Correlation between UV index, temperature and humidity with respect to incidence and severity of COVID 19 in Spain

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Abstract

Background

Different studies support the inverse correlation between solar exposure and Coronavirus SARS-CoV-2 infection. In Spain, the global incidence of COVID-19 is different depending on latitude from Canary Islands to North Spain which could be related with different meteorological conditions as temperature, humidity, and ultraviolet index (UVI). The objective of the present work was to analyze the association between UVI and other relevant environmental factor such as temperature or humidity with the incidence and severity/mortality of COVID19 in different latitudes in Spain.

Methods

An observational prospective study was used to analyzed number of new cases, hospitalizations, patients in critical units as well as mortality and annual variations related to UVI, temperature, and humidity in 5 different provinces of Spain from January 2020 to February 2021.

Results

Statistically significant inverse correlation (Spearman coefficients) was observed between UVI and temperature and the annual evolution and COVID-19 incidental cases in all and almost all latitudes respectively.

Conclusion

Higher ultraviolet radiation levels and mean temperature could contribute in reducing COVID-19 incidence, hospitalizations and mortality.

Introduction

SARS-CoV-2 coronavirus pandemic is believed to start in December 2019 at Wuhan, China¹. Mild cases, commonly teens and young adults, usually present symptoms as cough, fever, or throat pain. However severe cases may present refractory hypoxemia ARDS (adults respiratory distress syndrome), multiple organ failure and even death; most of these require conventional hospitalization and even intensive care unit (ICU) hospitalization². Diagnosis is clinical and when is suspected must be confirmed with nasopharyngeal smear PCR test, or with serological blood test in advanced disease phases. Since the pandemic started, more than 4.900.000 people have died from COVID19 disease in the world, most of them were over 65 years old³.

Virus spread mechanism is still being studied. Nowadays is believed to transmit same way other similar coronavirus do, by droplets from an infected person to another⁴. Generally, respiratory disease-causing virus are more contagious when the infected people is symptomatic. Basic hygienic rules to prevent transmission are hands washing, social distancing, mask wearing and coughing or sneezing in disposable tissues.

Sun radiation divides in Infrared, visible and ultraviolet (UV) radiation. UV radiation levels oscillate along the different seasons, with greater levels during spring or summer, and lower along autumn and winter. Also clouds or pollution can contribute in reducing UV radiation levels⁵.

Ultraviolet Index (UVI) measures the intensity of UV radiation reaching earth surface. There's a globally standardized scale for measuring UVI, where 0–2 is considered low exposure, 3–5 is mild exposure, 6–7 is high exposure, 8–10 very high exposure, and 11 or more is considered extremely high⁶.

UV radiation exerts different effects either in human health and also in the environment. Regarding health, UVB radiation is crucial for vitamin D synthesis in the skin, and consequently in regulating all its functions, including the immune modulatory effect⁷; in fact, several studies support the association between low serum vitamin D levels and more severe COVID19 disease⁸. In regard to the environmental effect of UV radiation, UVC has been shown to be very effective decontaminating the air from SARS-CoV-2⁹. Although UV radiation from the sun does not content UVC, UV radiation has been proposed to be an environmental determinant in shaping the transmission of COVID-19 at the seasonal time scale¹⁰. Temperature seems to be also important for SARS-CoV-2 which was highly stable at 4°C but sensitive to heat¹¹. Several studies suggest that environmental conditions may affect the COVID-19 pandemic, although the results are controversial. Evidence that the COVID-19 pandemic may be partially suppressed with temperature and humidity increases¹².

Taking all of this into consideration, our objective was to analyze the association between UVI and other relevant environmental factor such as temperature or humidity with the incidence and severity/mortality of COVID19 in different latitudes in Spain.

Material And Methods

A prospective observational study, selecting incident cases, hospitalized cases, ICU-admitted cases and deaths caused by COVID19 infection from January 2020 to February 2021 in five provinces in Spain was carried out. The provinces were selected to cover the whole latitude of Spain from the North to South as follows Guipuzcoa (latitude N 43.257), Zaragoza (latitude N 41.6563), Madrid (latitude N 40.4167), Málaga (latitude N 36.72016) and Tenerife (latitude N 28.46824). In order to compare the different cities, we obtained the incidence rate per 100.000 inhabitants of the four variables, dividing the number of cases among the total population of each province: Madrid 6.779.888, Málaga 1.685.929, Tenerife 1.044.887, Zaragoza 972.528 y Guipuzcoa 727.212 inhabitants. These data were collected from the National Epidemiology Centre (INE). Meteorological data, including daily UVI, humidity and mean

temperature of the five places, were collected from the National Meteorology Agency in Spain (AEMET). Daily data were collected from INE and AEMET but they were represented by mean data per week in figure, taking first, second and third week from 1–7, 8–14 and 15–21 respectively. Last week data were mean values from day 22 to the end of each month. For comparison between the different latitudes, mean data per season were also represented as well as the mean of the total study period (Table 1).

Table 1

Mean UVI, temperature and humidity per season as well as the incidence of COVID-19 variables from winter 2020 to end of winter 2021 in the five different studied provinces. Global mean data followed by SD are also represented for each variable and localization.

		Guipuzcoa	Zaragoza	Madrid	Málaga	Tenerife
		Mean UV index				
2020	WINTER	2.6	2.5	2.9	3.5	5.4
	SPRING	6.8	7.6	7.9	8.0	9.9
	SUMMER	6.5	7.3	7.7	7.9	9.6
	AUTUMN	1.8	2.0	2.4	2.9	4.6
2021	WINTER	2.0	2.0	2.2	2.8	4.5
	Mean (SD)	4.0 (2.5)	4.3 (2.9)	4.6 (2.9)	5.0 (2.7)	5.0 (2.7)
		Mean temperature (°C)				
2020	WINTER	11.5	9.7	9.8	15.4	19.7
	SPRING	17.6	19.3	18.4	20.8	21.9
	SUMMER	21.7	24.9	24.9	26.7	25.4
	AUTUMN	13.3	12.0	11.1	17.5	22.3
2021	WINTER	10.4	9.0	6.9	14.0	18.6
	Mean (SD)	14.9 (4.7)	15.0 (6.9)	14.2 (7.3)	18.9 (5.1)	21.6 (2.6)
		Mean Relative Humidity (%)				
2020	WINTER	76.9	79.4	63.1	69.2	67.1
	SPRING	81.9	67.3	50.4	59.9	72.1
	SUMMER	81.8	52.7	41.9	54.4	76.4
	AUTUMN	74.8	78.8	70.5	68.4	72.9
2021	WINTER	74.9	78.8	57.7	70.4	73.9
	Mean (SD)	78.4 (3.6)	71.4 (11.6)	56.4 (11.1)	64.5 (7.0)	72.5 (3.4)
		COVID19 Incidence (number of cases/100.000 habitants)				
2020	WINTER	1.59	1.89	6.05	1.14	0.91
	SPRING	2.20	2.96	5.51	0.74	0.69
	SUMMER	14.86	25.91	27.91	8.37	2.57

		Guipuzcoa	Zaragoza	Madrid	Málaga	Tenerife
	AUTUMN	42.44	33.09	24.61	15.07	9.97
2021	WINTER	22.57	30.60	42.89	38.91	6.12
	Mean (SD)	16.73 (16.9)	18.89 (15.3)	21.39 (15.8)	12.84 (15.7)	4.05 (4.0)
COVID19 Hospitalizations (number cases/100.000 habitants)						
2020	WINTER	0.75	1.05	4.07	0.67	0.42
	SPRING	0.52	1.18	2.11	0.24	0.26
	SUMMER	0.80	2.24	1.15	0.54	0.24
	AUTUMN	0.63	3.32	1.33	1.13	0.92
2021	WINTER	10.92	13.75	17.00	15.92	3.25
	Mean (SD)	2.73 (4.6)	4.31 (5.4)	5.13 (6.7)	3.70 (6.8)	1.02 (1.3)
COVID19 Intensive Care Units patients (number cases/100.000 habitants)						
2020	WINTER	0.07	0.16	0.33	0.08	0.08
	SPRING	0.02	0.13	0.17	0.02	0.03
	SUMMER	0.09	0.11	0.06	0.05	0.05
	AUTUMN	0.08	0.29	0.07	0.08	0.14
2021	WINTER	0.01	0.32	0.16	0.27	0.12
	Mean (SD)	0.05 (0.04)	0.20 (0.10)	0.16 (0.11)	0.10 (0.10)	0.08 (0.05)
COVID19 Deaths (number cases/100.000 habitants)						
2020	WINTER	0.08	0.15	0.55	0.07	0.04
	SPRING	0.38	0.65	0.81	0.11	0.08
	SUMMER	0.12	0.44	0.18	0.07	0.02
	AUTUMN	0.70	0.94	0.33	0.25	0.14
2021	WINTER	0.39	0.65	0.44	0.59	0.14
	Mean (SD)	0.39 (0.29)	0.56 (0.33)	0.46 (0.27)	0.22 (0.09)	0.08 (0.05)

As variables did not follow normality, Spearman correlation test was used to analyze the correlations between daily meteorologic variables and the incidental cases of the different variables of COVID19.

COVID19 infection is occasionally diagnosed several days after the patient gets infected, with a mean incubation period of five days¹³. As we wanted to evaluate the influence of climate in COVID19

transmission and severity, in order to perform an accurate analysis, we considered that COVID19 incidence had to correlate with meteorological data from five days before. This method was also applied to hospitalization, correlating with data from nine days before¹⁴; ICU admission, correlating with data from fifteen days before¹⁴; and deaths being correlated with data from twenty days before¹³.

Results

Description of meteorological and COVID-19 variables

Meteorological data (UVI, temperature and humidity) as well as the weekly changes in the incidence of COVID 19 (total cases and hospitalizations/ 100.000 inhabitants) are represented in Fig. 1. Seasonal data for all meteorological as well as incidence variables are described in Table 2. The annual variations in the UVI are observed from lower values (around 1), at the beginning of January, until higher values in July (around 10). The exception was Tenerife with variations of UVI from lower winter values of around 3 until maximal values of 12 at the beginning of July. The mean UVI per season are represented in the Table 1 showing significant variations from San Sebastian values with respect to the rest southern localizations. Similar annual pattern was observed for temperature and humidity in the peninsula provinces, with a gradual increase of temperature from winter to mid-summer and the inverse was observed for humidity. The exception was Tenerife with lower annual variations of temperature, around 25 °C with humidity over 70% for the whole year.

Table 2
Correlations between UVI and COVID19 incidence rate, hospitalized cases, ICU-admitted cases and deaths per 100.000 inhabitants.

	Cases	Hospitalized	ICU-admitted	Deaths
	/100.000 inh.	/100.000 inh.	/100.000 inh.	/100.000 inh.
GUIPUZCOA	-0.242 p < 0,001	N.S.	N.S.	-0.302 p < 0,001
ZARAGOZA	-0.111 p = 0.02	-0.201 p < 0.001	-0.174 p < 0.001	-0.219 p < 0.001
MADRID	-0.188 p < 0.001	-0.144 p = 0.005	NS	NS
MÁLAGA	-0.362 p < 0.001	-0.333 p < 0.001	NS	-0.264 p < 0.001
TENERIFE	-0.456 p < 0.001	-0.374 p < 0.001	-NS	NS

Table 3
Correlations between mean temperature and COVID19 incidence rate, hospitalized cases, ICU-admitted cases and deaths per 100.000 inhabitants

	Cases /100.000 inh.	Hospitalized / 100.000 inh.	ICU-admitted /100.000 inh.	Deaths /100.000 inh.
GIPUZCOA	NS	0.138 p = 0.007	NS	-0.291 p < 0.001
ZARAGOZA	0,105 p = 0.031	NS	-0,173 p < 0.001	-0,116 p = 0.019
MADRID	NS	NS	NS	NS
MÁLAGA	NS	-0.150 p = 0.003	NS	-0.220 p < 0.001
TENERIFE	NS	-0.110 p = 0.031	NS	NS

Table 4
Correlations between mean humidity and COVID-19 incidence rate, hospitalized cases, ICU-admitted cases and deaths per 100.000 inhabitants.

	Cases /100.000 inh.	Hospitalized / 100.000 inh.	ICU-admitted / 100.000 inh.	Deaths / 100.000 inh.
GIPUZCOA	-0.163 p = 0.001	NS	0.138 p = 0.005	-0.115 p = 0.02
ZARAGOZA	-0,168 p = 0.01	NS	0,131 p = 0.008	NS
MADRID	NS	NS	NS	NS
MÁLAGA	0.118 p = 0.015	NS	NS	NS
TENERIFE	0,191 p < 0.001	-0.159 p = 0.002	NS	NS

The greatest mean of the incidence of COVID19 cases per 100,000 inhabitants per day observed in the whole studied period was seen in Madrid (21.39, SD 15.8), followed by Zaragoza 18.89, SD 15.3), Guipuzcoa (16.73, SD 16.9) while Málaga incidence was almost the half of Madrid (12.84, SD 15.7) and

the lowest rate was Tenerife's (4.05, SD 4.0). Difference between Tenerife and the rest of provinces were all statistically significant ($p < 0.001$).

The mean number of daily hospitalizations per 100.000 inhabitants was also lower in Tenerife (1.02, SD 1.3) compared to the rest of the studied cities, with statistically significant differences with all other provinces ($p < 0.05$) (Table 1). The mean number of ICU-admitted patients per 100.000 inhabitants per week was significantly higher in Zaragoza (0.2, SD 0.1) followed by Madrid (0.16, SD 0.11) than in the rest of the provinces. Differences between Zaragoza and Guipuzcoa ($p = 0.001$), Málaga ($p = 0.002$) and Tenerife ($p = 0.006$) were statistically significant. Higher death mean was also seen in Zaragoza (0.56, SD 0.33) and Madrid (0.46, SD 0.27), followed by Guipuzcoa (0.39, SD 0.29), Málaga (0.22, SD 0.09) and Tenerife (0.08, SD 0.05). Differences in the mean of deaths between Málaga and Tenerife and the rest of the northern provinces were statistically significant ($p < 0.05$).

Correlation between COVID-19 and UVI

A statistically significant inverse correlation was observed between UVI and the daily incidental cases per 100.000 inhabitants in all the studied provinces (Table 2). The greatest correlation coefficient was in Tenerife ($r = -0.456$) and the lowest in Zaragoza ($r = -0.111$). Hospitalization was also inversely correlated to UVI in Zaragoza ($r = -0.201$), Madrid ($r = 0.144$), Málaga ($r = -0.333$) and Tenerife ($r = -0.374$). There was no association between ICU-admission and UVI, except for Zaragoza ($r = -0.174$). Inverse correlation between deaths and UVI were statistically significant in Zaragoza ($r = -0.219$), Málaga ($r = -0.264$) and Guipuzcoa ($r = -0.302$).

Correlation between COVID-19 and temperature

Association between COVID-19 and mean temperature was separately studied, observing less homogeneous and strong correlations than with UVI. Temperature was only associated to COVID-19 incidence in Zaragoza ($r = 0.105$). Temperature also showed a positive correlation with hospitalization in Guipuzcoa ($r = 0.138$), but an inverse correlation in Málaga ($r = -0.150$) and Tenerife ($r = -0.110$). ICU admission did not show correlation with temperature except for Zaragoza ($r = -0.173$). A statistically significant inverse correlation between temperature and deaths caused by COVID-19 was observed in Guipuzcoa ($r = -0.291$), Zaragoza ($r = -0.166$) and Málaga ($r = -0.220$).

Correlation between COVID-19 and relative humidity

Correlation between humidity and COVID19 variables were very heterogeneous and mostly non-statistically significant. An inverse correlation was observed between humidity and incidental cases in Guipuzcoa ($r = -0.163$) and Zaragoza ($r = -0.168$); meanwhile Málaga ($r = 0.118$) and Tenerife ($r = 0.191$) showed a positive correlation between COVID-19 incidence and humidity. Hospitalization did not associate with humidity, except for Tenerife ($r = 0.159$). Humidity showed a positive statistically significant correlation with ICU-admission in Guipuzcoa ($r = 0.138$) and Zaragoza ($r = 0.131$). Humidity was only inversely correlated with mortality in Guipuzcoa ($r = -0.115$).

Discussion

The present study shows that the incidence of COVID-19 is inversely correlated to the seasonal variation of UVI in the five provinces studied. Hospitalization and mortality were also seen inversely correlated to UVI but not in all of the studied provinces. According to temperature, correlations were less consistent and weaker in terms of incidental cases, but clearly it was observed an inverse correlation between temperature and hospitalizations in the less cold provinces (Málaga and Tenerife). Deaths were also correlated with mean temperatures in Guipuzcoa, Zaragoza and Málaga. The role that humidity plays remains uncertain, because the correlations found with the different COVID-19 variables are inconsistent.

The greatest media of incidence per 100.000 inhabitants along the studied period was seen in Madrid (21.39 SD 15.8), followed by Zaragoza (20.98 SD 21.02), Guipuzcoa (17.67 SD 20.35), Málaga (11.53 SD 15.97) and Tenerife (3.82 SD 4.16). These differences were statistically significant between Tenerife and the rest of the provinces. This matches some studies that confirm a lineal correlation between latitude and COVID19 incidence with and not clear association with temperature or humidity¹⁵. The highest incidence of Madrid, Zaragoza and Gipuzkoa might be related with the fact that Norther latitudes in Spain, together with high population density have been found an important factor for the spread of COVID-19¹⁶. It has to be pointed out that the COVID19 incidence at the beginning of the pandemic in Spain was underestimated because the low number of PCR performed.

This studio's most relevant and consistent highlight is the negative correlation between COVID19 cases incidence and the UVI in every studied latitude. These results agree with those published by Páez *et al.*¹⁷ also in Spain which found that daily UV increase was related to a decrease of the accumulated daily growth rate of COVID-19 cases for the following two and a half weeks, however these results were obtained from data of only the three first months of the pandemic.

Tang *et al.* also found a correlation between the average percentage of positives of five human coronavirus (SARS-CoV-2, CoVHKU1, CoVNL63, CoVOC43 y CoV229E) with the sunlight UV radiation but only in the east side of the United States, not in the west side¹⁸. Recently, in a world analysis, the UV exposure had a U-shaped effect of the reproduction number, with a minimum UVI of around 6.3¹⁹. Their conclusions agree with ours considering that UVI could reduce transmission in temperate regions during summer such as Spain, but lead to higher risk in equatorial regions with very high UV exposure, although they found the later result unexpected.

Temperature had been described as the main climatic factor involved in COVID-19 transmission in a study performed in Spain during first months of pandemic, where Spanish regions with the highest temperature showed the lower incidence of infection²⁰. Another recent study performed in China and United States also described a strong correlation between reduction of COVID-19 transmission with temperature and relative humidity²¹. Recently, a weak moderate (less robust than with UV), negative relationship between the estimated reproduction number and temperatures warmer than 25°C (a decrease of 3.7% [95% CI 1.9–5.4] per additional degree¹⁹). However, our study shows no clear correlation between

mean temperature with COVID-19 incidence or hospitalization in the studied provinces, showing weak positive correlation in Zaragoza and weak negative in Tenerife and Málaga. This could be due to the latter had a yearly mean temperature of 23°C whereas in Zaragoza is 13°C, and lower temperatures may promote indoor activities and human gatherings, leading to virus transmission²². Some other studies have also shown positive correlations between temperature and COVID-19 incidence, such as the one performed by He Z.²³ along 9 different Asian cities including Japan ($r = 0.416$, $p < 0.01$).

According to our results, we can say that the spring and end of summer COVID19 outbreaks support a relationship between UVI and temperature with the COVID incidence. In this sense, the spring COVID outbreak end was related to UVI over 4 and temperatures over 15°C, while summer-autumn outbreak was observed with UVI under 5–6 for all the latitudes and again temperatures under 20°C.

Relative humidity seems to potentially affect COVID-19 transmission. Our results show that in northern provinces, relative humidity is negatively correlated with COVID-19 incident cases five days after; meanwhile in southern provinces as Málaga or Tenerife, relative humidity shows a positive correlation. In a recent global analysis of different meteorological factors in SARS-CoV-2 transmission, humidity did not show statistically significant association¹⁹. However, previous works support the theory of a negative correlation between relative humidity and COVID-19 transmission^{20,21}. An investigation performed in India along April 2020, considering also a 5-days lag between meteorological and COVID-19 variables, found how relative humidity and also average temperature were negatively associated with COVID-19²⁴. Tong *et al.* concluded that 1% increase in relative humidity was correlated with 1.7%~3.7% increase in the daily confirmed cases of COVID-19²⁵, supporting the theory of relative humidity increasing COVID-19 transmission. Jain *et al.*²⁶ in a study performed in six South Asian countries from March to June 2020 found that high humidity and high temperature increase the transmission of the COVID-19 infections, results applicable to regions with great transmission rates where the minimum temperature is mostly over 21 °C.

Admission in ICU is apparently not related to any of the studied climatic factors, as several studies have shown, being the disease severity mainly conditioned by each patient comorbidities²⁷. Fang *et al.* made a review where male sex, elderly age, chronic kidney disease or chronic obstructive pulmonary disease were significantly associated with severity²⁸. Hypertension or diabetes were also found more prevalent among deceased patients.²⁸

According to our results, higher mean temperature and ultraviolet radiation correlates with COVID-19 caused deaths. In a retrospective study carried out in Wuhan, temperature was also inversely associated with COVID-19 deaths, whereas diurnal temperature range was positively associated²⁹.

So, environmental data from our work as well as other related studies could support two ways of seasonal variations in the different COVID-19 outbreaks along 2020 and the beginning of 2021. First, high UVI and temperatures make air and earth surface free for virus at dates corresponding to UVI over 4–5 and temperatures over 20°C; and second, spring and summer seasons in Spain, due to the mild

temperatures invite to population to spend time outside and the social distancing is increased. This fact indicates that other factors apart from the environment can influence the transmission of SARS-CoV-2 such as social distancing, protective masks, lockdowns and vaccination. These are some of the measures that were globally implemented in our societies that have been fundamental in controlling COVID-19 pandemic, as several studies show how implementation of lockdown was crucial to control the transmission of COVID-19²⁵. In addition, numerous individual factors can contribute to the severity and mortality over the meteorological agents. Taking all limitations into consideration, meteorological factors, especially UV radiation and probably temperature, seem to play a role in the COVID-19. Other limitation of the study is the geographical one, as only Spain was studied.

Conclusions

UV radiation seems to be the most relevant meteorological factor in the incidence and hospitalization of COVID-19 in Spain along the pandemic. Higher UV levels can contribute to lower rates of COVID-19 incident cases and hospitalizations Temperature seems to have less effect and different on warmer places (inverse correlation) than in colder places (direct correlation) whereas the effect of humidity remains unclear. ICU-admissions caused by COVID-19 infection seem not to be influenced by meteorological factors. Higher mean temperature and ultraviolet radiation levels could contribute in reducing COVID-19 caused deaths.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

J.B.P.G.:Data analysis writing—review & editing—original draft. N.M.I.: Formal analysis, data curation, methodology, J.A. Conceptualization, data curation, formal analysis, review & editing, M.A.B. data curation, formal analysis, methodology M.V.G. A Conceptualization, data curation, formal analysis, writing—review & editing Y.G. Conceptualization, data curation, formal analysis, , writing—review & editing-.

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Figures

Figure 1

Seasonal variation of mean weekly UVI, COVID-19 incidence rate and hospitalized cases (A-E) as well as seasonal variation of mean weekly temperature and humidity data for the same localizations (F-J).