Evidence of Protective Role of Ultraviolet-B (UVB) Radiation in Reducing COVID-19 Deaths

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Research Article

Keywords: COVID-19, Ultraviolet-B radiation, deaths, fixed-effect log-linear regression model

Posted Date: June 1st, 2020

DOI: https://doi.org/10.21203/rs.3.rs-32953/v1

Version of Record: A version of this preprint was published on October 19th, 2020. See the published version at https://doi.org/10.1038/s41598-020-74825-z.

Abstract

Background. Prior studies indicate the protective role of Ultraviolet-B (UVB) radiation in human health, mediated by vitamin D synthesis. In this observational study, we empirically outline a negative association of UVB radiation as measured by ultraviolet index (UVI) with the number of COVID-19 deaths.

Methods. We apply a fixed-effect log-linear regression model to a panel dataset of 152 countries over 108 days (n=6524). We use the cumulative number of COVID-19 deaths and case-fatality rate (CFR) as the main dependent variables and isolate UVI effect from potential confounding factors.

Findings. After controlling for time-constant and time-varying factors, we find that a permanent unit increase in UVI is associated with a 1.2 percentage points decline in daily growth rates of cumulative COVID-19 deaths [$p < 0.01$] and a 1.0 percentage points decline in the CFR daily growth rate [$p < 0.05$]. These results represent a significant percentage reduction in terms of daily growth rates of cumulative COVID-19 deaths (-11.88%) and CFR (-38.46%).

Interpretation. We find a significant negative association between UVI and COVID-19 deaths, indicating evidence of the protective role of UVB in mitigating COVID-19 deaths. If confirmed via clinical studies, then the possibility of mitigating COVID-19 deaths via sensible sunlight exposure or vitamin D intervention will be very attractive.

1 Introduction

COVID-19 is causing significant economic, healthcare and social disruption globally. However, it is not yet known how to prevent or treat COVID-19. Prior studies indicate the protective role of Ultraviolet-B (UVB) radiation in human health. UVB radiation exposure is a major source of vitamin D, which increases immunity and reduces the likelihood of severe infections and mortality.

A recent COVID-19 study indicates abnormally high case-fatality-rate (CFR) of 33.7% among nursing home residents 1, which is consistent with the studies indicating higher prevalence of vitamin D deficiency among them, due to lower mobility 2,3. Increasingly, studies establish a link between vitamin D deficiency and comorbidities such as cardiovascular disease 4, hypertension 5, obesity 2,6, type 1, and type 2 diabetes 7. This evidence is consistent with the clinical studies in China and Italy that indicate comorbidities such as hypertension, diabetes and cardiovascular diseases could be important risk factors for critical COVID-19 cases 8–10. Epidemiology of COVID-19 provides evidence that vitamin D might be helpful in reducing risk associated with COVID-19 deaths11,12. If such a link is true, then it will be cost-effective to mitigate COVID-19 via sensible exposure to sunlight or via vitamin D nutritional intervention. Yet, to the best of our knowledge, so far, no empirical study has used data across many countries to explore the association between UVB radiation as measured by ultraviolet index (UVI) and the number of deaths attributed to COVID-19 (COVID-19 deaths).

The aim of this study is therefore to examine the relation of UVB radiation, as measured by ultraviolet index (UVI), with the number of COVID-19-deaths. The results of our study demonstrate that a one-unit increase in UVI is associated with a 1.2 percentage points decline in daily growth rates of cumulative COVID-19 deaths. The robustness checks show similar effect of UVI on case fatality rate (effect size: -0.010) and the results are consistent across a variety of different model specifications (effect size: -0.006 to -0.012).

A major threat to identifying the effect of UVB with the number of COVID-19 deaths is the presence of time trends, which could affect UVI as well as the number of COVID-19 deaths. For example, many countries affected by COVID-

19 are in the northern hemisphere leading to a natural phenomenon that UVI increases over time. In addition, growth rates of the cumulated COVID-19 deaths are decreasing over time. This negative correlation between UVI and the cumulated COVID-19 deaths due to time is the source of the identification problem. We address this problem through our statistical analysis in which we flexibly isolate UVI from linear or non-linear time trends which can be either similar across countries or even country-specific.

2 Importance Of Uvb Radiation For Human Health

Prior studies find that UVB radiation plays a protective role in human health because it reduces the severity of immune diseases 13, reduces the risk of getting cancer - e.g., prostate cancer 14 and dying from cancer 15,16 and may reduce the prevalence of hypertension17.

Humans receive vitamin D either from their diet (natural food, fortified food or supplements) or from skin synthesis by solar UVB radiation exposure 18. In general, skin synthesis is the major source of vitamin D 19,20, as the dietary intake is usually insufficient 21. Various studies consider that UVB exposure twice a week is sufficient to maintain vitamin D levels 21 and vitamin D once produced can be stored in body fat and can be utilized later21, indicating a lagged effect of UVB.

UVB radiation shows significant variation according to latitude, seasons and time of the day. Specifically, during winter months in northern latitudes (e.g., above 35o latitude - Oklahoma - US), the ozone absorbs most of the UVB22, leading to reduced likelihood of UVB radiation exposure and thereby insufficient vitamin D synthesis as indicated in Figure 1.

Other weather factors such as cloud cover, precipitation, visibility and temperature influence the likelihood of exposure to UVB radiation and thereby vitamin D deficiency due to reduced skin synthesis. For example, clouds not only reduce the amount of UVB radiation but also the likelihood of UVB radiation exposure as people are more likely to undertake outdoor activities on less cloudy days. Lifestyle and mobility also influences the likelihood of UVB radiation exposure 3,23,24. Similarly, the likelihood of vitamin D deficiency also increases with age 21, skin pigmentation 25 and obesity due to reduced skin synthesis 26.

In Figure 1, we summarize these different factors explaining the potential protective role of UVB radiation in reducing COVID-19 deaths, mediated by vitamin D synthesis and deficiency. Since UVB radiation exposure is a major source of vitamin D, an increase in the likelihood of skin exposure to UVB radiation increases vitamin D synthesis, thereby reducing the likelihood of vitamin D deficiency. Therefore, different time varying and time-constant factors influencing the UVB radiation variation and exposure also influence the likelihood of vitamin D synthesis and thereby deficiency. Prior studies indicate that vitamin D deficiency increases the likelihood of weakened immune response 18,27,28, infectious diseases in the upper respiratory tract 21,29,30 and the severity as well as mortality in critically ill patients 31.

Therefore, we expect that an increased skin synthesis of vitamin D due to increased UVB radiation increases the likelihood of immunity and reduces the likelihood of severe infections, thereby reducing the critical COVID-19 cases. Thus, we anticipate that an increase in UVB radiation as measured by ultraviolet index (UVI) relates to a reduction of the number of COVID-19 deaths.

3 Methods

3.1 Description of Data

In order to identify the relation of UVB radiation and COVID−19 deaths, we constructed the dataset outlined in Table 1. We collected data covering 108 days from 22 January 2020 until 8 May 2020 across 183 countries of which 158 reported COVID−19 deaths prior to 8 May 2020 and of which 152 reported more than 20 COVID−19 infections prior to 8 May 2020. We focus on those 152 countries to ensure that the results are not biased by countries that are at a very early stage of COVID−19 outbreak, which would limit data points with respect to COVID−19 deaths. In addition, we drop the first 20 daily observations of every country after that country reported the first COVID−19 infection to further ensure that results are not biased by the observations at the very early stage of the COVID−19 outbreak.

The corresponding country level data consist of the cumulative daily COVID−19 deaths and infections, the daily ultraviolet index (UVI), which is closely connected to the daily UVB radiation, and a set of control variables such as daily weather parameters such as precipitation index, cloud index, ozone level, visibility level, humidity level, as well as minimum and maximum temperature.

Table 1: Summary of Dataset

Number of countries in the world	195
Number of countries in our dataset	183
... > 0 cumulated COVID-19 deaths before 8 May 2020	158
... > 20 cumulated COVID-19 infections before 8 May 2020	152
Covered time-period	22 January 2020 - 8 May 2020 (108 days)
Granularity of data	Daily
COVID-19 data source	https://github.com/ CSSEGISandData/COVID-19
Weather data source	https://darksky.net/

We present descriptive statistics of the dataset in Table 2. As of 8th of May, the cumulative COVID−19 deaths of these 152 countries were on average 1,808 and the growth rate of COVID−19 deaths on May 8 was on average 2.6% as compared to the average growth rate of COVID−19 deaths across countries and time which was 10.1%. The cumulative COVID−19 infections were on average 25.888. The case-fatality-rate (CFR), as measured by the cumulative COVID−19 deaths divided by the cumulative COVID−19 infections per country, was on average 4.3% on May 8. The growth rate of CFR on May 8 was on average −1.1% as compared to the growth rate of CFR across countries and time which was 2.6%. We use cumulative COVID−19 deaths as the main dependent variable to test our hypothesis linking UVB radiation to COVID−19 deaths and use the CFR to test the consistency of our results. On average, the first reported COVID−19 infection in each country happened 68.15 days before 8 May 2020. UVI is on average 6.81 representing a moderate to high risk of harm from unprotected sun exposure.

Table 2: Descriptive Statistics of Dataset

Variable	Number of Countries	Number of Observations	Mean	Std. Dev.	Min	Max
Cumulated COVID-19 deaths on 8 May	152	152	1,808	7,779	1	77,180
Growth rate of cumulative COVID-19 deaths on 8 May	152	152	0.026	0.051	0	0.4
Daily growth rate of cumulative COVID-19 deaths	152	6,589	0.101	0.259	-1	9
Cumulated COVID-19 Infections on 8 May	152	152	25,888	111,303	23	1,283,929
CFR on 8 May	152	152	0.043	0.037	0.001	0.206
Growth rate of CFR on 8 May	152	152	-0.011	0.057	-0.421	0.238
Daily growth rate of CFR	152	6,589	0.026	0.200	-1	5.935
Time-passed by from first reported infection until 8 May	152	152	68.15	17.59	29	108
Daily Ultraviolet Index (UVI)	152	7,471	6.81	3.05	0	14
Daily precipitation index	152	7,471	0.29	0.31	0	1
Daily cloud index	152	7,471	0.50	0.30	0	1
Daily ozone level	152	7,471	308.48	47.06	235.5	472.7
Daily Visibility level	152	7,471	15.29	2.17	0.117	16.09
Daily humidity level	152	7,471	0.63	0.20	0.04	1
Minimum temperature per day within a country	152	7,471	12.45	9.78	-23.45	30.87
Maximum temperature per day within a country	152	7,471	22.83	10.47	-16.41	45.82

3.2 Illustration of Ultraviolet Index (UVI) and COVID−19 Deaths

The graph on the top of Figure 2 shows the cumulative COVID−19 deaths and the associated daily growth rates for Italy from 26 February 2020 until 8 May 2020. As time progresses, the cumulative COVID−19 deaths increase but at a slower rate. Initially, the growth rate is high at 41.67% (growth rate from 26 February to 27 February) and it gradually slows to 0.81% (growth rate from 7 April to 8 May).

The graph on the bottom of Figure 2 shows the daily growth rates and daily UVI for Italy as well as the UVI values lagged by one, two, three, four and five weeks respectively. It is important to consider the lagged effect of UVI because synthesized vitamin D is cumulative and can be stored in body fat to be used later21. Therefore, it seems more plausible that an increase of UVI today will continue to support an individual’s immunity later i.e., two- or more weeks’ time. Furthermore, the likelihood of skin synthesis is low in severely infected people, while they are hospitalized, indicating the importance of lagged UVI values.

It is evident that the growth rates slow down over time, as counter-measures imposed by governments take effect, which results in lower infection rates and lower mortality rates. At the same time, the UVI is increasing due to seasonal changes in the northern hemisphere countries. In order to approximate the association of UVI, we need to isolate it from the underlying time-trends, which are potentially affecting both UVI as well as the growth rates of cumulative COVID–19 deaths.

4 Results

We estimate the effect of UVI on the cumulative COVID–19 deaths by using log-linear fixed-effects regression. The effect of UVI is isolated from time-constant country-specific factors (see Figure 1) by using a within-transformation of the transformed structural model as outlined in equation (1) in *Supplementary Appendix.* Further, we use the partialling-out property to isolate the effect of UVI from all linear as well as some non-linear effects of time varying factors such as weather and time, which may confound the results. Our statistical analysis is outlined in detail in *Description of Methodology* section in *Supplementary Appendix.*

The key finding is the significant negative long-run association of UVI on cumulative COVID–19 deaths. As we outline in the *Identification of UVI Effect* section in *Supplementary Appendix,* the estimate is likely to identify an upper bound of the relation, indicating that the association could be even stronger. Our results presented in Table 3 suggest that a permanent unit increase of UVI is associated with a decline of 1.2 percentage points in daily growth rates of cumulative COVID–19 deaths [$p < 0.01$]. Relative to the average daily growth rate of cumulative COVID–19 deaths (10.1%), this decline translates into a significant percentage change of –11.88% (= –1.2%/10.1%). We further find that a permanent unit increase of UVI is associated with a decline of 1.0 percentage points in the daily CFR growth rate [$p < 0.05$].

Compared with the average daily growth rate of CFR (2.6%), this decline translates into a significant percentage change of –38.46% (= –1.0%/2.6%).

Results indicate no significant association from an increase of UVI on cumulative COVID–19 deaths on the same day or a week ahead. This insignificant finding is consistent with the fact that severely infected people are more likely to be hospitalized and therefore less likely to be exposed to UVB radiation during their hospital stay. We further recognize that UVB radiation may not make a real difference, when someone is already severely infected and developed severe complications. The results also show that UVI has a stronger relation to COVID–19 deaths than CFR. We anticipate that the weaker association with CFR is plausible as UVI helps in vitamin D synthesis, making the infection less severe due to increased immunity, thereby prompting fewer people to take the test.

The results of the robustness checks presented in Table 2 and Table S3 (*Robustness Checks* section in *Supplementary Appendix)* suggest that the relation of UVI on cumulative COVID–19 deaths is consistent (–0.006 —–0.012) across different model specifications which isolate the association of UVI from underlying time trends in flexible ways. In fact, the most flexible model - Model 8 of Table S3 (*Robustness Checks* section in *Supplementary Appendix)* - reveals substantial and significant evidence of the UVI relation with cumulative COVID–19 deaths (–0.008, $p < 0.05$). A decline of 1.2 percentage points in daily growth rates of cumulative COVID–19 deaths has significant long-run effects on the cumulative COVID- 19 deaths as outlined in Figure 3. In order to simulate the long-run effects, we take the average number of cumulative COVID–19 deaths across all 152 countries as of May 8, 2020, i.e., 1,808 as cumulative COVID–19 deaths at day 0 as shown in Figure 3. A scenario with a permanent unit increase of UVI over the baseline scenario of average UVI of 6.81 across countries is associated with 989 or 14.22% fewer deaths in 14 days.

Table 3: Effect of UVI on the Cumulative COVID-19 Deaths

	Model 1	Model 2
Dependent Variable	COVID-19 Deaths	CFR
L0.UVI	-0.002 (-1.53)	-0.001 (-0.41)
L1.UVI	0.000 (0.02)	-0.001 (-0.37)
L2.UVI	-0.002 (-1.03)	-0.004* (-2.18)
L3.UVI	-0.002 (-1.29)	-0.002 (-1.49)
L4.UVI	-0.003* (-2.03)	-0.003 (-1.53)
L5.UVI	-0.002 (-1.23)	0.000 (0.08)
Long-Run Coefficient	-0.012** (F: 8.33)	-0.010* (F: 6.23)
Control Variables		
Time Trend of Growth Rate	Linear	Linear
Country Fixed Effects	Yes	Yes
Precipitation index	Yes	Yes
Cloud index	Yes	Yes
Ozone level	Yes	Yes
Visibility level	Yes	Yes
Humidity level	Yes	Yes
Temperature (min and max)	Yes	Yes
Number of Estimates	49 (+152 FE)	49 (+152 FE)
Number of Observations	6,524	6,524
Number of Countries	152	152
R-squared Within	13.74%	1.80%

Note: +: $p < 0.10$, *: $p < 0.05$, **: $p < 0.01$. t-statistics based on robust standard errors in parentheses. F-statistic for long-run coefficient in parentheses. L0.UVI stands for the effect of UVI at time t on the cumulated number of COVID-19 deaths at the same time, whereas L1.UVI, L2.UVI, L3.UVI, L4.UVI and L5.UVI stand for the effect of UVI lagged by one, two, or three, four and five weeks respectively. FE stands for country fixed-effects.

5 Discussion

In this study, we find evidence of the protective role of UVB radiation in reducing COVID−19 deaths. Specifically, we find that a permanent unit increase in ultraviolet index (UVI) is associated with a 1.2 percentage points decline in daily growth rates of COVID−19 deaths [p < 0.01] as well as a 1.0 percentage points decline in the daily growth rates of CFR [p < 0.05]. These results translate into a significant percentage reduction in terms of the daily growth rates of cumulative COVID–19 deaths (–11.88%) and CFR (–38.46%). Our results are consistent across different model specifications.

We acknowledge that we may not be able to isolate the association of UVI with cumulative COVID–19 deaths from all confounding factors. Still, we anticipate that an increased likelihood of immunity and a reduced likelihood of infections mediated by an increased likelihood of vitamin D synthesis may plausibly explain this finding. We also acknowledge that we may not be able to rule out the possibility of mediation by other UVB induced mediators—such as cis-urocanic acid, nitric oxide 13,32. Therefore, further clinical studies - observational or randomized controlled trials - are required to establish the casual relationship of vitamin D deficiency and COVID–19 deaths, potentially leading to a cost-effective policy intervention for the prevention or as a therapy for COVID–19. The possibility of mitigating COVID–19 via sensible exposure to sunlight or via vitamin D intervention seem to be very attractive from a policy maker's perspective because of its low cost and side effects.

Various countries are implementing lockdown as a preventive measure to mitigate COVID- 19 impact on healthcare system. Unfortunately, confinement at home also leads to limited UVB exposure, possibly increasing the risk of COVID–19 deaths. While sensible exposure to sunlight helps in synthesizing vitamin D, disproportionate exposure may also increase the risk of sunburn and skin cancer21. Countries could create awareness among the population regarding the importance of sensible exposure to sunlight, whilst continuing other measures such as social distancing as well as cautioning against disproportionate exposure. If confirmed via additional clinical studies, then countries could adopt a cost-effective vitamin D intervention program—especially among vulnerable populations with increased risk of vitamin D deficiency, e.g., elderly populations living in nursing homes, people with high body mass index, dark skinned people residing in higher latitudes, people with indoor lifestyle, or vegetarians.

Declarations

Declaration of Interests

RKM is a PhD student at Goethe University, Frankfurt. He also is a full-time employee of a multinational chemical company involved in vitamin D business and holds the shares of the company. This study is intended to contribute to the ongoing COVID-19 crisis and is not sponsored by his company. BS also holds shares of the company. All other authors declare no competing interests. The views expressed in the paper are those of the authors and do not represent that of any organization. No other relationships or activities that could appear to have influenced the submitted work.

Acknowledgements

We would like to acknowledge Sharath Mandya Krishna, and Rukhshan Ur Rehman for their immense contribution to this paper - for providing inputs and assisting with data collection, data transformation and data engineering. We thank Matthew Little for his assistance in review. We would also like to acknowledge Michael Niekamp, Magdalena Ceklarz and Daniel Gutknecht for their valuable contributions to our paper and the discussions about COVID-19.

Author Contributions

RKM conceptualized the research idea, conducted literature research, designed theoretical framework and collected the data. LK designed empirical methods and analyzed the data. RKM and LK interpreted the results and wrote the article. BS provided critical inputs, edited and revised the article.

Role of the Funding Source

This study is not sponsored by any organization. The corresponding author had full access to all the data and had final responsibility for the submission decision.

Additional Information

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Data Sharing

The data used in the study are from publicly available sources. Data regarding COVID-19 are obtained on 9th May 2020 from *COVID-19 Data Repository* by the *Center for Systems Science and Engineering (CSSE)* at *Johns Hopkins University* and can be accessed at https://github.com/CSSEGISandData/COVID-19. Data regarding weather is obtained from *Dark Sky* on the 9th May 2020 and can be accessed at https://darksky.net/. We will make specific dataset used in this study available for any future research. Interested researchers can contact one of the authors via email to get access to the data.

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Figures

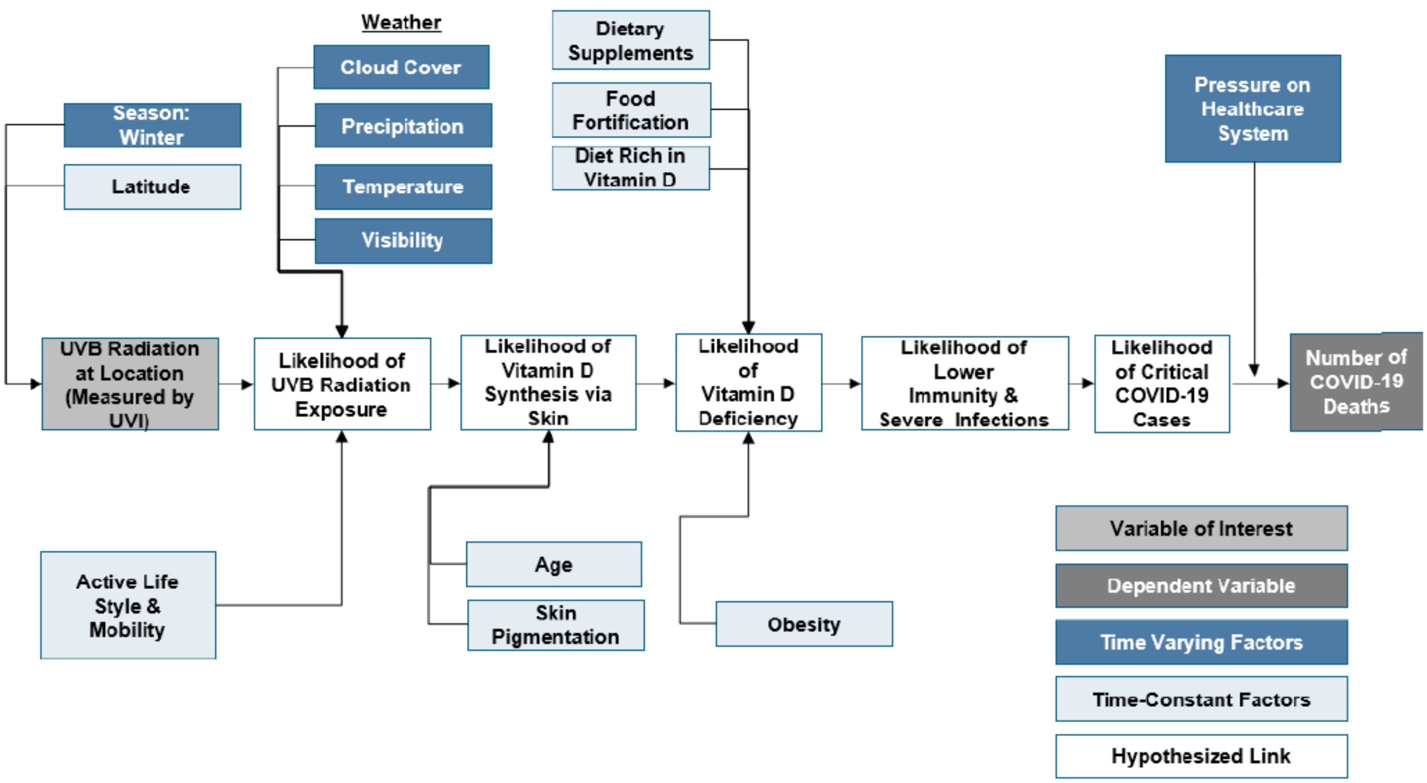

Figure 1

Explanation of Protective Role of Ultraviolet-B (UVB) Radiation in COVID-19 Deaths Mediated by Vitamin D Synthesis & Deficiency

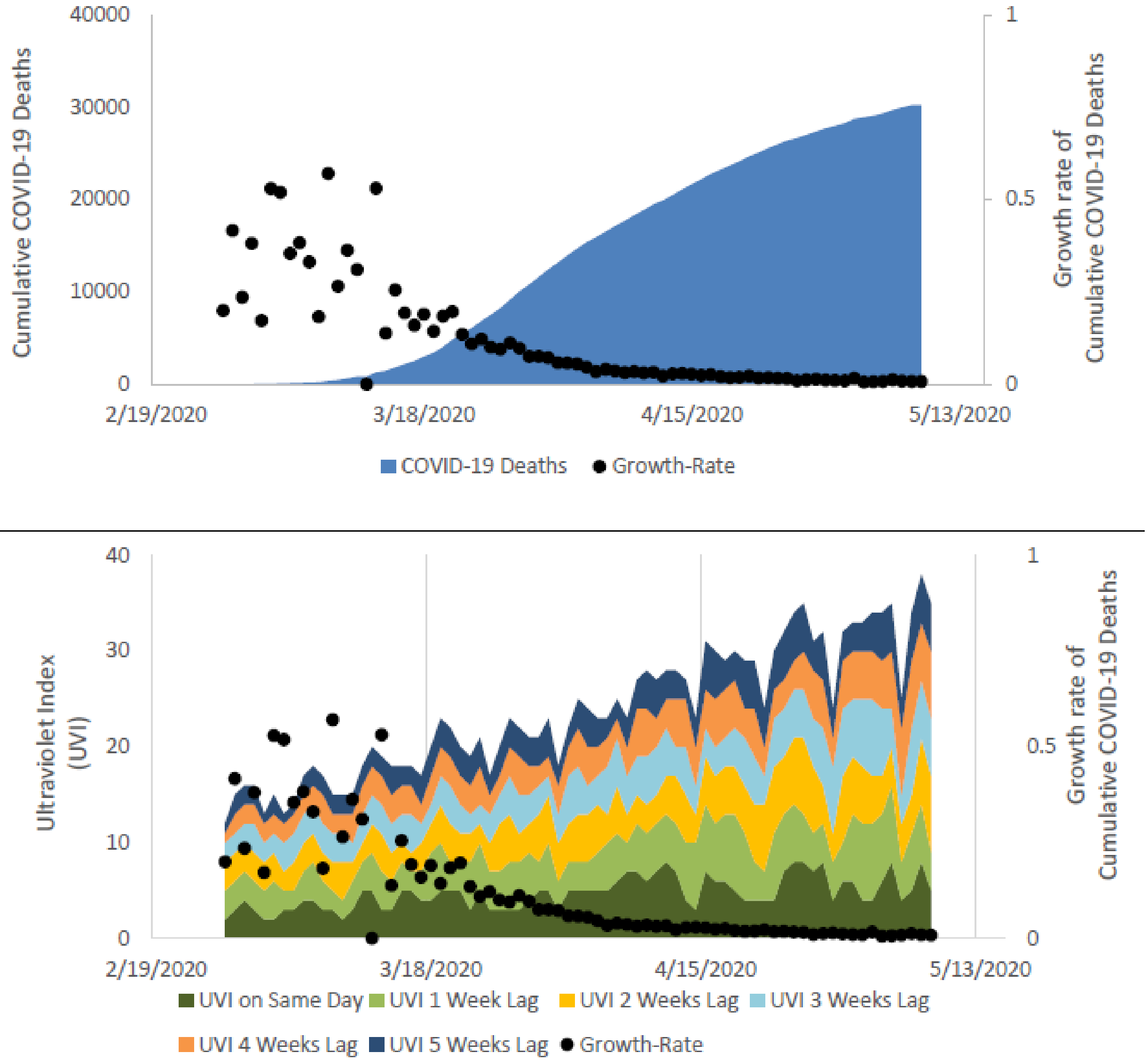

Figure 2

Number of COVID-19 deaths, Growth Rates and ultraviolet index (UVI) for Italy

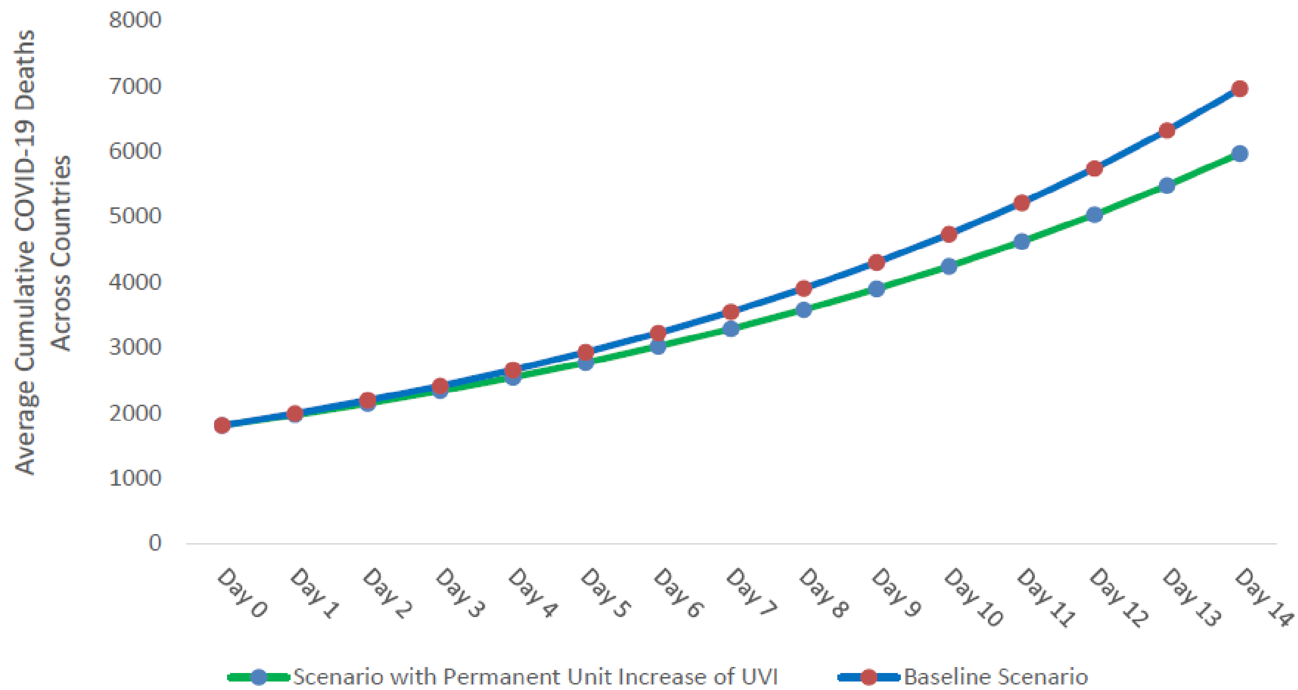

Figure 3

Long-run Effects of a Permanent Unit Increase of UVI on Average Cumulative COVID-19 Deaths Across Countries

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- supplementaryinformationEvidenceofProtectiveRoleofUltravioletBUVBRadiationinReducingCOVID19Deaths.pdf