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Short Communication

Act early, save lives: managing COVID-19 in Greece

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ABSTRACT

Objectives: The aim of the study was to assess the impact of social distancing interventions in Greece and to examine what would have happened if those interventions had not been implemented.
Study design: A dynamic, discrete time, stochastic individual-based model was developed to simulate coronavirus disease 2019 (COVID-19) transmission.
Methods: The model was fitted to the observed trends in COVID-19 deaths and intensive care unit (ICU) bed use in Greece.
Results: If Greece had not implemented social distancing interventions, the healthcare system would have been overwhelmed between March 30 and April 4. The combined social distancing interventions and increase in ICU beds averted 4360 (95% credible interval: 3050, 5700) deaths and prevented the healthcare system from becoming overwhelmed.
Conclusions: The quick and accurate interventions of the Greek government limited the burden of the COVID-19 outbreak.

Introduction

The coronavirus disease 2019 (COVID-19) pandemic presents a global public health emergency, with more than 2.4 million reported cases.[1] The absence of a vaccine or targeted antiviral treatment has led public health responses to be concentrated on non-pharmaceutical interventions, such as social distancing (SD) measures, to reduce the impact of the outbreak. The goal is to slow the spread of the virus to keep the number of people infected at a manageable level and ensure that hospitals are not overwhelmed.

Greece is a country with a vulnerable public healthcare system as a result of the financial recession of the previous decade. Health spending in Greece accounts for 7.8% of the gross domestic product, and the number of intensive care unit (ICU) beds was about 6 per 100,000 individuals (47.8% less than the Organisation for Economic Co-operation and Development average).[2,3] In addition, on March 18, the Ministry of Health announced in the Greek parliament that only 120 ICU beds were available for patients with COVID-19.[4] Given these complexities, Greece was at risk of facing a significant COVID-19 epidemic, which would strain the healthcare system.

The first laboratory-confirmed case and the first death were reported on February 26 and March 12, 2020, respectively. It is important to note that the initial SD interventions were launched before the first death. More specifically, on March 9, 16 and 19, schools and universities were closed, SD was encouraged and public events were banned, respectively. Four days later, significant restrictions on public movements and gatherings were imposed. Thanks to the quick implementation of SD interventions, deaths and the use of ICU beds were kept to manageable levels.[5]

Public health decision makers need evidence-based information to evaluate and update strategic interventions to minimise the COVID-19 outbreak. Mathematical models can provide important insights by examining the effectiveness of interventions that have already been implemented.[6] The aim of this study was to investigate the impact of the SD interventions implemented in Greece and to examine what would have happened, in terms of deaths and healthcare system use, if the interventions had not been implemented.

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Methods

Study design

In infectious disease epidemiology, mathematical models are a common way to explain the spread of diseases and to predict or assess the impact of potential intervention policies. Those models stratify individuals into compartments representing different states of the infection process (e.g., susceptible, infected, recovered individuals). In these models, individuals move between states based on transition rates. The impact of an intervention can be simulated by modifying these rates; for example, the effect of the SD measures can be simulated by reducing the probability of an individual becoming infected.

Description of the mathematical model

To model COVID-19 transmission, a discrete time, stochastic, individual-based model, which categorises the population into susceptible, exposed, infectious or recovered (SEIR) individuals, was developed in low-level programming language C++ (Dev-C++ v.5.11) (see Fig. S1 in the supplementary material).

In short, every day a susceptible individual might acquire the infection and enter the exposed disease state before he/she becomes infectious. As per the clinical experience in Greece, about 80–90% of infected individuals would have no or mild symptoms and would not need hospitalisation; these individuals would recover from the disease after 5–7 days.[7] The rest of the infected population would need to enter the healthcare system; the majority would need hospitalisation, whereas a smaller group would also need to move to an ICU bed. The average duration that a patient would be in the hospital, provided he/she does not need to be transferred to an ICU bed, is 15 days. If a patient required intensive care, he/she would stay there for 14 days and an additional 14 days in the hospital for recovery. The probability of death for patients during hospitalisation or in an ICU bed is 15% and 50%, respectively.[8] Further details about the description of the model and the calibration procedure are available in the supplementary material.

Model parameterisation and examined scenarios

The model was calibrated using COVID-19 epidemiological and clinical data from the Greek epidemic. More specifically, we varied the transmission rate, the proportion of patients who would need to be hospitalised and the effect of SD interventions to optimise the fit on the observed trends in deaths and ICU bed use. The end date was set to be April 27 because this day is expected to be the last day of the existing SD measures.

A ‘status quo’ scenario was used to generate predictions with regard to the observed course of the outbreak, and a ‘counterfactual’ scenario, wherein no SD interventions were implemented, was used to estimate how the outbreak would have unfolded if no interventions had taken place. For each scenario, 1000 runs were performed, and the results were summarised. To include the appropriate uncertainty (stochastic variability), the 2.5 and 97.5 percentiles of simulations were also calculated.

Results

Epidemic parameters

After the reconstruction of the observed data on mortality and ICU bed use in Greece, the best estimate for the basic reproduction number (R_0) was 2.6. Furthermore, the model estimates that 8.5% and 4.5% of the population would need hospitalisation and to be treated in ICU beds, respectively, if infected.

Model projections under status quo and counterfactual scenarios

Fig. 1a and 1b show that the status quo scenario accurately captures the overall trends in deaths and the use of ICU beds between February 27 and April 15.

The strain on the healthcare system would be significantly higher without the SD interventions. More specifically, if Greece had not implemented the SD interventions, the healthcare system would have been overwhelmed between March 30 and April 4 (Fig. 1).

Under the status quo scenario, the number of COVID-19–related deaths is anticipated to be 140 (95% credible interval [CrI]: 120, 190) by April 27. On the contrary, under the counterfactual scenario, that is, without any SD intervention, the projected COVID-19–related number of deaths would be 860 (95% CrI: 720, 1020) by April 27 (Fig. 1b). Furthermore, considering the potential additional deaths that could occur owing to the non-availability of an ICU bed when the healthcare system reaches its limits, the disease-related mortality would be significantly higher (assuming that ICU bed availability would be the same as the pre-outbreak levels). Specifically, after a healthcare system collapse, if we assume that 90% of those in need of an ICU bed would die, the additional deaths by April 27 would be 3500 (95% CrI: 2500, 4400). Thus, the expected deaths without the implementation of any interventions (neither SD measures nor increase in ICU bed capacity) would be 4360 (95% CrI: 3050, 5700) by April 27.

Concerning the total number of cases under the status quo scenario, the model predicted that about 10,000 (95% CrI: 8300, 11,500) cases would exist in Greece by April 27. In the absence of SD measures, the number of infected individuals would have been 230,000 (95% CrI: 208,000, 247,000) (Fig. 1c). At the end of the study prediction dates (April 27), it is estimated that there would be 35 new infections per day (95% CrI: 26, 58) (see Fig. S2 in the supplementary material).

Regarding the course of the outbreak, the model estimated that the number of infected individuals peaked in Greece on March 23 (Fig. S3 in the supplementary material). Finally, the R_0 on April 27 was estimated to be 0.52 (an 80% reduction compared with the R_0 in the prelockdown period).

Discussion

In the present study, the COVID-19 epidemic in Greece has been reproduced using a mathematical transmission model. To evaluate the impact of interventions, a counterfactual model, without the SD measures, has been used, and this has been compared with the actual model. The analysis highlights that the SD interventions took place sufficiently early in the outbreak and were highly successful as they managed to keep the number of deaths and need for ICU

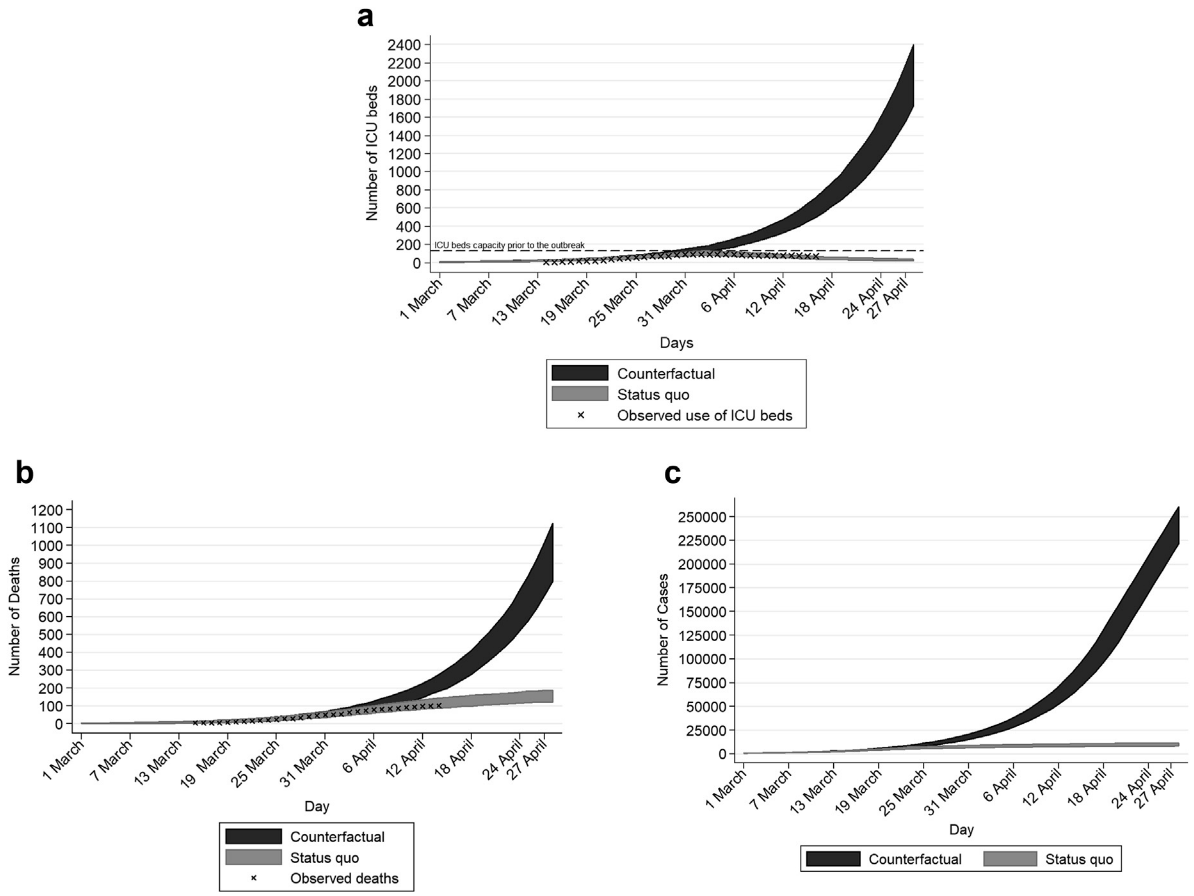

Fig. 1. Projections of future coronavirus disease 2019 (COVID-19) cases and complications under the status quo and counterfactual scenarios. For comparison, x indicates the observed trends under the status quo scenario. (a) COVID-19–related intensive care unit (ICU) bed use, (b) COVID-19–related deaths and (c) total number of infected individuals.

beds at low levels and within the capacity of the national healthcare system. It is estimated that the SD measures averted 4360 (95% CrI: 3050, 5700) deaths. In addition, the model highlights that any interventions to boost ICU capacity, without the simultaneous implementation of SD interventions, would not have been an effective healthcare policy as the demand for the ICU beds would have been very high without the SD interventions.

It should be noted that the estimates with regard to the effectiveness of the SD interventions are conservative as in the counterfactual scenario, we only removed the SD interventions while assuming that everything else remained exactly the same as in the status quo scenario. This assumption ignores additional potential complications, such as healthcare system overload or system collapse. When a healthcare system becomes overwhelmed, several different scenarios could have occurred; for example, if the prevalence of COVID-19 inside the healthcare settings had increased, a larger number of doctors and nurses could have been infected with the virus, and thus, the capacity of the healthcare system would be reduced.

It is important to note that the outputs of the model have also been computed elsewhere. The estimates with regard to the basic reproduction number and the total infected population are in line with estimates from the Imperial College COVID19 Response Team.[9] Furthermore, it has been shown that elderly individuals are the most at risk of experiencing COVID-19 complications.[6] In Greece, the proportion of the population aged >70 years is 14.8%,[10] which is close to the estimates of the current model that found 13.0% of individuals would need to enter the healthcare system if they became infected.

Conclusions

The decision of the Greek government to launch early SD measures resulted in limiting the burden of the COVID-19 outbreak and prevention of the healthcare system becoming overwhelmed.

Author statements

Ethical approval

The manuscript describes and analyses a theoretical model, and therefore, there is no need for ethical approval.

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Competing interests

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2020.08.016.

References

1. Dong E, Du H, Gardner L. An interactive web-based dashboard to track COVID-19 in real time. *Lancet Infect Dis* 2020 May;**20**(5):533–4. https://doi.org/10.1016/S1473-3099(20)30120-1.
2. Organisation for Economic Co-operation and Development (OECD). *Health spending*. 2019. 2019, https://data.oecd.org/healthres/health-spending.htm#indicator-chart. [Accessed 10 April 2019].
3. Rhodes A, Ferdinande P, Flaatten H, Guidet B, Metnitz PG, Moreno RP. The variability of critical care bed numbers in Europe. *Intensive Care Med* 2012;**38**(10):1647–53.
4. Athens News Agency - Macedonian Press Agency. *120 ICUs beds are available for coronavirus patients (in Greek)*. 2020. https://www.amna.gr/home/article/441011/B-Kontozamanis-120-krebatia-METh-gia-koronoio.
5. https://www.worldometers.info/ *Coronavirus in Greece*. 2020. https://www.worldometers.info/coronavirus/country/greece/?fbclid=IwAR1B0LClRQ7uDpin1GvhrCi2RLV5oH6GY738-0FJycYyZ5GjOxsF5dZYiRE.
6. Prem K, Liu Y, Russell TW, et al. The effect of control strategies to reduce social mixing on outcomes of the COVID-19 epidemic in Wuhan, China: a modelling study. *Lancet Public Health* 2020 May;**5**(5):e261–70. https://doi.org/10.1016/S2468-2667(20)30073-6.
7. Roman W, Wolfgang G, Michael S, et al. Clinical presentation and virological assessment of hospitalized cases of coronavirus disease 2019 in a travel-associated transmission cluster. *medRxiv* 2020. Published online March 5, https://doi.org/10.1101/2020.03.05.20030502.
8. Verity R, Okell LC, Dorigatti I, et al. Estimates of the severity of coronavirus disease 2019: a model-based analysis. *Lancet Infect Dis* 2020 Jun;**20**(6):669–77. https://doi.org/10.1016/S1473-3099(20)30243-7.
9. Institute for Disease and Emergency Analytics ICL. *COVID-19 model Greece*. 2020. https://imperialcollegelondon.github.io/covid19estimates/?fbclid=IwAR0gULKANiGKvN6NPwsfQqMC2z_mdqZIpVt0utiSzWkMK8MFFJHymKdh9Tw#/details/Greece.
10. Hellenic Statistical Authority. *Population-housing census 2011 (in Greek)*. 2014. https://www.statistics.gr/documents/20181/1210503/A1602_SAM01_DT_DC_00_2011_03_F_GR.pdf/e1ac0b1c-8372-4886-acb8-d00a5a68aabe.