Analysis of COVID-19 Pandemic Waves in Death Figures of Turkey

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SUMMARY

Introduction: The COVID-19 pandemic has resulted in a substantial number of deaths worldwide, making it crucial to conduct a periodical behavior analysis of the COVID-19 death figures. By understanding the trends and patterns in mortality rates, decision-makers can make informed choices on prioritization of interventions to pandemics.

Method: Death figures due to COVID-19 between 17 March 2020 and 27 November 2022 were taken into account in this study. Mortality data were analyzed using statistical and graphical methods. Von Bertalanffy's growth model parameters were estimated for each wave. Then the model performance measures were calculated.

Discussion: In this study, the course and change of daily mortality data over time were examined. The data reveal that the COVID-19 pandemic occurred in Turkey as four waves. Von Bertalanffy's growth model appears to be an explanatory model for all pandemic waves according to the performance measures.

Conclusion: It was observed that the COVID-19 pandemic spread in Turkey in four waves. Investigating COVID-19 and similar pandemics using versatile and multidisciplinary methods is of great importance in understanding and predicting the behavior of pandemics.

Keywords: COVID-19; pandemic waves; growth models.

INTRODUCTION

COVID-19, also known as Coronavirus Disease 2019, is a highly contagious viral illness caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). First identified in December 2019 in Wuhan, China, it rapidly spread across the globe, resulting in a global pandemic [1]. The COVID-19 pandemic has had a profound impact on global health, society, and economies. To effectively combat this unprecedented crisis, extensive research on various aspects of COVID-19 is of paramount importance.

The COVID-19 pandemic has resulted in a substantial number of deaths worldwide, making it crucial to conduct a periodical behavior analysis of the COVID-19 death figures. By analyzing the trends, patterns, and factors influencing COVID-19 mortality rates, researchers and policymakers can gain valuable insights that contribute to effective response strategies, resource allocation, and public health interventions. Globally, as of 14 June 2023, there have been 767.984.989 confirmed cases of COVID-19, including 6.943.390 deaths, reported to WHO. As of 12 June 2023, a total of 13.397.334.282 vaccine doses have been administered [2]. In Turkey, from 3 January 2020 to 19 June 2023, there have been 17.042.722 confirmed cases of COVID-19 with 101.492 deaths, reported. As of 28 January 2023, a total of 139.694.693 vaccine doses have been administered [3].

A periodic behavior analysis of COVID-19 death figures provides a means to track and monitor the progression of the pandemic's impact on mortality rates. By examining the data over time, researchers can identify fluctuations, spikes, or declining trends in death figures, enabling a better understanding of the disease's trajectory. This analysis allows for the identification of hotspots or regions experiencing a surge in fatalities, facilitating targeted interventions and resource allocation to mitigate further spread and save lives.

A periodic behavior analysis of COVID-19 death figures provides policymakers with essential data-driven insights for evidence-based decision-making. By understanding the trends and patterns in mortality rates, decision-makers can make informed choices regarding resource allocation, healthcare system strengthening, preventive measures, and prioritization of interventions. COVID-19 seems to have lost its feature of being a serious epidemic lately. Although

there are reports of cases in some countries, its place on the international agenda has declined. It is not on the agenda in Turkey at the moment, but efforts are being made to eliminate the socio-economic effects of the pandemic.

Numerous mathematical models are being produced to forecast the future of COVID-19 pandemic in the US and worldwide [4,5]. Several growth models, time series models, SIR model with their variants are used for forecasting the case and the death figures of COVID-19 in the literature [6-13]. WHO collects scientific studies containing the latest international findings and information about COVID-19 and publishes them in the WHO COVID-19 Research Database by updating them daily [14].

METHODOLOGY

Analyzing the behavior of COVID-19 death figures allows for the evaluation of the effectiveness of intervention measures implemented to control the spread of the virus. This information is valuable for refining public health strategies, modifying interventions, and identifying best practices to minimize mortality rates. For these reasons, analyses were made and interpreted on the time series to determine the increases, decreases and peaks in daily mortality data. It has been determined that the periodic increases and decreases in daily mortality data occur in four waves. In addition, Von Bertalanffy's growth model (VBGM) parameters were estimated for each pandemic wave.

Data Analysis

Turkish authorities had announced COVID-19 figures daily between 17 March 2020 and 30 May 2022. After 31 May 2022, Turkish authorities have announced the figures as weekly, biweekly, and more recently three weekly periods [3].

Mortality data were analyzed using statistical and graphical methods. Cumulative and daily death figures of COVID-19 have been given in Figure 1 and Figure 2 respectively. The waves of the pandemic are illustrated by Figure 3. Summary information and statistics on the waves of the pandemic are given in Table 1.

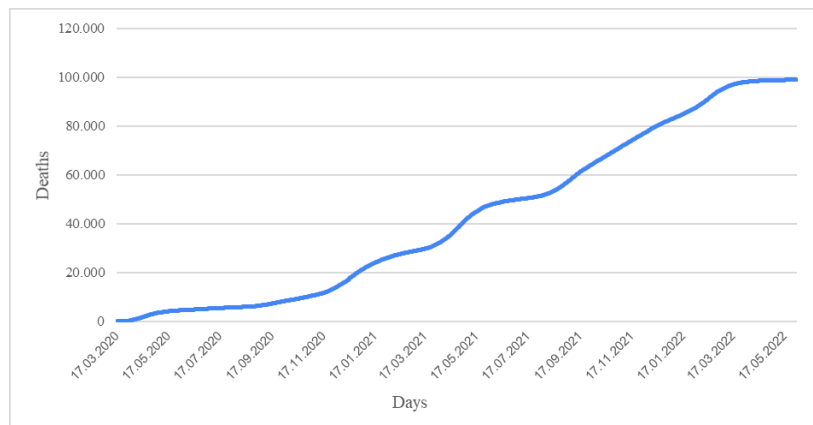*Figure 1. Cumulative daily death figures of COVID-19 in Turkey*

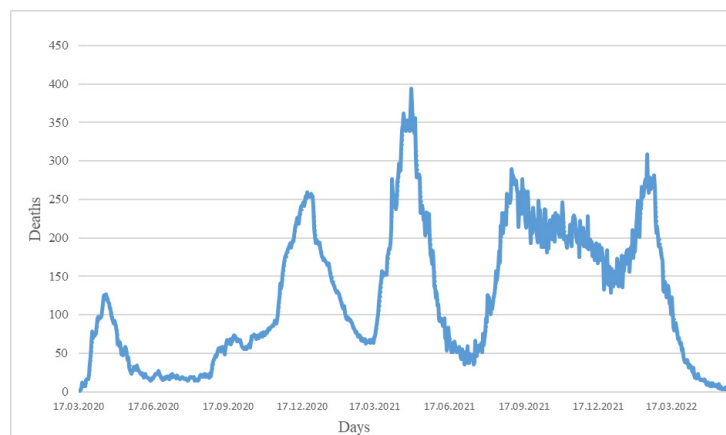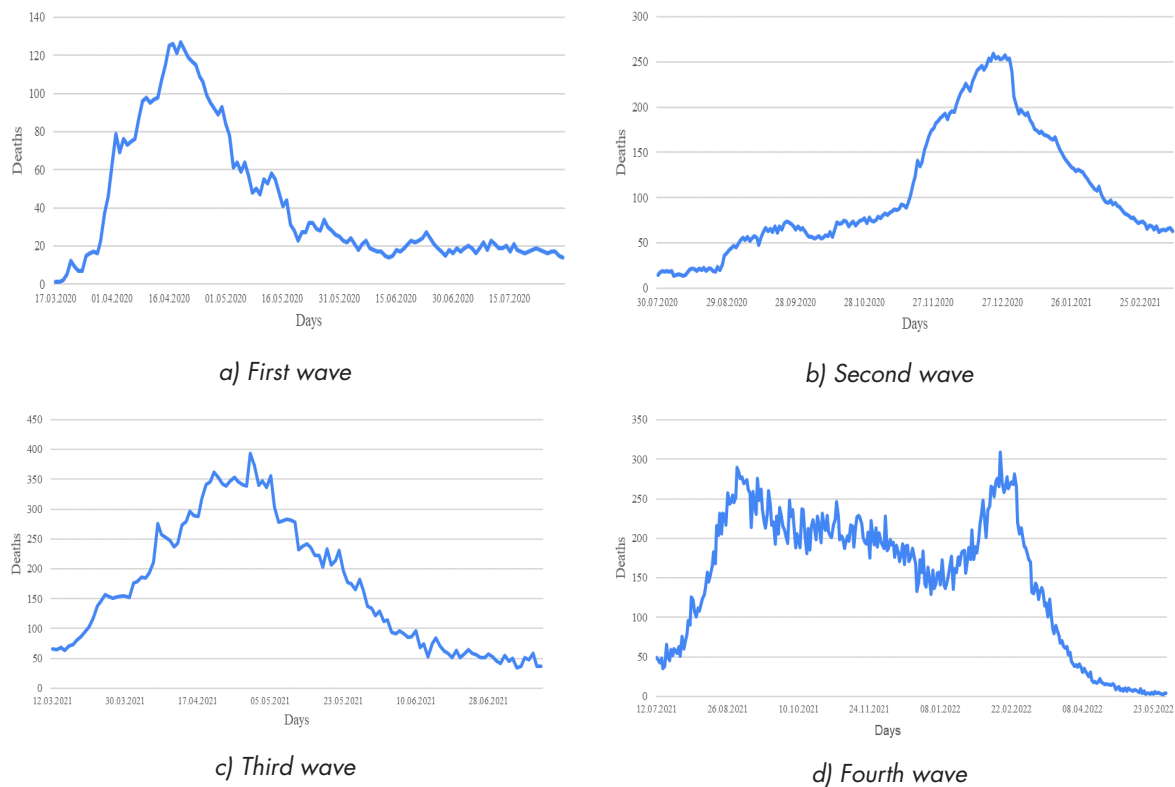*Figure 2. Daily death figures of COVID-19 in Turkey*

Figure 3. Waves of daily deaths

a) First wave

b) Second wave

c) Third wave

d) Fourth wave

The first wave of the COVID-19 pandemic lasted for 135 days, with the minimum number of deaths 1 and the maximum number of deaths 127 during this period. The average death figures during this period were 42 with a standard deviation of 34.26. The second wave of the pandemic lasted for 225 days, with the minimum number of deaths being 14 and the maximum number of deaths being 259. The third wave of the pandemic which has shortest period lasted for 122 days, with the minimum number of deaths being 35 and the maximum number of deaths being 394. The fourth wave of the pandemic which is the longest wave lasted for 324 days, with the minimum number of deaths being 2 and the maximum number of deaths being 309 in this period. Fourth wave between 12 July 2021 and 31 May 2022 has bimodal behavior which

were on 1 September 2021 with 290 deaths and on 15 February 2022 with 309 deaths.

The death figures were reported weekly between 3 May 2022 and 2 October 2022, biweekly between 3 October 2022 and 13 November 2022 and tree weekly after 14 November 2022. The maximum number of deaths being 380 were occurred on the week of 01-07.08.2022. The average number of deaths per day this week is about 54. During this 189-day period, a total of 2527 deaths due to COVID-19 were reported, with a daily average of approximately 14.

Although it is the shortest wave, the third wave has the highest daily death value with 394 deaths among all waves of the pandemic. The highest variation in standard deviations is also seen in the third wave.

Table 1. Descriptive statistics and information by waves

Waves	Begin Date	End Date	Peak Date	Maximum Deaths	Minimum Deaths	Average Deaths	Standard Deviations
First Wave	17.03.2020	29.07.2020	19.04.2020	127	1	42	34,6
Second Wave	30.07.2020	11.03.2021	23.12.2020	259	14	105	68,52
Third Wave	12.03.2021	11.07.2021	30.04.2021	394	35	172	106,39
Fourth Wave	12.07.2021	31.05.2022	15.02.2022	309	2	150	86
Last period	30.05.2022	27.11.2022	01-07.08.2022	380	11	≈ 14	NA

Von Bertalanffy's Growth Model

Growth curve models are often used in the biological sciences to model population size, height, biomass, fungal growth, and other variables, but these methods are also used for modeling and analysis in economics, public health, and other statistical fields. There are many growth curve models in the literature. One of them is Von Bertalanffy's growth model (VBGM). Von Bertalanffy [15] has introduced the growth curve model to model fish weight growth. VBGM is used to model mean length depending on age in animals. A simplified form of the growth model given in (1) is used in this study. Where, α_0, α_1 and α_2 are the model parameters. This model is also used for the pandemic figures in recent years [6]. The parameters of the growth model were estimated by Least Squared Error method in (2) for each pandemic wave and given in Table 2.

$$g(t) = \alpha_0 \, (1 - \exp(-t/\alpha_1))^{\alpha_2} \qquad (1)$$

$$\hat{\alpha} = \arg\min \sum (y(t) - \hat{g}(t))^2 \qquad (2)$$

Where, $\hat{\alpha}$ is the estimation of the α, $y(t)$ is the observed value at time t, and $\hat{g}(t)$ is the prediction at time t by the considered model $g(t)$.

Mean Square Error (MSE) and R^2 have been used to model performance measures in this study, and they are given in (3), (4) respectively. Where n is the number of observations and $\bar{y}$ is the average value of the observations. Model performance are given in Table 3.

$$\text{MSE} = \frac{1}{n}\sum_{i=1}^{n}(y(t) - \hat{g}(t))^2 \qquad (3)$$

$$R^2 = 1 - \sum_{i=1}^{n}(y(t) - \hat{g}(t))^2 / \sum_{i=1}^{n}(y(t) - \bar{y})^2 \qquad (4)$$

Cumulative death figures for each wave have been log transformed and the parameters given in Table 2 have been obtained.

Table 2. Model parameters by waves

Period	α_0	α_1	α_2
First Wave	8,536	15,947	0,907
Second Wave	14,091	728,767	0,239
Third Wave	10,281	48,868	0,249
Fourth Wave	10,957	104,229	0,24

According to the performance measures in Table 3, the model represents successfully the cumulative death figures of Turkey. Model performance values were recalculated for the original values and are given in

Table 3. According to the results, the VBGM appears to be an explanatory model for all pandemic waves.

Table 3. Model performances by waves

Waves	Transformed data		Original data	
	MSE	R^2	MSE	R^2
First Wave	0.012	0.996	43756	0.988
Second Wave	0.009	0.997	1714336	0.975
Third Wave	0.008	0.995	1182078	0.979
Fourth Wave	0.005	0.997	1175434	0.996

DISCUSSION

This article highlights the significance of a periodical behavior analysis of COVID-19 death figures in understanding the impact of the pandemic and shaping evidence-based decision-making. In this study, the course and change of daily mortality data over time were examined. The data reveal that the COVID-19 pandemic occurred in Turkey as four waves. VBGM parameters were estimated for each wave, and it is seen that the model parameters of each wave differ. According to the results, the VBGM appears to be an explanatory model for all pandemic waves. This analysis helps optimize public health responses, minimize the loss of life, and reduce the burden on healthcare systems.

There are limited studies in the literature from statistical analyzing perspective of pandemic waves using the death figures. However, some related example studies exist as following. Wei et al. [16] studied to classify the epidemic patterns of countries and territories worldwide. They evaluated the pandemic situation over the first year in countries and territories across the world and identified their similarities in terms of situation and trend. Kunno et al. [17] compared the characteristics of three waves during the COVID-19 pandemic in Thailand. Significant differences between the pandemic waves were concluded. Seong et al. [18] compared demographics, transmission chains, case fatality rates, social activity levels and public health responses between the second and third waves in South Korea. Significant differences in transmission chains between the second and third waves were concluded.

CONCLUSION

A periodical behavior analysis of COVID-19 death figures is of paramount importance in understanding

the impact of the pandemic, identifying high-risk groups, assessing intervention effectiveness, and guiding evidence-based decision-making. By continually monitoring and analyzing these figures, researchers and policymakers can develop targeted strategies that effectively address the challenges posed by COVID-19 and mitigate its impact on global health and well-being.

During the past 3.5 years, the COVID-19 pandemic has had significant effects in many areas, from public health to tourism, education, food and industrial production supply chain. Investigating COVID-19 and similar pandemics using versatile and multidisciplinary methods is of great importance in understanding and predicting both the behavior of pandemics and their spread and death rates.

With this study, it was observed that the COVID-19 pandemic spread in Turkey in four waves, causing deaths. Considering the performance criteria, it has been shown that the pandemic behavior can be explained for each wave with VBGM, and it has been observed that the pandemic preventive measures should continue until the results are obtained.

In future studies, the effects of preventive measures on the spread of the pandemic and changes in the death rate will be investigated with some stochastic models.

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