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Correlation Analyses between Ultraviolet Radiation, Global Solar Radiation, and Metrological Variables and the COVID-19 Cases in Arid Climate

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Abstract

The transmission of infectious diseases is influenced by several meteorological factors. In this study, the influence of several such factors in the transmission of COVID-19 (from 26 March 2020 to 29 July 2021) in the arid weather of Riyadh, Saudi Arabia was investigated using the Spearman and Kendall rank tests. The factors considered were the average, maximum, and minimum values of air temperatures, air pressure, wind speed, relative humidity, absolute humidity, dew point temperatures, and the average values of the global solar radiation and ultraviolet radiation at bands A and B. The data on meteorological factors were obtained from the King Abdulaziz City for Science and Technology (KACST) weather station, whereas the data on the daily COVID-19 cases were obtained from the official webpage of the Saudi Arabian Ministry of Health (MOH). The results revealed that air temperature (average, minimum, and maximum) average and maximum wind speed, maximum dew point temperature, global solar radiation, and ultraviolet radiation at A and B bands are positively associated with the daily number of COVID-19 cases reported in Riyadh. However, relative humidity, atmospheric pressure (averages, minimum, and maximum) is anti-correlated with the number of daily COVID-19 cases, while absolute humidity exerts no influence. These results are in total agreement with some of the previously established studies and are either contradicted partly or totally with others conducted at several locations around the world. The results could help not only epidemiologists understand the behavior of COVID-19 against meteorological variables but also national and international organizations and healthcare policymakers devise control strategies to combat the virus.

Keywords

COVID-19, Dry Conditions, Meteorology, Ultraviolet Radiation, Correlation

1. Introduction

Ever since it was first reported in Wuhan, China, in December 2019, the Coronavirus disease (COVID-19) has spread worldwide, developing into a pandemic and one of the most significant global health threats in a century (e.g., Wang *et al.*, 2020). Shortly afterwards, several research studies were conducted worldwide to investigate the association between COVID-19 and a wide range of factors—social and economic as well as weather-related, including meteorological and environmental factors such as air temperature and air pollution [1]. The effect of meteorological conditions on COVID-19 transmission has been studied in several places, including China [2]-[7], Iran [8], Europe [9], Turkey [10], Brazil [11] [12] and the United States of America [13] [14] [15].

These studies did report the significant effect of meteorological factors on COVID-19 transmission, but regarding the relationship between the two, they reached contradictory conclusions. The exact mechanisms the meteorological factors employ to increase COVID-19 transmission and their potential role in it remain overlooked and yet to be clearly understood. The reported association could also differ from one climatic region to another. Moreover, most of the studies covered extremely short investigative periods, which could have affected their outcomes, thus necessitating the examination and evaluation of each region within its dynamics.

To the best of our knowledge, very few studies have been conducted between weather parameters and the evolution of COVID-19 in desert climate regions. In light of this, this study aims to fill this research gap by exploring the relationships between the metrological variables and the daily confirmed COVID-19 infections in Riyadh, Saudi Arabia. Riyadh was chosen because of its arid conditions, its population density, and its highest number of daily COVID-19 cases in Saudi Arabia.

2. Material and Method

2.1. Data

The maximum, minimum, and average values of the air temperature, relative humidity, atmospheric pressure, dew point temperature, wind speed, the daily mean values of the global solar radiation, and ultraviolet radiation in bands A and B were the considered meteorological variables. These data were collected from the KACST weather station installed on the roof of the radiation detector lab. The station is equipped with all the sensors that continuously monitor several weather parameters. The detailed explanations about these sensors are described in [16]. The daily data of the COVID-19 cases were taken from the official website of the Saudi Ministry of Health. The data used in this study cover the period from 26 March 2020 to 29 July 2021.

2.2. Statistical Tests

Studies have used several statistical tests and procedures to investigate the relationships between the number of daily COVID-19 cases and meteorological parameters: the Spearman's rank correlation coefficient [17], Kendall's rank correlation, the generalized linear model [18], and polynomial linear regression. In this study, the Spearman and Kendall rank correlation tests were used. The factors were considered influential in COVID-19 transmission if significant differences were observed in both statistical tests. The Spearman's rank correlation coefficient is the nonparametric version of the Pearson product-moment and is used to examine the associative strength between two variables (monotonic relationship). The Spearman rank correlation test's formula is as follows (e.g., [9]):

$$\rho = 1 - 6 \times \frac{\sum d_i^2}{n\left(n^2 - 1\right)}$$

ρ is the Spearman rank correlation coefficient; d_i is the difference between the ranks of corresponding values x_i and y_i; n is the number of x and y pairs.

Kendall rank correlation, also another non-parametric test, is used to assess the statistical associations based on the ranks of data and can be estimated as follows:

$$\tau = \frac{n_c - n_d}{\frac{1}{2} n\left(n - 1\right)}$$

τ is the Kendall rank correlation coefficient; n_c and n_d represent the number of concordant and discordant pairs, respectively; n represents the number of pairs.

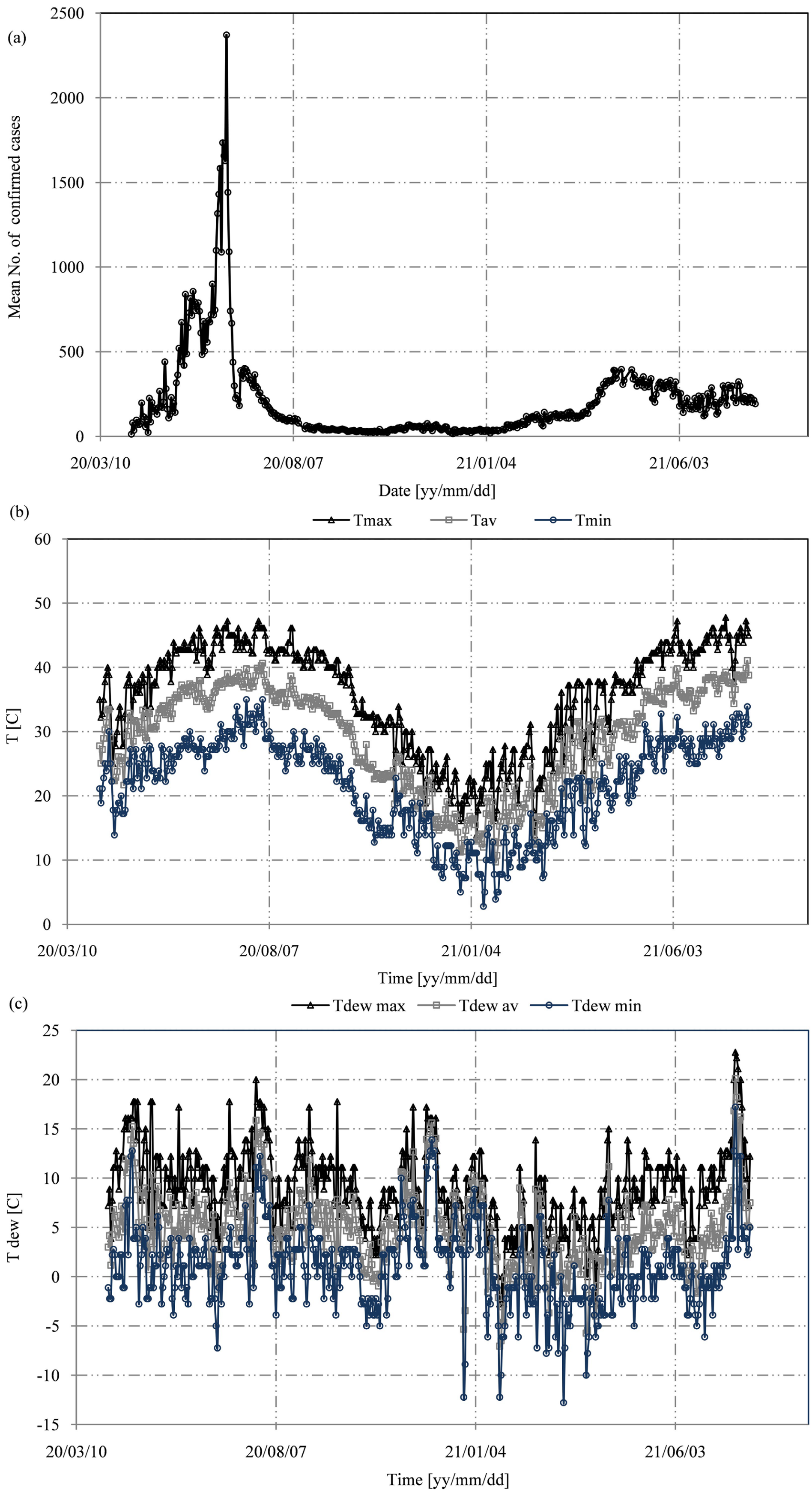
3. Results

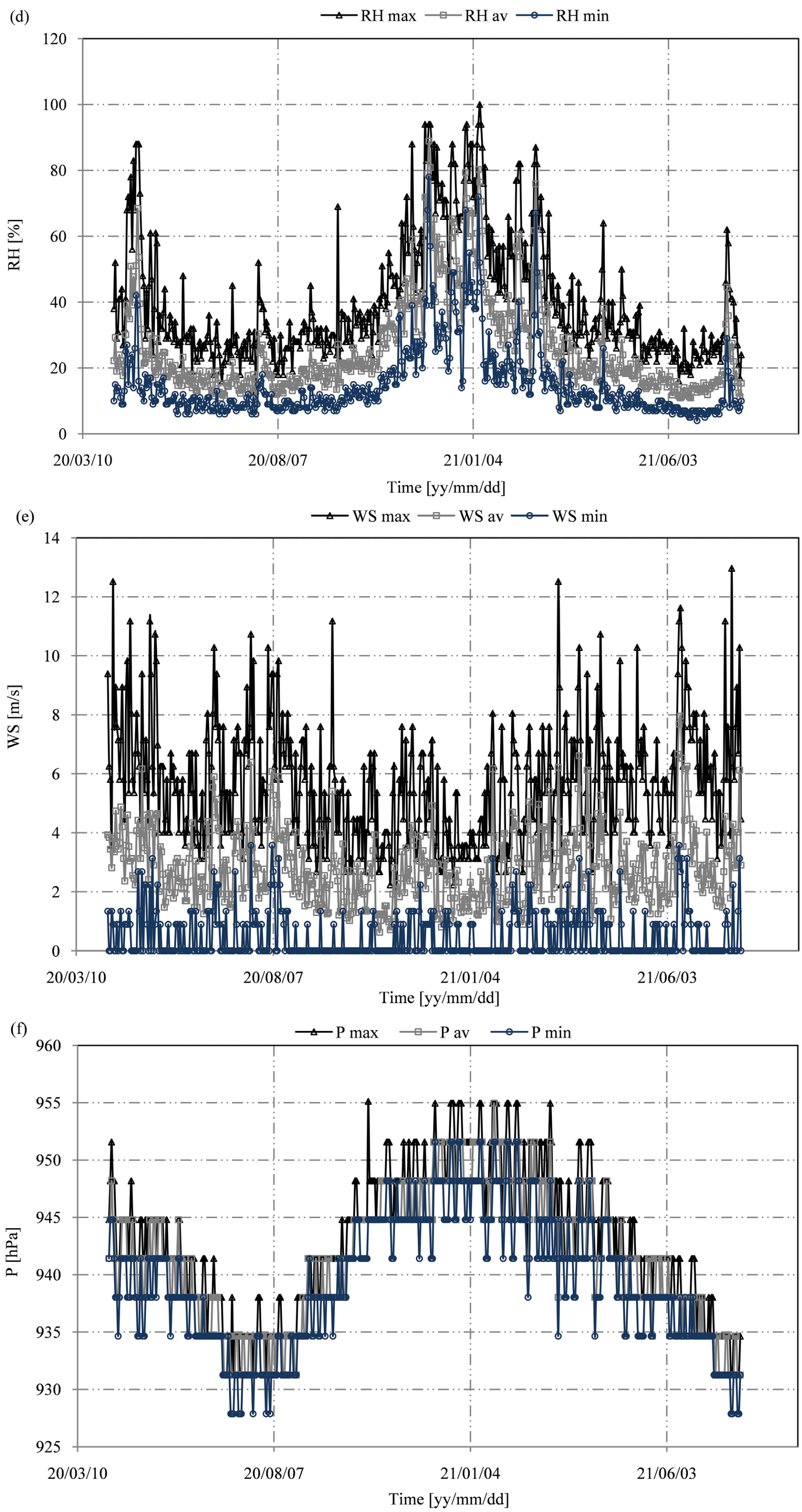
Since the first confirmed case of COVID-19 in Saudi Arabia (on March 2, 2020), a total of 542,000 cases have been reported as of August 20, 2021. During our study period-26 March 2020 to 29 July 2021-103,729 confirmed locally transmitted COVID-19 cases were identified in Riyadh.

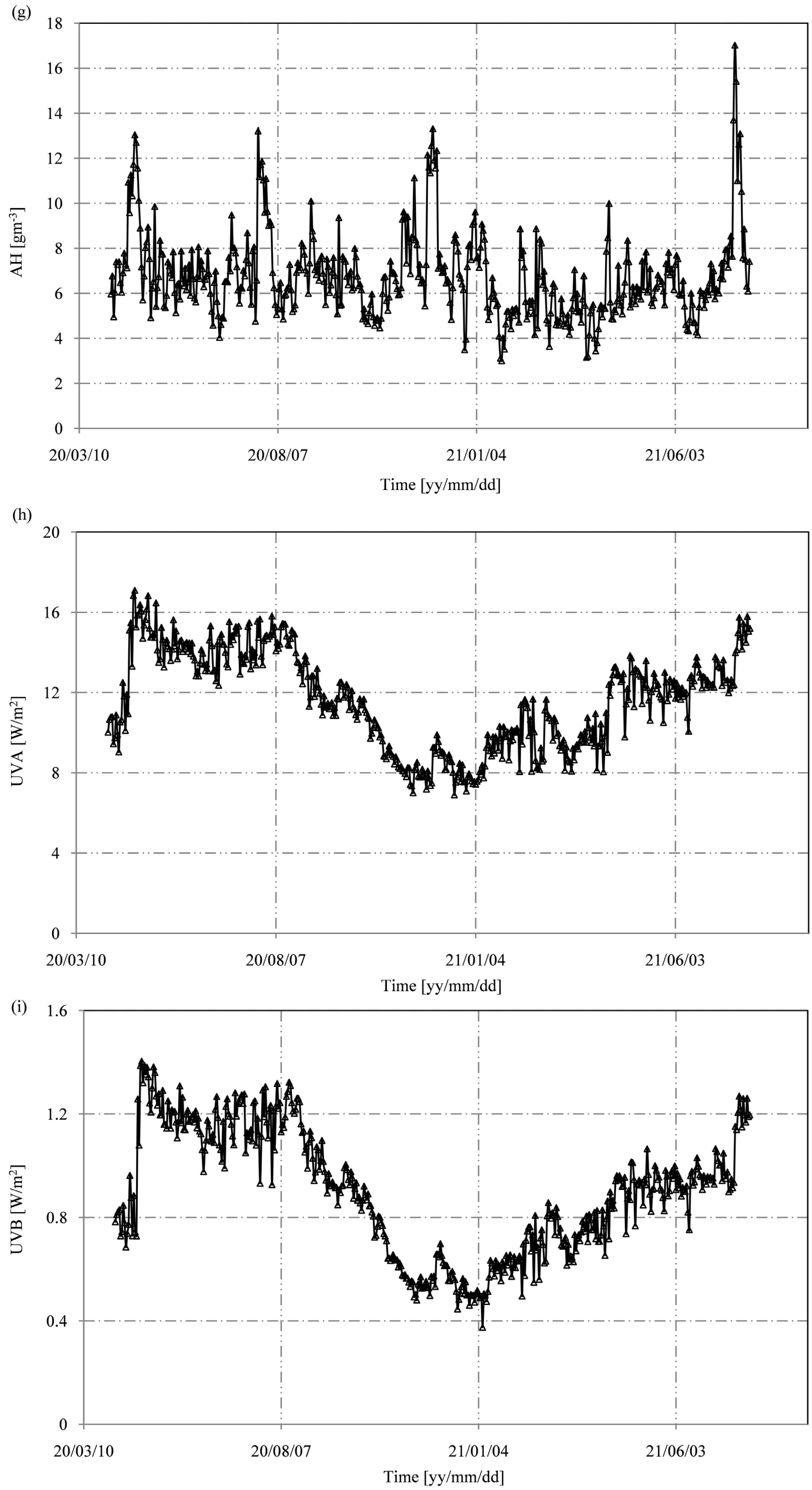
Figure 1 shows the daily mean values of the confirmed COVID-19 cases and the meteorological variables in Riyadh considered in this study.

During the study period, the mean number of COVID-19 confirmed cases was 207.54 ± 256.38, with a maximum of 2371 and a minimum of 13. The time series profile (**Figure 1(a)**) of the reported cases can be divided into three phases.

The first period covered the period between April 3, 2020 to August 10, 2020. This period was characterized by great variations in the number of reported COVID-19 cases. The number of cases increased rapidly and reached a maximum of 2317 cases on June 16. Then it dropped significantly within about a week, reaching 225 on June 26, and then reached a minimum of 45 by about August 10.


(a)
Mean No. of confirmed cases
2500
2000
1500
1000
500
0
20/03/10
20/08/07
21/01/04
21/06/03
Date [yy/mm/dd]
(b)
Tmax
Tav
Tmin
T [C]
60
50
40
30
20
10
0
20/03/10
20/08/07
21/01/04
21/06/03
Time [yy/mm/dd]
(c)
Tdew max
Tdew av
Tdew min
T dew [C]
25
20
15
10
5
0
-5
-10
-15
20/03/10
20/08/07
21/01/04
21/06/03
Time [yy/mm/dd]


(d)
RH max
RH av
RH min
RH [%]
0
20
40
60
80
100
120
20/03/10
20/08/07
21/01/04
21/06/03
Time [yy/mm/dd]
(e)
WS max
WS av
WS min
WS [m/s]
0
2
4
6
8
10
12
14
20/03/10
20/08/07
21/01/04
21/06/03
Time [yy/mm/dd]
(f)
P max
P av
P min
P [hPa]
925
930
935
940
945
950
955
960
20/03/10
20/08/07
21/01/04
21/06/03
Time [yy/mm/dd]


(g)
AH [gm^{-3}]
0
2
4
6
8
10
12
14
16
18
20/03/10
20/08/07
21/01/04
21/06/03
Time [yy/mm/dd]
(h)
UVA [W/m^2]
0
4
8
12
16
20
20/03/10
20/08/07
21/01/04
21/06/03
Time [yy/mm/dd]
(i)
UVB [W/m^2]
0
0.4
0.8
1.2
1.6
20/03/10
20/08/07
21/01/04
21/06/03
Time [yy/mm/dd]

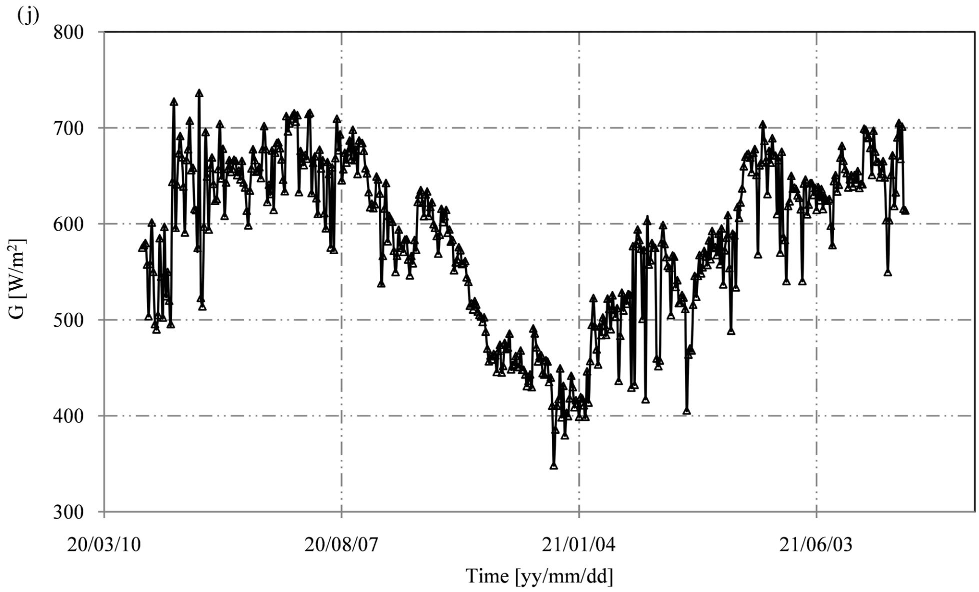


Figure 1. the time series of the daily values of (a) the number of cases of COVID-19; (b) the maximum, minimum, and mean values of air temperatures; (c) the maximum, minimum, and mean values of dew point temperature; (d) the maximum, minimum, and mean values of relative humidity; (e) the maximum, minimum, and mean values of wind speed (f) the maximum, minimum, and mean values of atmospheric pressure; (g) absolute humidity; (h) ultraviolet radiation at band A; and (i) ultraviolet radiation at band b; (j) global solar radiation in Riyadh during the study period.

The second phase covered the period between August 10, 2020 to February 3, 2021. This period had small variations in the number of cases. The mean number of the reported cases was 42, with a minimum of 14 and a maximum of 78.

The third phase was from the end of the second phase until the end of the study period. This phase featured a steady and slight increasing trend in the number of the reported cases until March 18, 2021. The average number of cases was 114. Afterwards, the number of cases increased dramatically to reach a maximum of about 400 cases on April 14, which may be attributed to family gatherings and social activities after the holy month of fasting during April. For the next two months, the number of cases decreased slightly to reach a mean of about 220 cases and remained around this number for the rest of the period.

Apart from the wind speed, absolute humidity, mean dew point temperature, all of which showed no clear trends during the study period, the rest of the variables followed a cyclical pattern. Air temperature, ultraviolet (A and B), and global solar radiation reached their maximum in summer and minimum in winter. On the other hand, relative humidity and atmospheric pressure showed the opposite trend.

The considered variables obviously covered a wide range of values during the study period. For instance, the air temperature ranged between 47.78 and 2.77, RH was between 4% to 100%, and air pressure was 965.12 and 927.80 hPa.

Table 1 summarizes the results of the Kendall and Spearman correlation tests on the association of daily COVID-19 cases and weather parameters in Riyadh from 26 March 2020 to 29 July 2021.

Table 1. Summary of nonlinear correlation (Kendall τ and Spearman ρ) results between COVID-19 and meteorological parameters and solar radiation data (26 March 2020 to 29 July 2021; N = 492) in Riyadh.

Test	T max	T	T min	Tdew max	T dew	Tdew min	RH max	RH	RH min	WS max	WS	WS min	P max	P	P min	AH	UVA	UVB	G
Kendall τ	0.317**	0.313**	0.313**	0.091**	−0.001	−0.056	−0.284**	−0.312**	−0.312**	0.182**	0.134**	0.063	−0.289**	−0.298**	−0.308**	−0.021	0.330**	0.326**	0.360**
Sig. (2 tailed)	0.000	0.000	0.000	0.003	0.983	0.074	0.000	0.000	0.000	0.000	0.000	0.068	0.000	0.000	0.000	0.494	0.000	0.000	0.000
Spearman ρ	0.470**	0.480**	0.473**	0.139**	−0.003	−0.085	−0.430**	−0.477**	−0.456**	0.269**	0.205**	0.081	−0.417**	−0.425**	−0.439**	−0.036	0.492**	0.478**	0.532**
Sig. (2 tailed)	0.000	0.000	0.000	0.000	0.947	0.057	0.000	0.000	0.000	0.000	0.000	0.070	0.000	0.000	0.000	0.422	0.000	0.000	0.000

**Correlation is significant at the 0.01 level (2-tailed).

The results reveal that, unlike the mean and minimum values of the dew point temperatures, the minimum values of wind speed, and absolute humidity, the rest of the considered variables do have significant correlations with the number of the COVID-19 cases with a 99% confidence interval (2-tailed significance). However, the strength and type of this correlation (either positive or negative) were different from one variable to another.

Moreover, the Kendall and Spearman tests revealed that global solar radiation, UVA, UVB, air temperature, and wind speed (maximum, minimum, and mean values) are correlated positively with the number of COVID-19 cases. While the correlations between the number of COVID-19 cases and the mean wind speed and maximum dew point temperature were the lowest ($\tau = 0.134$; $\rho = 0.207$ for the former and $\tau = 0.0.091$; $\rho = 0.139$ for the latter), the rest of the variables presented slightly stronger relationships with the number of the COVID-19 cases (τ ranges between 0.300 - 0.360; ρ ranges between 0.532 - 0.400).

The mean values of the relative humidity, atmospheric pressure, and their maximum and minimum values anti-correlated significantly with the number of COVID-19 cases. For all the correlations, the Kendall coefficients ranged between 0.319 and 0.290, whereas the Spearman coefficients ranged between 0.427 and 0.494.

4. Discussions and Conclusions

According to the no-parametric analyses conducted in this study, the air temperature (mean, minimum, and maximum) mean and maximum wind speed, the maximum dew point temperature, global solar radiation, and ultraviolet radiation at A and B bands are all positively associated with the daily number of the COVID-19 cases reported in the arid climate of Riyadh. Moreover, the relative atmospheric pressure (mean, minimum, and maximum) are anti-correlated with the number of COVID-19 cases, whereas absolute humidity exerts no influence.

These results are aligned with some of the previously established studies and are either contradicted partly or totally with others conducted at several locations around the world. For instance, our finding of the positive effect of the mean temperature and wind speed and the number of COVID-19 cases is supported by [2] [14] [17] [19] [20] [21] reported that only the mean air temperature was significantly correlated with the transmission of COVID-19. According to [22], temperature and absolute humidity have been reported as crucial weather indices associated with the spread of COVID-19. Auler [11] established that mean temperature and average relative humidity are significant in the transmission of COVID-19 in Brazil. Yao *et al.* [3] claimed no correlation between COVID-19 and UV radiation. Rosario *et al.* [23] showed that solar radiation has a strong negative relationship with COVID-19 transmission. Wang *et al.* [15] showed that warm weather plays an important role in suppressing the virus. Islam *et al.* [24] found that temperature and wind speed have a negative relationship with the number of infections. Xie and Zhu [2] conducted a study in

122 cities across China and established that the humidity, wind speed, and temperature are inversely associated with the infection rate of COVID-19. Wu *et al.* [25] and Qi *et al.* [18] stated that the temperature and RH were both negatively associated with daily new cases and mortality.

As we can see from our results and the findings of different studies, the meteorological factors, though they exert different degrees of influence, do have pronounced effects on COVID-19 transmission. Moreover, this study covers a longer period than most of the previous researches and contributes additional knowledge to the understanding of the effects of meteorological and atmospheric factors on influenza activities. Our findings can be useful and important for the development of influenza surveillance and early warning systems.

This study has several limitations. First, the infected cases might have been impacted by several additional factors—such as social behaviors, demography, economic, immunology, and epidemiology factors—and so the number of confirmed cases due to meteorological factors might be inaccurate. Moreover, due to data and time constraints, this study focused only on one region, so further studies covering more sites are recommended to better confirm the relationship between meteorological factors and COVID-19 cases.

Authorship Contribution Statement

The author was responsible for all the work presented in this article.

Conflicts of Interest

We declare no conflict of interest.

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