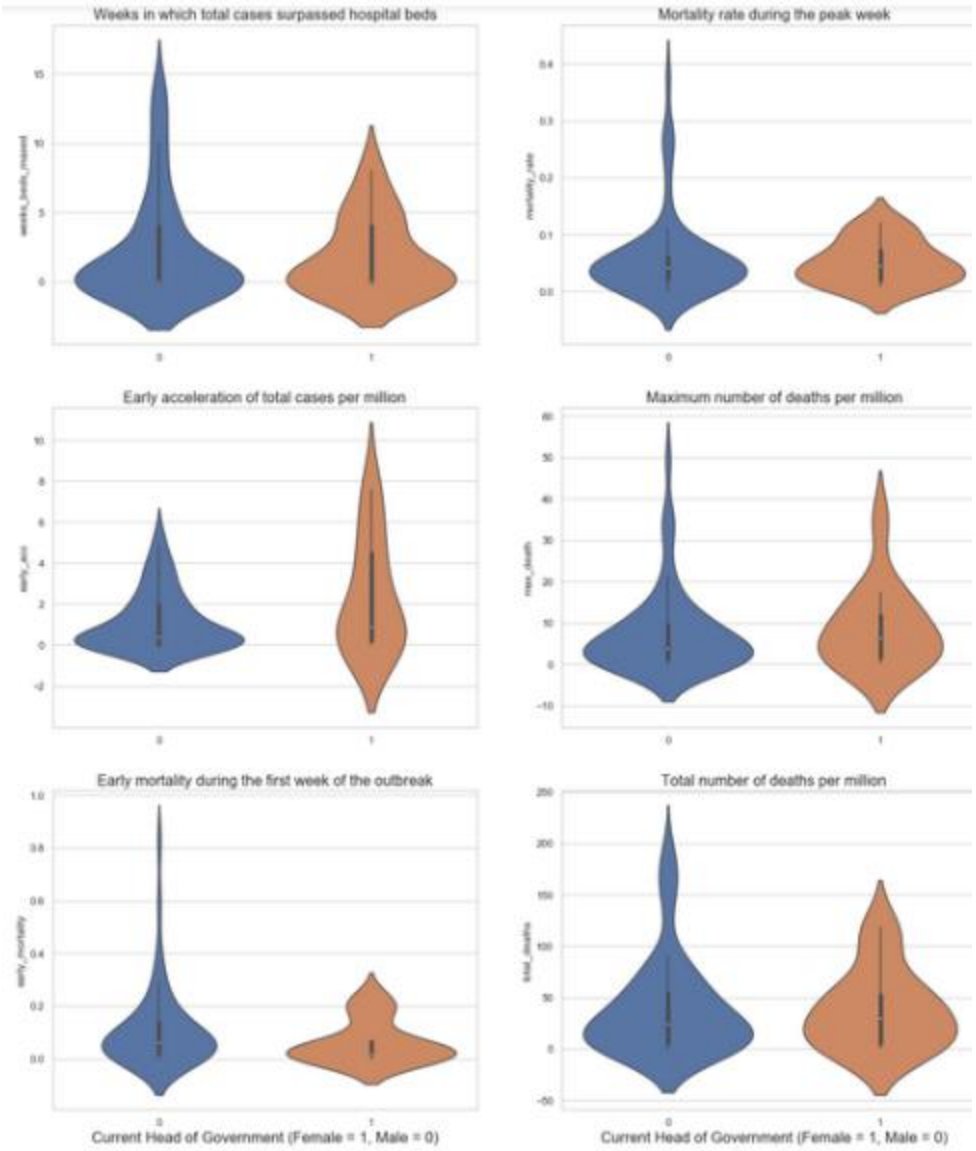

Figure 16 Violin plot for countries with male and female leaders and different features

Conclusion

In this report, the effect of several features on the total_deaths numbers of countries with nonzero total tests were studied. Out of these features, days_maxed_beds, early_mortality, gdp_per_capita, age_over_65 and early_acc are all significantly correlated with total_deaths with 0.05 significance level.

None of these features showed strong linear relationship with total_deaths. It is assumed that total_deaths is not just solely dependant on any of these features but rather a combination of different parameters such as policies, restrictions measures, etc.

Finally, even though countries with female leaders showed lower numbers for total deaths and cases, there is not enough evidence to suggest that there is a significant difference between countries with male leaders and female leaders with 95 percent confidence interval.

References

1. https://towardsdatascience.com/which-countries-react-similar-to-covid-19-machine-learning-provides-the-answer-5971ec2f6f31