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Impact of COVID-19 on mortality and excess mortality of midlife from 40 to 64 age groups

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ABSTRACT

The COVID-19 pandemic has significantly affected the middle-aged population in the US. Leveraging the CDC dataset, this study quantifies the number of fatalities across various midlife age brackets, specifically 40–44, 45–49, 50–54, 55–59, and 60–64 for both males and females, spanning the years 2015 to 2020. A novel Python Package Index (PyPI) application, midlife was developed to compute and visualize these findings. The PyPI midlife application was also validated via Code Ocean for reproducibility of the application. The analysis revealed that males aged 55–59 and females aged 50–54 experienced the highest excess mortality due to COVID-19, likely due to a previously declining death trend in these groups. This research not only provides a method to visualize and calculate the impact of COVID-19 on midlife mortality by age and sex, but also highlights the potential economic repercussions of rising midlife mortality rates.

1. Introduction

The scope of this paper is to investigate the effect of COVID-19 on mortality and excess mortality in the middle-aged population. The middle-aged population was divided into five age groups as 40–44, 45–49, 50–54, 55–59, and 60–64. Centers for Disease Control and Prevention (CDC) dataset was used for the proposed investigation on mortality of the midlife from 40 to 64 years old.

A literature review was conducted on the economic impact of midlife mortality. The result concluded that the more deaths in middle age, the worse the economy. Life and death in midlife have a profound impact on the economy [1]. In other words, midlife mortality can have a negative impact on the economy. Preston et al. investigated impact of excess mortality in the US [2]. Their result predicted the negative impact on the economy. Intensive research on the relationship between midlife mortality and the economy has shown adverse economic effects [3].

The Python program, midlife.py was developed for calculating and visualizing the number of deaths from 2015 to 2020 by five age groups of male and female. The Python program was converted to a new Python Package Index (PyPI) application, midlife. In other words, the midlife PyPI application can generate five graphs on the number of deaths from 2015 to 2020 respectively.

PyPI is a software repository for the Python programming language. PyPI helps you find and install software developed and shared by the Python community. PyPI enables the software ‘midlife’ to run on Windows, MacOS, and Linux Operating Systems respectively as long as Python is installed on the system. The PyPI midlife application was also validated via Code Ocean for reproducibility of the application.

There are many definitions of middle age. Middle age is defined from 40 to 70 years old [4] or from 40 to 60 years old [5]. According to the 1981 U.S. Census, "middle age" is defined as ages 45 to 64 [6]. The period of middle age, which according to the Oxford and Cambridge dictionaries is usually considered to be from about 45 to 60 years of age. This paper investigates middle-aged people between the ages of 40 and 64 due to CDC classification.

Excess mortality studies provide important information on the health burden of the COVID-19 pandemic [7,8]. In order to calculate the excess mortality due to COVID-19, the number of deaths in 2020 was predicted using the time-series data from 2015 to 2019 based on the best polynomial regression model. Linear regression computes the linear equation that minimizes the distance between the fitted line and all data points. R-squared or r2 is an indicator or a goodness-of-fit measure for linear regression models. The higher the r2, the better the fit. In other words, if there were no COVID-19, the number of deaths in 2020 could be predicted based on mortality trends in historical data. The challenge of this paper is to predict the number of deaths in 2020 without COVID-19 based on time-series polynomial regression model using CDC data from 2015 to 2019. The best prediction model can be selected by R-squared.

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2. Methods

This paper studies the impact of COVID-19 from 2015 to 2020 on mortality of five age groups from 40 to 64 such as 40–44, 45–49, 50–54, 55–59 and 60–64 age groups by sex of male and female. The CDC dataset [9] was used to visualize the transition and trends of mortality from 2015 to 2020. The CDC dataset is composed of seven determinants: "Data As Of", "Start Date", "End Date", "Year", "Sex", "Age Group and "Total Deaths". The Python program, midlife.py [10] was developed for calculating the number of deaths per year from 2015 to 2020 for five age groups such as 40–44, 45–49, 50–54, 55–59 and 60–64 with sex of male and female.

The program automatically scrapes a dataset [11] from the CDC site over the Internet and can extract the number of deaths in five age groups per year from 2015 to 2020 to generate five graphs of male and female respectively. The midlife.py was converted to a midlife PyPI application [12]. Within one month of midlife's development, midlife has been downloaded 657 times worldwide.

The PyPI midlife was validated via Code Ocean for software reproducibility [13]. The midlife PyPI allows users to visualize the number of deaths of midlife by five groups with sex of male and female. The five generated graphs of male and female indicate the number of deaths from 2015 to 2020 respectively. The impact of COVID-19 on excess mortality can be observed in 2019 and 2020 respectively.

The excess mortality was calculated by the predicted number of deaths in 2020 based on polynomial regression model using time-series data from 2015 to 2019. In linear regression, the linear equation that minimizes the distance between the fitted line and all data points can be selected by R-squared metric. In other words, R-squared or r2 is a good indicator or a goodness-of-fit measure for linear regression models. The higher the r2, the better the fit.

The impact of COVID-19 on excess mortality is calculated: dividing the excess deaths by predicted deaths. The number of excess deaths is equivalent to the difference between the number of real COVID-19 deaths in 2020 and the predicted deaths in 2020 using the past data from 2015 to 2019 with the best linear regression model.

3. Results

The midlife PyPI application allows users to observe R-squared and predicted values. The data shown in Figs. 1 and 2 are perfectly linear when fit with a fourth-degree polynomial regression. The horizontal axis indicates the years from 2015 to 2020. The vertical axis indicates the number of deaths by age group per year. As the degree of the polynomial decreases, the curve-fitting quality degrades. A four-order polynomial

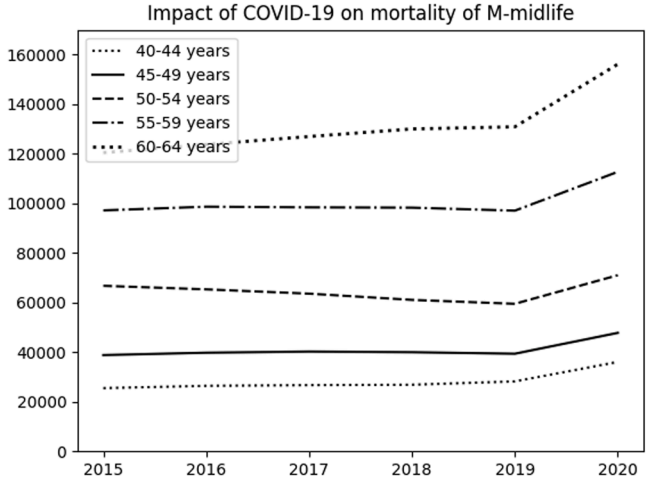

Fig. 1. The number of deaths from 2015 to 2020 in five male age groups from 40 to 64.

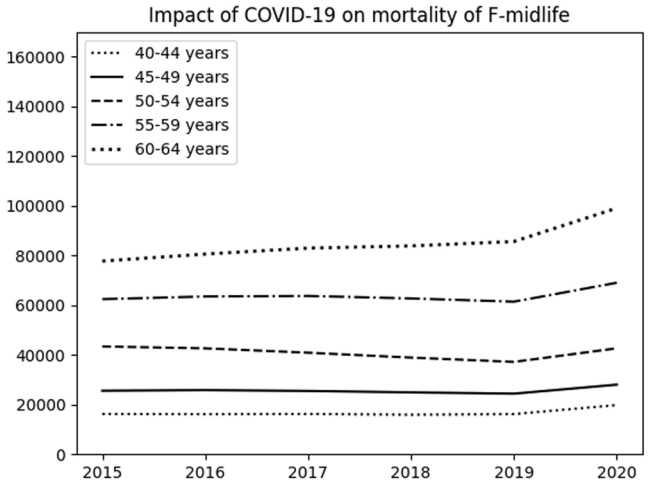

Fig. 2. The number of deaths from 2015 to 2020 in five female age groups from 40 to 64.

curve was fitted to the data, resulting in an R-squared value of 1. Even with the third degree, R-squared values are around 0.9. This indicates that the polynomial curve perfectly fits the data and there is no deviation from linearity. To avoid cluttering the figures, the predicted lines were not included in Figs. 1 and 2. The calculated results are presented in this paper. The curve-fitting quality degrades because only 5 values were used from 2015 to 2019 for prediction. Therefore, R-squared may not be the best method with a small amount of data.

The excess mortality in 2020 was calculated as the difference between the predicted number of deaths based on a regression model fit to data from 2015 to 2019, and the actual number of deaths in 2020. The excess mortality rate is expressed as a percentage and is calculated by dividing the excess mortality by the actual number of deaths in 2020 and multiplying by 100.

However, the impact of COVID-19 on excess mortality is different from visualized death result as shown in Figs. 1 and 2. When the 4th degree of polynomial regression has r2 = 1.0 for all male groups, the impact of male age groups on excess mortality is as follows: 40–44 years: 0.1, 45–49 years: 0.216, 50–54 years: 0.131, 55–59 years: 0.246, and 60–65 years: 0.244. This indicates that 55–59 age group has the highest impact of COVID-19 on excess mortality. This is because of the declining death trend of the male 55–59 age group from 2016 to 2019: 98,650 in 2016, 98,387 in 2017, 98,261 in 2018, and 97,055 in 2019.

When the first degree of polynomial regression with r2=0.991 was used for the male 50–54 age group, the impact of COVID-19 on excess mortality of age group 50–54 years is 0.233 due to declining trend on the number of deaths of 50–54 years from 2015 to 2019: 66,740 in 2015, 65,317 in 2016, 63,581 in 2017, 61,061 in 2018, 59,489 in 2019, 71,016 in 2020. From the viewpoint of excess mortality, the male 55–59 age group has the highest impact of COVID-19.

Similarly, when the 4th degree of polynomial was used with r2 = 1.0, the female age group of 50–54 years has the highest impact of 0.193: 40–44 years: 0.021, 45–49 years: 0.162, 50–54 years: 0.193, 55–59 years: 0.113, and 60–64 years: 0.054. This is because the death trend from 2015 to 2019 was declining: 43,377 in 2015, 42,614 in 2016, 40,863 in 2017, 38,903 in 2018, 37,165 in 2019, and 42,630 in 2020. The impact of COVID-19 on female excess mortality is milder than its impact on male excess mortality.

4. Discussion

The results of five graphs of male and female in Figs. 1 and 2 show that COVID-19 has a strong effect on the older adults in middle age. However, when the impact of COVID-19 on excess mortality was calculated, male age groups have the stronger effect than female age

groups. In the male age groups, 55–59 age group has the highest impact of COVID-19 on excess mortality: 0.246. This is due to the death declining trend of the male 55–59 age group from 2016 to 2019. The female age group of 50–54 years has the highest impact of 0.193 on excess mortality. For excess mortality, however, the effect of COVID-19 on excess mortality in women is milder than in male age groups. From an economic perspective, midlife excess mortality can have a significant negative impact on the economy soon.

A study by Shiels et al. found that there was a significant increase in mortality in the United States in early 2020 [14]. Their study estimated that there were 535,191 excess deaths in 2020, compared to 2019. The CDC reported that the overall death rate in the United States increased by 17 % from 2019 to 2020, from 715 deaths per 100,000 to 835 deaths per 100,000. The CDC also reported that 385,000 deaths in 2020 involved COVID-19, while another 34,000 deaths were attributed to COVID-19 as a contributing factor but not the underlying cause [15]. These findings suggest that the death spike in 2020 was largely due to COVID-19. The annual increase in deaths in 2020 was the largest in 100 years, with a spike of almost 19 % [16]. This increase followed the onset of the COVID-19 pandemic in March 2020. The pandemic has disrupted historical patterns of mortality, and it is unclear when or if these patterns will return to pre-pandemic levels [16].

The COVID-19-related run out of medical resources might be one of the important causes of deaths [17]. Based on the experience of Wuhan's COVID-19 run on medical resources, they recommended that governments take control and reform measures to increase the supply of medical resources, improve the capacity of primary medical care, ensure timely virus information, formulate principles for the allocation of medical resources that are appropriate for a country's national conditions, optimize medical insurance schemes and public health fund allocations, and enhance emergency support for medical resources [17].

Further study may be needed to determine the cause of the excess mortality and to assess the impact of the COVID-19 vaccine and the emergence of mutant strains. One possible area for future study would be to track the excess mortality in 2021 and 2022, after the COVID-19 vaccine was widely available. This would allow researchers to assess the impact of the vaccine on mortality, and to determine whether the emergence of mutant strains had a significant impact on the number of deaths.

Another possible area for future study would be to investigate the causes of excess mortality in 2020, 2021, 2022 and 2023. This could involve examining the medical records of people who died during this period, to determine whether they had COVID-19 or other underlying health conditions. It would also be important to assess the impact of the COVID-19 pandemic on healthcare systems, as this could have contributed to the excess mortality.

5. Conclusion

COVID-19 has a stronger effect on middle-aged males than females, with the highest impact on males aged 55–59. The death spike in 2020 was largely due to COVID-19, disrupting historical mortality patterns. The run out of medical resources might be a significant cause of deaths. Future studies could assess the impact of the COVID-19 vaccine and the emergence of mutant strains on excess mortality.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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