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EXPLORING THE DETERMINANTS OF COVID-19 MORTALITY RATE WORLDWIDE

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ABSTRACT

SARS-CoV-2, also known as COVID-19, is a coronavirus that causes severe acute respiratory syndrome. The recent outbreak of COVID-19 had caught the world by surprise, resulting in millions of confirmed infected cases and 5,325,079 deaths documented worldwide. This study aims to explore the significant factors associated with COVID-19 mortality rate by focusing on the number of active cases, total cases, critical cases, vaccination doses, and screening tests. Secondary data from 219 countries was retrieved from CNN Health, Worldometer, and GitHub Our World in Data, which was later analysed using multiple linear regression. The results showed that total cases and vaccination doses of COVID-19 are the significant factors associated with COVID-19 mortality rate; active cases, critical cases, and screening tests were found to have insignificant relationships to COVID-19 mortality rate. This study offers further recommendations which can be accomplished using the updated data that include the patients' common comorbidities, such as obesity, hypertension, and diabetes mellitus.

Keywords: COVID-19; mortality rate; multiple linear regression; vaccination doses

Introduction

Recently, the world was shocked by the outbreak of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), mainly known as COVID-19. Early cases of COVID-19 were reported in late December 2019 in Wuhan City, Hubei Province, China (Liu et al., 2020); however, the airborne virus later found its way to other countries and was declared a global pandemic by the World Health Organization (WHO).

As of April 2021, Worldometer (2021) reported more than 130 million cases of COVID-19 with 2.9 million deaths across 200 countries around the globe (see Figure 1). The first confirmed death was reported in Wuhan, China on 9 January 2020 while the first death outside of China occurred in the Philippines on 1 February 2020. Additionally, the United States of America (USA) recorded the first COVID-19 death outside Asia that happened on 6 February 2020. The number of COVID-19 cases and mortality rate continued to soar across countries with more than 757,849 deaths were reported in the USA as of 26 October 2021.

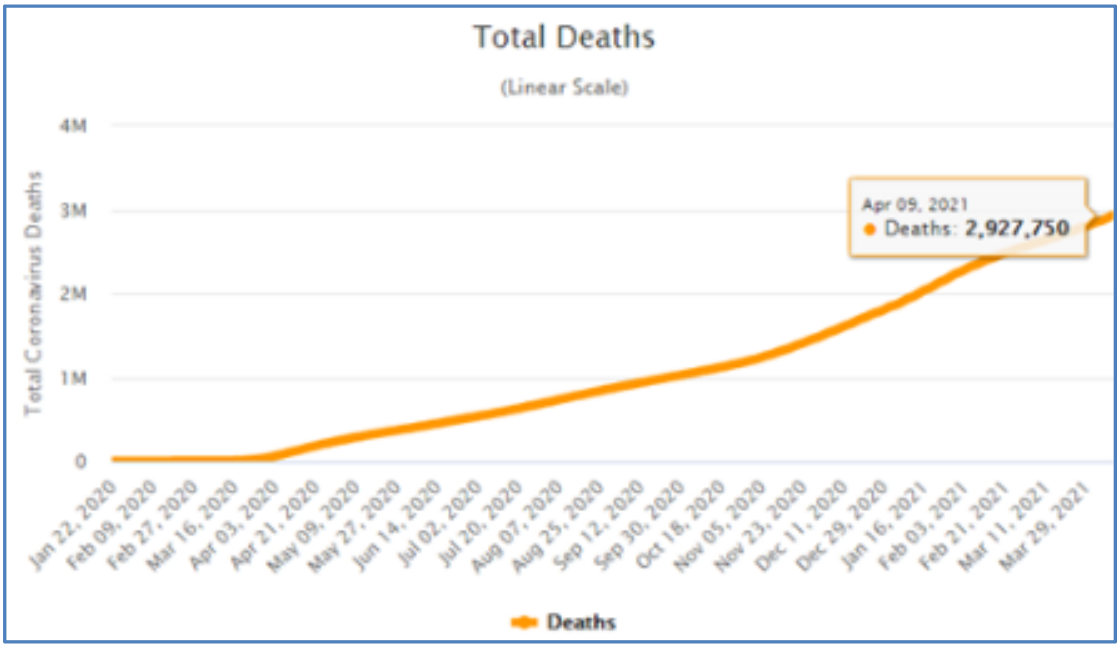

Figure 1: The number of total deaths in the world

Furthermore, statistics on cumulative confirmed COVID-19 deaths by Johns Hopkins University CSSE COVID-19 Data (see Figures 2 and 3) show that as of 12 April 2021, Europe had the highest number of deaths with 956,604 compared to other states. Meanwhile, 445,893 deaths were reported across Asia, excluding China. The lowest number of COVID-19 casualties was recorded by Oceania with 1,007 deaths. Numerous efforts and preventive measures were implemented by governments across the world to curb the spread of the pandemic, and while COVID-19 has been under control since the middle of 2022, it emerged as the fifth global pandemic ever recorded in world history (Liu, Kuo, & Shih, 2020).

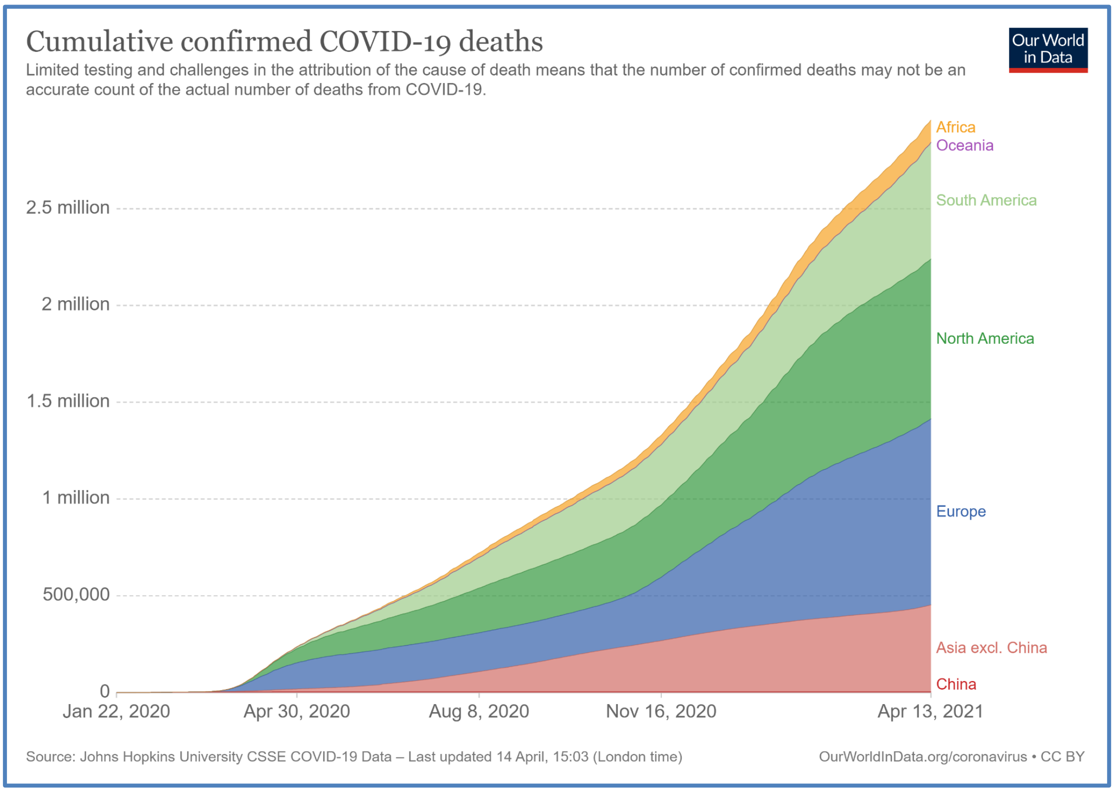

Figure 2: Cumulative confirmed COVID-19 deaths as of 13 April 2021

Apr 12, 2021	
Africa	115,974 deaths
Oceania	1,007 deaths
South America	596,866 deaths
North America	824,550 deaths
Europe	956,604 deaths
Asia excl. China	445,893 deaths
China	4,843 deaths
Total	**2.95 million deaths**

Figure 3: Cumulative confirmed COVID-19 deaths as of 12 April 2021

Problem statement

Global-scale pandemics, such as COVID-19, have been known to impose adverse impacts on the world community, particularly in the aspect of health and mortality. Therefore, there is a need to understand the factors involved in the mortality rate of world crises and pandemics for better preparation in the future. Motivated by the recent pandemic outbreak, this study aims to explore the determinants related to the mortality rate of COVID-19. The analysis focuses on the factors of active cases, total cases, critical cases, screening tests, and vaccination doses in each country to determine its influence over the global mortality rate of COVID-19.

Research objective

The purpose of this study is to identify the significant factors associated with COVID-19 mortality rate.

Research hypothesis

H1 : There is a positive relationship between active cases of COVID-19 and COVID-19 mortality rate.

H2 : There is a positive relationship between total cases of COVID-19 and COVID-19 mortality rate.

H3 : There is a positive relationship between critical cases of COVID-19 and COVID-19 mortality rate.

H4 : There is a negative relationship between screening tests of COVID-19 and COVID-19 mortality rate.

H5 : There is a negative relationship between vaccination doses of COVID-19 and COVID-19 mortality rate.

Literature Review

Active cases of COVID-19

Active cases are defined as the total cases, which exclude death and recoveries. The emphasis on active cases is prompted by the fact that they are increasing over time. Individuals infected by COVID-19 are at a high risk of dying, especially those with comorbidities as well as senior citizens. Javanmardi et al. (2020) investigated the prevalence of underlying diseases, such as hypertension, diabetes, cardiovascular disease, liver disease, lung disease, malignancy, cerebrovascular disease, COPD, and asthma, over the death cases of COVID-19. They found that 46% of COVID-19 patients who died were suffering from hypertension, followed by those with diabetes (26%) and cardiovascular disease (21%). However, asthma has the lowest prevalence (3%) towards COVID-19 deaths. This suggests that patients with underlying diseases contribute to the high mortality rate of COVID-19.

Total cases of COVID-19

Total cases refer to the number of cases, including death cases, active cases, and recovery cases. Past research suggests that the total cases of COVID-19 may have an impact on the mortality rate of each country. For instance, Meo et al. (2020) stated that COVID-19 has affected 750,890 people with a mortality rate of 4.84%, illustrating that the quantity of cases has been relative to the quantity of deaths. They also claimed a positive relationship between frequency and death rate.

Critical cases of COVID-19

The critical cases of COVID-19 stand as one of the factors contributing to the increase in mortality rate. A study by Grasselli et al. (2020) investigated the independent risk factors associated with the mortality of patients with COVID-19 who required Intensive Care Unit (ICU) treatment within the Lombardy region of Italy. The findings showed that among the first subgroup of 1715 patients in Lombardy, Italy, 50.4% were discharged from the ICU, 48.7% had died in the ICU, and 0.8% were still in the ICU. Additionally, 53.4% of the total critical patients died in the hospital as of 30 May 2020.

Screening test of COVID-19

Screening test is another factor that may contribute to the mortality rate of COVID-19. Previous research by Mahajan, Sivadas, and Solanki (2020) reported that the mortality and spread of COVID-19 can be reduced by increasing the number of COVID-19 tests in India. They also suggested increasing the total number of testing from 2,500 to 10,000 per day for controlling COVID-19 cases.

Vaccination doses of COVID-19

Vaccination is one of the methods to lower the rate of COVID-19 infection. Globally, various efforts have been made to develop vaccines for COVID-19. All vaccines were carefully evaluated in clinical trials and would only be authorised or approved if they resulted in substantially low COVID-19 infection. While these vaccines were developed against the race of time, routine procedures remained in place to ensure its safety. Moghadas et al. (2020) studied the impact of vaccination on COVID-19 outbreaks in the USA and reported the impact of the two doses of COVID-19 vaccination campaign in reducing COVID-19 incidence, hospitalizations, and deaths in the country.

Methodology

The data in this study was retrieved from Worldometer and CNN Health to estimate the relationship between the independent variables and mortality rates using multiple regression analysis, comprising general fitness and model adequacy checking. All missing values from 219 countries in the data were removed, making a final tally of 132 countries for further analysis. The variables under investigation were active cases of COVID-19, total cases of COVID-19, critical cases of COVID-19, and the screening test of COVID-19, which were extracted from Worldometer data. Meanwhile, data on the vaccination doses of COVID-19 was obtained from CNN Health. The cumulative data for all 132 countries were retrieved between 31 December 2019 and 21 October 2021.

Description of Data

Table 1: Description of Data

No	Variable	Description	Level of measureme
1.	Country	2 countries in the world	Nominal
2.	Active cases	tive cases = total cases – total deaths – recovery cas umber of people diagnosed and confirmed to be infect th COVID-19 for all 132 countries	Ratio
3.	Total cases	tal cumulative number of people diagnosed with COV for all 132 countries	Ratio
4.	Critical cases	tal number of patients currently being treated in Inten are Unit (ICU) for all 132 countries	Ratio
5.	Screening test	tal number of people who were screen tested for CO for all 132 countries	Ratio
6.	Vaccination doses	tal number of people who were vaccinated for all 132 untries	Ratio
7.	Mortality rate	ortality rate = (number of death / total population) × 10 e death rate of COVID-19 for all 132 countries	Ratio

Theoretical framework

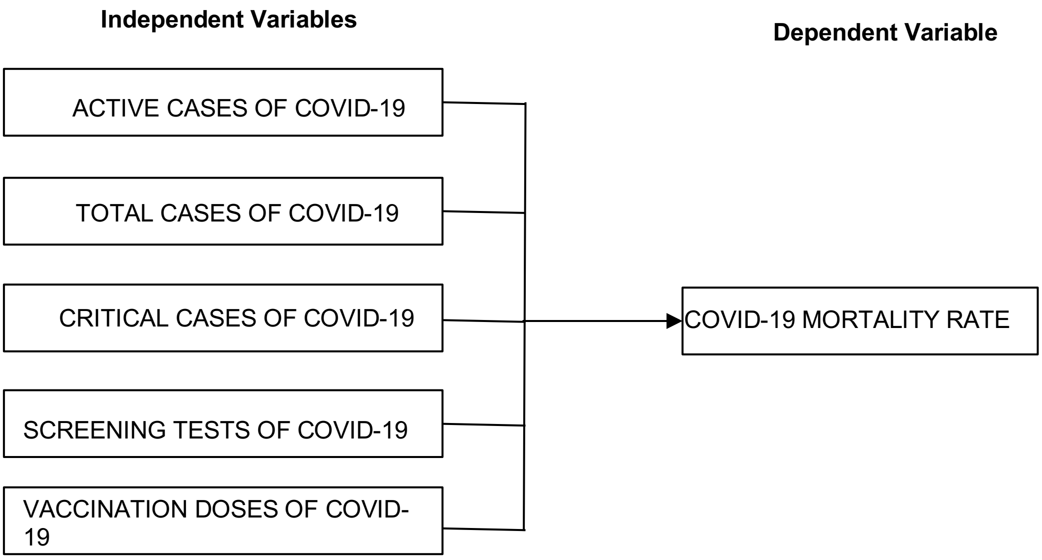

Figure 4: Theoretical Framework

Regression analysis of worldwide mortality rate

The general multiple regression model for this study is as follows:

$$\widehat{Y}_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_5 X_5 + \varepsilon_i$$

(1)

where

$\widehat{Y}_i$ denotes the criterion in the i th trial for the mortality rates;
β_0,β_1,β_2,...,β_5 are the parameters of the model;
X_1 represents the active cases of COVID-19;
X_2 represents the total cases of COVID-19;
X_3 represents the critical cases of COVID-19;
X_4 represents the screening test of COVID-19;
X_5 represents the vaccination doses of COVID-19; and
ε_i is the error term in the i th trial.

Moreover, the criterion variables of this study were denoted as the mortality rate of COVID-19 ($\widehat{Y}_i$). For ε_i, we assumed that E (ε_i) would be zero as stated in the assumption of the model.

Results and Discussion

Multiple regression analysis using stepwise method

This study used the transformation method for multiple regression analysis to fulfil the assumptions of MLR using SAS Enterprise Guide 8.2. It involved the transformations for both independent variables and dependent variable. In this analysis, the researchers transformed Mortality Rate to Sqrt Mortality Rate, Total Cases to Sqrt Total Cases, and Vaccination Doses to Sqrt Vaccination Doses. The stepwise method was used to remove independent variables that were insignificant and maintain the significant variables. Results were obtained from the second time running where two countries were removed from the dataset, making a total of 130 countries. Finally, the results for the final model are shown below.

General fitness of the stepwise model

The final model was examined using stepwise regression. The full linear regression equation for the final stepwise model is as follows:

$$\begin{aligned} Sqrt(\hat{Y}_i) &= 0.23564 + 2.9389x10^{-4} SqrtTotalCases \\ &\quad - 5.455x10^{-5} SqrtVaccinatedDoses \end{aligned}$$

(2)

where

Sqrt($\hat{Y}_i$) = Sqrt mortality rate of COVID-19
SqrtTotalCases = Sqrt total cases of COVID-19
SqrtVaccinatedDoses = Sqrt vaccination doses of COVID-19

ANOVA table

Table 2: ANOVA

Analysis of Variance		
	Value	> F
odel	.13	0001

Table 2 shows the Analysis of Variance (ANOVA) for the final stepwise model. The value of p < .0001 indicates that the model is significant it is less than a = 0.05. The ANOVA results showed that the data is significant, suggesting that this model is a good fit model and is valid to be used in this study.

Model summary

Table 3: Model Summary

Square	2915

Based on the R-Squared value, 29.15% of the total variation in mortality rate can be explained by total cases and vaccination doses. The remaining 70.85% of the total variation is explained by other factors.

Coefficient Table

Table 4: Final Coefficient Table

Variables	D	Parameter Estima	Standard Err	t valu	Pr|t|	Standardised Estimat	95% Confidence Limits	
rcept	1	0.23564	0.01656	13.5	<.000	0	0.20287	0.26841
Total Cases of COVID-19	1	0.00029389	0.00004151	8.38	<.000	1.09770	0.0002117	0.0003760
Vaccination Doses of COV	1	-0.00005455	0.0000099	-6.7	<.000	-0.85268	-0.000074	-0.0000349

Table 4 shows the significant variables in the final stepwise model, which are total cases (<0.0001) and vaccinated cases (<0.0001), where the p-values are less than a = 0.05. The significant values explained that the total cases of COVID-19 have a positive impact on COVID-19 mortality rate. Meanwhile, the vaccination doses of COVID-19 have a negative impact on COVID-19 mortality rate. Therefore, these two significant variables can be used in the model.

Model adequacy checking

Several assumptions of multiple linear regression were checked to determine whether they had been fulfilled. This included the assumptions of linearity, normality of error term, multicollinearity, independence of error term, and presence of outliers. For linearity, there was approximately a linear relationship between significant variables total cases and vaccination doses towards mortality rate. The normality of error term showed that the error term was normally distributed. Meanwhile, the multicollinearity results indicated the independent variables might have slight multicollinearity problems, suggesting that there was no multicollinearity issue among the variables. Furthermore, the assumption on independence of error term was also met where the value of Durbin-Watson Test was between 1.5 until 2.5. Finally, only two outliers existed in this model since there were only two points lying outside of the range of the line limit.

Discussion

Our results showed that 29.15% of the total variation in the mortality rate of COVID-19 can be explained by total cases and vaccination doses. In the final results, vaccination doses and total cases of COVID-19 demonstrated a significant impact on mortality rate. This implies that both vaccination doses and total cases of COVID-19 are the factors affecting the mortality rate of COVID-19. However, 70.85% of variations in mortality rate can be explained by other factors including random errors. Further investigation is required to explore other factors related to the mortality rate of COVID-19.

Total cases of COVID-19 represent the cumulative cases of COVID-19 for each country, hence standing as one of the significant variables in this study. The findings demonstrated that there is a positive relationship between the total cases of COVID-19 and the mortality rate of COVID-19. This can be verified by the previous research by Meo et al. (2020) who reported that the quantity of cases and deaths were inter-related and that there was a positive relationship between the number of cases and mortality rate.

Vaccination doses stand as another significant factor to the mortality rate of COVID-19. Our results demonstrated a negative relationship between the two variables. This is supported by Moghadas et al. (2020) who stated that two vaccination doses of COVID-19 had a significant impact in reducing hospitalizations, incidence, and deaths in USA. Thus, vaccination doses of COVID-19 indeed have a negative significant impact on the mortality rate of COVID-19.

Furthermore, active cases represent the number of people infected with COVID-19. This study found that active COVID-19 cases are insignificant towards its mortality rate. As stated by Javanmardi et al. (2020), underlying diseases have an adverse effect on COVID-19 positive patients, with a parallel relationship was established between disease severity and high mortality for COVID-19 cases. Additionally, the highest and lowest prevalence was related to hypertension (46%) and asthma (3%). Thus, the findings by Javanmardi et al. (2020) somehow agree with those reported in this study. this suggests that active COVID-19 cases are not the sole reasons for the mortality rate of COVID-19, but rather it is also related to other factors like the patients' comorbidities and underlying diseases.

Our results also showed that critical cases are insignificant towards the mortality rates of COVID-19. However, Grasselli et al. (2020) reported that the most critical COVID-19 patients in ICU required invasive mechanical ventilation and 53.4% of them died in the hospital, thus confirming a high mortality rate. This suggests that our results concerning the relationship between critical cases and mortality rate contradict the findings by Grasselli et al. (2020).

This study also found an insignificant relationship between the screening test of COVID-19 towards COVID-19 mortality rate. It disagrees with the previous research by Liang et al. (2020) who stated that the mortality rate of COVID-19 will decrease if COVID-19 screening tests increase. Our results also contradict the research on OLS by Velasco et al. (2021) who claimed that the increased number of total tests will reduce the mortality rate of each country.

Conclusion

This study found that total cases and vaccination doses of COVID-19 are the significant factors influencing COVID-19 mortality rate. It agrees with Meo et al. (2020) who claimed that total number of COVID-19 cases is related to mortality rate. Additionally, our findings also adhere to the result by Wise (2021) in which the increase of vaccination doses reduces the mortality rate of COVID-19. Unfortunately, it contradicts Grasselli et al. (2020) who claimed that one of the factors associated with the mortality rate of COVID-19 is the critical cases of COVID-19, along with Liang et al. (2020) who found that increasing the number of COVID-19 testing will reduce its mortality rate.

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