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SEIR MODEL ANALYSIS OF THE OMICRON VARIANT SPREAD IN BULGARIA – AN EMPIRICAL STUDY

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Abstract

We provide a study of the Covid-19 spread in Bulgaria in the period starting December 15, 2021 until early February, 2022. In particular, we provide predictive scenarios for the peak of the pandemic. Based on these scenarios, we estimate the risks in terms of fatalities in the case no restrictive measures are imposed. The main challenge is distinguishing the influence of the Delta variant which is still dominating in December, 2021, while Omicron becomes dominant in early January, 2022.

Key words: mathematical modelling, epidemiology, prediction, Covid-19, Omicron

2020 Mathematics Subject Classification: 37N25, 49J15, 92D30

1. Introduction. Rapid transmission of B.1.1.529 SARS-CoV-2 virus, designated as Omicron variant of COVID-19, rang an alarm on its potential hazard to the public health. Some exact key features of Omicron are still uncertain such as the immune escape of Omicron relative to Delta, the vaccine efficacy, its severity, etc. The results show that the effective reproduction number and basic reproduction number of the Omicron variant elicited 3.8 and 2.5 times higher transmissibility than the Delta variant, respectively.

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Recent research papers show why Omicron evades antibody-mediated immunity that comes from vaccination or infection with earlier variants – it is due to accumulation of numerous spike mutations. No previous variants have accumulated mutations and mediated immune evasion to the extent observed for the Omicron one. For instance, the Omicron spike (S) glycoprotein, which promotes viral entry into cells, harbours 37 residue mutations in the predominant haplotype relative to Wuhan-Hu-1 S variant, while approximately 10 substitutions in both Alpha and Delta variants were observed. The Omicron receptor-binding domain and the N-terminal domain contain 15 and 11 mutations, respectively, which lead to severe dampening of plasma neutralizing activity in previously infected or vaccinated individuals. For more details see references [1,2].

Furthermore, Omicron possesses an increased risk of reinfection, see [3,4]. The emergence of Omicron drives the fifth and sixth waves of COVID-19 pandemic, making it crucial to establish a reliable mathematical model of Omicron transmission and its potential impact on future substantial surge of cases, hospital and ICU admissions, and deaths.

The main purpose of the present research is to demonstrate the significant association between the restrictive measures called non-pharmaceutical interventions (NPIs), their degree of compliance or non-compliance, and the shape of the resulting infectious curve. We pay special attention to the period when the Omicron variant emerged – beginning of December 2021 to end of January 2022 – and the period after when the Omicron variant started to decay. Since early 2020, NPIs implemented at different levels of rigour and based on widely-divergent perspectives of risk tolerance, have been the primary means to control SARS-CoV-2 transmission. Due to the short time for reaction, practically about two months, NPIs were more suitable to implement in January-February 2022 in Bulgaria than vaccination (assuming boosters are excluded).

In the present paper we use the deterministic SEIR models for analysis and forecasting of the Omicron data, see [5,6]. More details are provided in the second part of this paper.

2. Simulation of disease spread. In the experiments below we use the classical SEIR model by fitting it to the data provided by Bulgarian Health Ministry [7]. We assume that coefficients σ and γ in the SEIR model are known. We have selected the parameter $\gamma = \dfrac{1}{6}$ since the average duration of the infectious period is considered to be **six** days. Here we take the average duration between the symptomatic persons, which are able to infect other people for about 3–4 days, and those who are asymptomatic, which we assume to be about 70%, and spread virus for eight days or so. Hence we obtain $\sigma = \dfrac{1}{3}$ since the incubation period is considered to be **three** days. The parameter β is found by fitting the SEIR model.

In all experiments below we follow the same algorithm: 1. We select a period of time $[t_1, t_2]$ such that in the time interval the constant coefficient SEIR model provides a good fit. Usually the time interval is not very large. 2. We fit constant coefficient SEIR model to the official statistical data for period of time $[t_1, t_2]$. 3. Running the SEIR model for time $t > t_2$ we provide a forecast of the epidemic development for $t > t_2$. **This forecast is just if the conditions for spreading of the virus remain the same in time interval $[t_1, t]$. Then the prediction is provided by the resulting SEIR curves.**

In view of the above statement some of the forecasts provided by us below seemed to be too overestimated and not very realistic. However the data during the same period of time from some countries with population comparable to the Bulgarian one show that the predicted peaks were very realistic (see `https://www.worldometers.info/coronavirus/country/bulgaria/` for the historical data):

	Period	Cases per Day
Austria	30.1.2022 – 11.2.2022	32 000
Denmark	30.1.2022 – 11.2.2022	40 000
Greece	20.1.2022 – 11.2.2022	20 000
Norway	30.1.2022 – 11.2.2022	20 000

In Bulgaria such high peaks were avoided due to the measures (NPIs) which have been introduced – on-line classes for students, green (digital) certificate has been applied, etc.

Remark 1. For the early period of the Omicron variant we have used the raw official data for the period 20.12.2021–15.01.2022. We see that the forecast curve is rather steep. The explanation for the shape of the infectious curve is that the data come right after the Christmas and New Year holidays which has highly increased the (basic) reproduction number, as seen from the fitted model. Also, we have to emphasize that the data are a mixture between the Delta and the Omicron variant which has changed progressively after 15.12.2021. We use the data from UK [8], Denmark or Germany to find out about the percentage of the Omicron variant, as well as the data from Bulgarian private laboratories Cibalab and from the laboratory in Military Medical Academy in Bulgaria [9] (which are preliminary about the presence of the S-gene characteristic/non-existing in the Omicron variant). These results show that Omicron variant dominates essentially after 15.12.2021.

3. Numerical experiments and forecasts, based on data for Bulgaria in the period 20.12.2021 – 15.01.2022 and comparison to the real data till 15.3.2022. In Fig. 1 we provide the result of the fitting of the SEIR model to the raw data. The blue curve and dots represent the historical data. We see that the curve of the daily infected cases provides a forecast with a peak in early March 2022, of about 70 000. Let us remind the meaning of this forecast: it is assumed that the social distancing conditions remain the same as before 15 January. It seems obvious that the peak is influenced by the very intensive social contacts

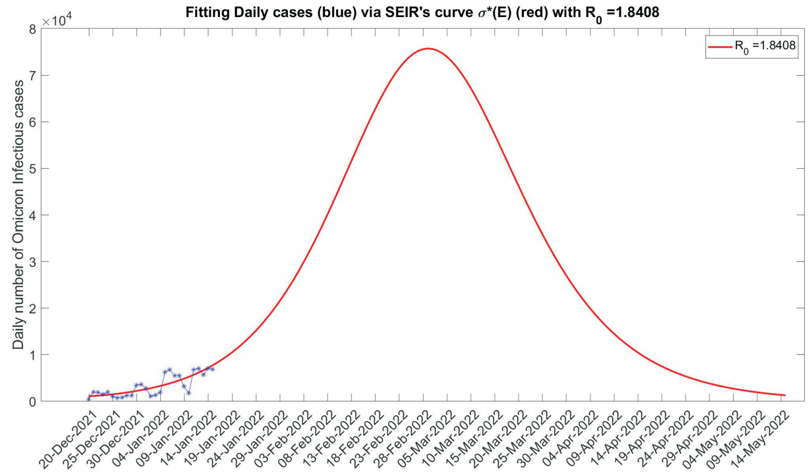

Fig. 1. Fitted SEIR model (red) to the data (blue)

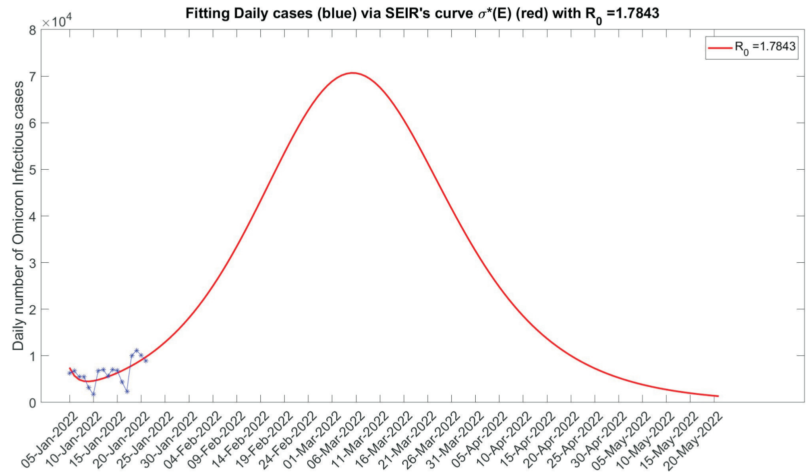

Fig. 2. Fitted SEIR model (red) to the data for the period January 5 – January 20, 2022

during Christmas and New Year events. Hence, the forecast in Fig. 1 should be understood as a warning against a complete release of all social restrictions.

One might speculate that the influence of the New Year holidays has played too big role on the data immediately after that, which produced the forecast of 70 000 cases. However in Fig. 2 we provide a forecast SEIR curve fitted to the data for the period January 5 – January 20, 2022, which shows a similar prediction scenario to that of Fig. 1. Similar results are obtained by data for the periods January 5 – January XX, 2022, where January XX is a date between January 14 and January 20.

In Fig. 3 we provide the cumulative curve of the forecasted curve from Fig. 1.

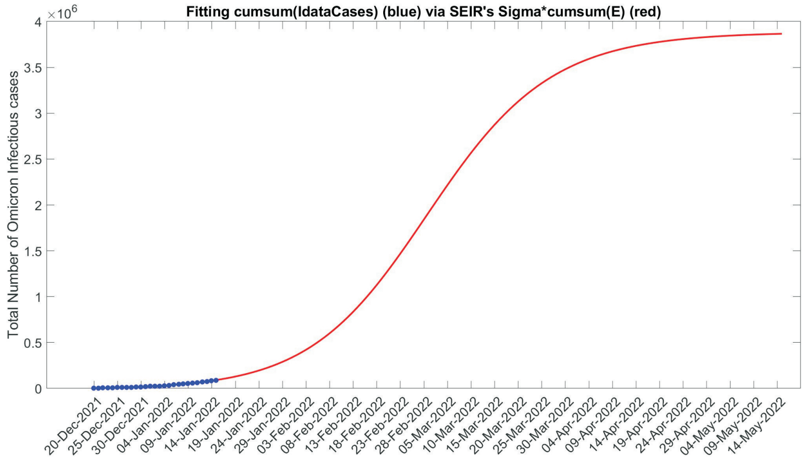

Fig. 3. Fitted cumulative SEIR model (red) to the cumulative data (blue)

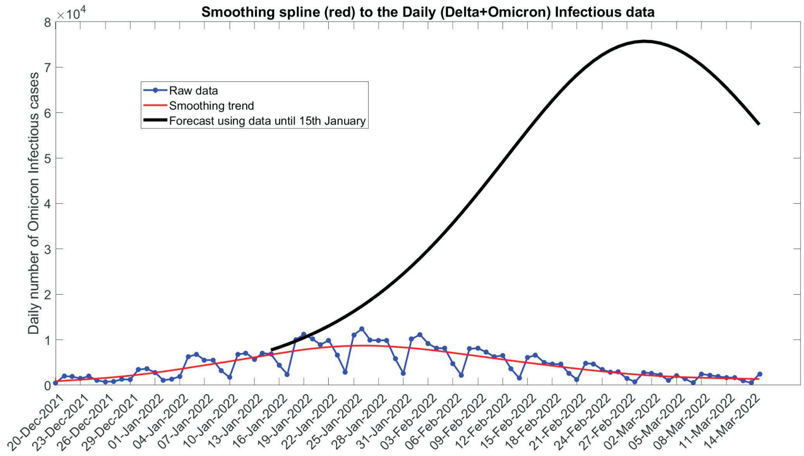

Fig. 4. Data of infections for Bulgaria (blue) overlaid by a SEIR model (black) fitted to the data until 15 January, 2022

It shows that by the end of April 2022 the officially announced data for infected would reach 3.5 million cases.

Let us remind that as a result of the above serious warnings by different analyzers, the government has introduced very timely severe social restrictions starting with January 24, 2022. In particular, schools, universities, kindergartens were closed, where possible online teaching was applied. Public places as restaurants, night clubs, shopping malls and others, were subjected to a special regime, by application of green (digital) certificates. In Fig. 4 we show the official data of the infectious cases in Bulgaria for the period 20.12.2021 – 15.03.2022, and illustrate the effect of the abovementioned restriction measures, by overlaying the forecasted curve (with black colour) from Fig. 1. In Fig. 4 we see that the peak of the raw official data happened at the end of January 2022, shortly after the introduction of the social restriction measures. This demonstrates the use of mathematical models for providing warning signals to estimate the scale of the risks in the case of epidemic/pandemic.

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