Higher solar irradiance is associated with a lower incidence of COVID-19

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Abstract

We studied the relationship between the incidence of coronavirus disease 2019 (COVID-19), demographical, and climatological measurements in different regions across the world. Lower solar irradiance and higher population density were independent predictors of greater COVID-19 outbreaks. Further studies on the potential protective effect of sunlight over COVID-19 are warranted.

Key-words: SARS-CoV-2; COVID-19; climatological factors; solar irradiance; incidence.

Introduction

The SARS-CoV-2 virus causes the coronavirus disease 2019 (COVID-19), with varying degrees of illness that include the frequent requirement of mechanical ventilation and high mortality in the elderly. After the initial outbreak in China, it is now causing a pandemic with severe economic and health consequences.[1] The key factors influencing the spread of the new SARS-CoV-2 virus are mostly unknown.[2] The higher incidence of COVID-19 cases in inland territories (e.g., Wuhan, Lombardy, Madrid), as opposed to coastal territories, suggests that climatological factors might influence the course of the pandemic. This is further supported by the seasonal nature of other betacoronaviruses,[3] and by previous research showing that environmental variables, such as high temperatures and high humidity, slowed the influenza spread.[4] Accordingly, some have suggested that COVID-19 will subside with the warmer weather expected in the Northern Hemisphere in the coming months,[5] while others claim that the effect of increasing temperatures and humidity during the summer will likely be modest, and not enough to stop transmission.[6] However, until now, the potential utility of sunlight has been largely overlooked. Learning about the factors influencing COVID-19 spreading could help anticipate the extent of its consequences and guide governments in the design of mitigation measures worldwide.[7]

Here, we studied whether differences in the occurrence of COVID-19 disease are associated with well-defined climatological factors, as well as population density. For this purpose, we correlated the number of COVID-19 cases in the first weeks of the epidemic in each country and region with matching geolocalized information on climatological measurements in the same period.

Methods

Information on COVID-19

The datasets on the number of COVID-19 affected persons around the world were obtained from the 2019 Novel Coronavirus COVID-19 (2019-nCoV) Data Repository by Johns Hopkins CSSE and two additional repositories for Italy and Spain (Supplementary materials). The pooled dataset contained geolocalization information and time trends in the number of confirmed COVID-19 and fatalities for a total of 359 countries and regions of those countries with the highest numbers of cases (namely China, Italy, USA, and Spain), as well as Canada and Australia. In order to account for the effect of potential confounding factors not included in the analysis, each of the studied areas was assigned a parent geographical location defined by the continent for each country (Asia, Oceania, Europe, Africa, North America, and South America) and the country for each region. After determining the date in which the number of confirmed cases was ≥ 10 for each of the studied regions, we defined the beginning of the study period at day -7 to account for the incubation period of around one week and prolonged it until day +30 or the day of the analysis (March 23, 2020) if shorter.[1] We gathered information on population and density of each of the studied regions (available in Wikipedia from several sources) and calculated the cumulative incidence of COVID-19 / 100,000 inhabitants during the study period.

Climatological measurements

We accessed the Weatherbit application-programming interface (weatherbit.io) to compile geolocalized information on daily measures of the following weather variables: average relative humidity (%); average dew point (Celsius); average, maximum and minimum temperature (Celsius); average pressure (mb); average sea level pressure (mb); average wind speed (m/s); wind gust speed (m/s); maximum 2-minute wind speed (m/s); average wind direction (degrees); average cloud coverage (%);

accumulated precipitation (mm); accumulated snowfall (mm); snow depth (mm); average diffuse horizontal solar irradiance (W/m^2); average global horizontal solar irradiance (W/m^2); maximum ultraviolet (UV) index (0-11+).

Statistical analysis

We described the study variables through descriptive statistics and histograms. The correlations between the primary outcome measure (incidence of COVID-19) and the mean and variance of each physical variable during the study period were studied with Spearman's rho correlation because of the asymmetric distribution of the incidence of COVID-19. The independent predictors of the (log-transformed) incidence of COVID-19 were tested with multiple linear regression analysis. The parent geographical location was forced into the model (as dummy variables) in order to account for differentially distributed factors likely to influence the course of the epidemic. Given the number of correlation tests, Bonferroni's correction was applied, and p values < 0.0025 were considered significant. We used Python 3.7.6 with the Numpy, Pandas, Matplotlib, and Seaborn libraries for the analyses.

Results

The cumulative incidence of COVID-19 was highly variable across the world (median 6.4/100,000 inhabitants, IQR 0.4 – 48.3), and the median (IQR) case fatality rate during the study period was 1% (0 – 3.5%). Population density (rho = 0.32) and all measures of solar irradiance significantly correlated with the occurrence of COVID-19 (rho = -0.41, -0.37 and -0.25 for global horizontal solar irradiance, diffuse horizontal solar irradiance, and maximum UV index, respectively) (Figure, Table 1 and Figure in Supplementary Materials). Other physical factors showing mild inverse correlations with the incidence of COVID-19 were average (rho = -0.28), maximum (rho = -0.30) and wind gust speed (rho = -0.30), average sea level pressure (rho = -0.21), and accumulated precipitation (rho = -0.29). The case fatality rate was not associated with any of the studied variables. The multiple linear regression model that included the population density, the parent geographical location, and global horizontal solar irradiance explained 70% of the variance in the differences in the incidence of COVID-19 (as indicated by the R2). Both population density (p = 0.019) and global horizontal solar irradiance (p = 0.027) were independent predictors of the cumulative incidence of COVID-19, and the equation was as follows:

Incidence = 0.491 -0.003 irradiance + 0.001 density + individual β for each parent geographical location (Table 2, Supplementary Materials).

Discussion

It is unclear how the COVID-19 pandemic will spread and whether it will have a seasonal nature. Efforts to combat the growth of SARS-CoV-2 are ubiquitous and rather overwhelming, from mandatory quarantines to imposed house confinement. Evidence from previous studies in other viral diseases, such as influenza, suggests that temperature or humidity may have only limited influence on the spread of COVID-19 throughout the world.[6] Our results show that the influence of ultraviolet radiation may be more important than any other climatological factor in determining the spread of COVID-19 disease.

UVB radiation from sunlight (the primary source of UV radiation) is the principal environmentally effective virucide, several orders of magnitude more relevant than other primary physical factors, such as temperature and relative humidity. Moreover, inactivation of viruses in the environment by solar UV radiation plays a role in the seasonal occurrence of influenza pandemics.[8,9] There is evidence on the environmental contamination as a potential medium of transmission of SARS-CoV-2, as it seems to remain active on the surface of different materials for several hours to days[1], thus higher solar radiation may help inactivate the virus. We found that higher variance on the weather variables that protected from COVID-19 was associated with a higher incidence of the disease. This was especially apparent for measurements of solar irradiance, suggesting that prolonged exposure to UV radiation may be needed for its protective effect. In addition to the potential virucidal effect of UV radiation, it also modulates host immunity against viral infections, both directly activating the innate immune response and controlling vitamin D production, which in turn harbor positive immune effects.[10]

However, the relationship between higher UV radiation and reduced incidence of COVID-19 was modest, and the independent association between population density and incidence of COVID-19 highlighted the risks of close interpersonal contacts during the epidemic and the need for social distancing measures to prevent its growth. Previous studies have shown that, in addition to population density, crowding may influence the intensity of viral epidemics like influenza and also COVID-19 as well.[11,12] The significant contribution of the geographic location over the incidence of COVID-19 suggests that several factors not included in our analysis may have been crucial for the variability in the transmission of the disease. These may include patterns of mobility of the population or different preventive measures in each country. Besides not being able to study every factor influencing the spread of the disease, the primary limitation of this analysis is its observational design, requiring further studies on the effects of environmental factors on COVID-19 transmission to confirm these findings. Varying diagnostic efficiency across countries may result in inaccurate quantification of the number of infected individuals. Finally, the limited accuracy of the co-localization of the weather information may have resulted in underestimating the magnitude of the associations described here.

Conclusions

We show a significant association of the incidence of COVID-19 and both reduced solar irradiance and increased population density. These results highlight the sterilizing properties of ultraviolet radiation and suggest that, even if not sufficient on its own, increasing sunlight exposure in the upcoming weeks may help flatten the epidemic. Further studies on the potential protective effect of sunlight over COVID-19 will be needed to study the effect of changes in weather conditions in the next months on the spread of COVID-19, and to ascertain whether UV radiation may have a meaningful protective effect on the disease.

Acknowledgments

Xabier Urra is sponsored by the Instituto de Salud Carlos III, reference number INT19/00020, and by the European Social Fund «The ESF – Investing in your future». Mar Guasp is a recipient of a Resident Award “Josep Font”, granted by Hospital Clínic de Barcelona, Research, Innovation, and Education Departments.

Author disclosures

Mar Guasp reports no disclosures.

Carlos Laredo reports no disclosures.

Xabier Urra reports no disclosures.

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Figure legend

A: Pairplot including the measures of solar irradiance, parent geographical location, population density and incidence of COVID-19 (per 100,000 inhabitants). The figure shows scatter plots for each pair of variables, and the diagonal axis shows the univariate distribution of the variable in that column. B: Heatmap with clustering analysis according to correlation information. In addition to parent geographical location, population density is positively correlated with the incidence of COVID-19, while measures of solar irradiation show negative correlations. Note that the three measures of solar irradiation are highly correlated each other. Max_UV: maximum ultraviolet index; GHI: average global horizontal solar irradiance; DHI: average diffuse horizontal solar irradiance; Log_Incidence: logarithmic transformation of the cumulative incidence of COVID-19; GeographicalRegion: parent geographical location.