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Original Article

Can climate help fighting COVID-19 trauma? A case study of Maricopa County, Arizona, USA

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Abstract

Introduction: Since the emergence of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) virus, the disease has spread rapidly throughout the world and became a traumatic stressor. Identification of the factors affecting the spread of the disease makes it possible to prevent its further propagation and save more people in similar situations. Environmental and climatic parameters are among the factors affecting the prevalence of diseases. Determination of environmental effects on Coronavirus disease (COVID-19) prevalence can help develop policies to suppress the spread.

Methods: This study investigated the effect of climatic parameters on the spread of COVID-19 disease in County Maricopa from March 11, 2020, to November 30, 2020. These parameters include maximum, minimum, and mean daily temperature as well as maximum, minimum, and mean daily humidity, wind speed, solar radiation, and Air Quality Index (AQI) of particulate matter10 (PM10), PM2.5, and O3. A Shapiro-Wilk test was used to evaluate the normality of variables and the Spearman correlation test was used to determine the correlation between parameters and daily COVID-19 cases. A simple linear regression was applied on parameters that had significant Spearman'sranked correlation with the daily COVID-19 cases to determine their contribution to the pandemic.

Results: The present study showed that the maximum, minimum, and mean temperature parameters and PM10 and PM2.5 particles had a positive and significant correlation ($P<0.01$) with the prevalence of COVID-19 disease. The effect of PM10 particles was higher than the other parameters (0.488, $P<0.01$). The parameters of maximum, minimum, and mean relative humidity along with solar radiation and O3 AQI had a significant and negative correlation with the development of COVID-19 disease ($P<0.01$). The effect of maximum humidity was higher than that of the other parameters (-0.364, $P<0.01$). A linear regression test showed that O3 ($\beta=-15.16$, $P<0.001$) and Tmean ($\beta=18.47$, $P<0.01$) significantly predicted daily COVID-19 cases.

Conclusion: It can be concluded that climatic parameters can affect the COVID-19 pandemic and should be addressed.

Keywords: Air Pollution, COVID-19, Pandemic

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Introduction

Corona virus disease (COVID-19) is a respiratory disease caused by the severe acute respiratory syndrome corona virus 2 (SARS-CoV-2) virus (1) which was first detected in Wuhan, China (2). The disease spread so rapidly (3) that by the end of 2020, all five continents and about 80 million people worldwide had been infected (4). One basic policy that has been implemented in different countries was lockdown that insisted on people staying home and canceling any outdoor activities which caused an increase in domestic violence and abuse (5).The pandemic has been recognized as a source of trauma because of its wide impact on various aspects of the lives of people, such as their occupations, identities, and family losses (5-7). This may have more severe effects on those who have experienced the loss of their loved ones or the complete destruction of their occupations (8).

The first case of the disease in the USA was reported on January 20, 2020(9). While less than 5% of the total global population lives in the United States, by the end of 2020, a quarter of all infected people in the world were in the United States(10-11), indicating that the virus was more prevalent in the USA than other countries. Approximately, 22% of the USA population is over 60years of age (12) and chronic respiratory disease is the fourth leading cause of death in this country (13). This calls attention to the COVID-19 disease as it attacks the respiratory system which is more dangerous for the elderly and people with comorbidities (14).

The mortality rate of COVID-19 patients in the USA is 1.7%, resulting in the death of approximately 345,000 people by the beginning of 2021(11).

The transmission pathways of COVID-19 are like those of the influenza virus (15) and it is mainly transmitted by respiratory droplets (16). Asymptomatic people can also be carriers of the disease (17-18); hence, the general use of masks and maintenance of social distance are two compelling factors in preventing the spread of the disease (17-19-22).

Identification of other factors that influence the prevalence of the disease and also implementation of appropriate measures make it possible to prevent the further growth of the disease and potentially save lives (23). Climate change has been identified as a factor influencing the prevalence of SARS, Middle East Respiratory Syndrome (MERS), and influenza respiratory diseases (24–26). Considering the similarities amongCOVID-19, SARS, and MERS diseases (27-28), it can be said that climatic factors do influence the spread of COVID-19, although their exact effects are not apparent (23).

Studies have been conducted on the relationship of climatic parameters, like temperature and humidity or air pollution, with the spread of COVID-19, but the results of each study are different and even contradictory to those of the studies conducted in different cities or countries (29). For example, Bashir et al., (2020) founda positive correlation between corona expansion and air temperature in New York (30), while Gupta and Gupta (2020) found a negative correlation between corona expansion and temperature in California(31). Therefore, it is necessary to study the impact of weather conditions in each region on the spread of COVID-19 to determine specific policies in each region according to its climatic conditions to fight its trauma in the future.

This study aimed to investigate the impact of climatic conditions and qualitative pollution levels on the spread of COVID-19 disease in Maricopa County, Arizona, USA.

Materials and Methods

In this cross-sectional study, climate factors and air pollutants in Maricopa County, Arizona were examined. The county is located in the Sonoran Desert which has a hot and arid climate (32-33). Its area is 23,890 square km and has a population of 4,485,414 people (34).

Moreover, it should be mentioned that it is the fourth largest county in the USA (35). The location of Maricopa County is illustrated in (Figure 1).

The daily count of COVID-19 cases was taken from the Arizona Department of Health's dashboard (36) from March 11, 2020, the day of the outbreak, to November 30, 2020. Data on the maximum(T_{max}),

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mean (T_{mean}), and minimum (T_{min}) air temperatures measured in degrees Celsius, maximum (Rh_{max}) and minimum (Rh_{min}) relative humidity (%), as well as solar radiation (W/m^2) and wind (m/s) were obtained from 40 measurement stations in Maricopa County from the Maricopa county official government website (37).

The available data from all stations were received for each day between March 11, 2020, and November 30, 2020.

The value of each parameter (per day) was considered the mean of the data received from the 40 stations on that day. The mean (Rh_{ave}) relative humidity (%) was also calculated by finding the mean of the minimum and maximum values. The Arizona Department of Air Quality also submitted the Air Quality Index (AQI) parameters for particulate matter$_{10}$ (PM_{10}), $PM_{2.5}$ and O_3(38). All data were gathered from online public sources and did not contain names or addresses; hence, no ethical considerations were required.

A Shapiro-Wilk test was used to evaluate the normality of variables. Since the variables had no normal distribution, the Spearman correlation test was used.

A simple linear regression was applied on parameters that had a significant Spearman's ranked correlation with the daily COVID-19 cases to determine their contribution to the pandemic.

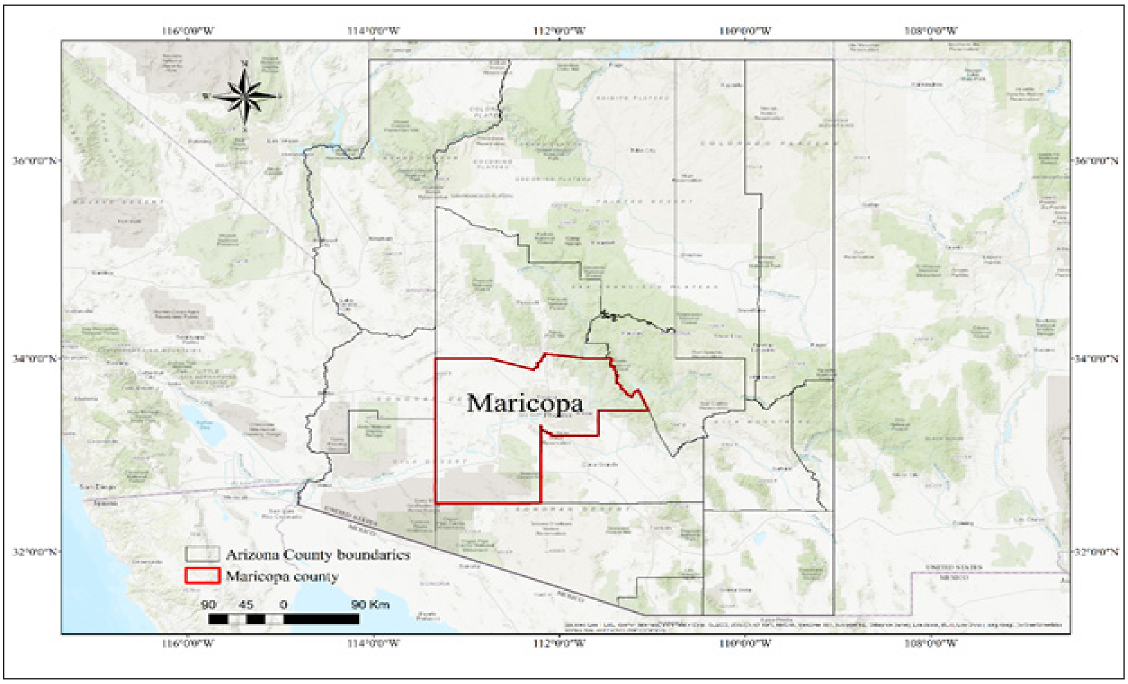

Figure1. Location of Maricopa county in Arizona state.

Results

According to (Figure 2), the incidence rate of the disease was not high until the end of May 2020; however, it became prominent since the beginning of June. On June 29, the first peak of the disease appeared and the outbreak slowed thereafter. From early August 2020 to the end of October 2020 the increase in cumulative morbidity was almost horizontal, suggesting that the rate of spread of the disease decreased. However, in late October, it started to increase again, indicating an increase in morbidity cases. The number of total daily COVID-19 reported cases in 265 days of the study was 223,189 with a mean of 842 positive cases per day.

During the nine months of the study, the climate and air quality data were obtained from March 11 to November 30, 2020. The upper and lower limits of each variable are summarized in (Table 1) and their time series are shown in (Figure 3).

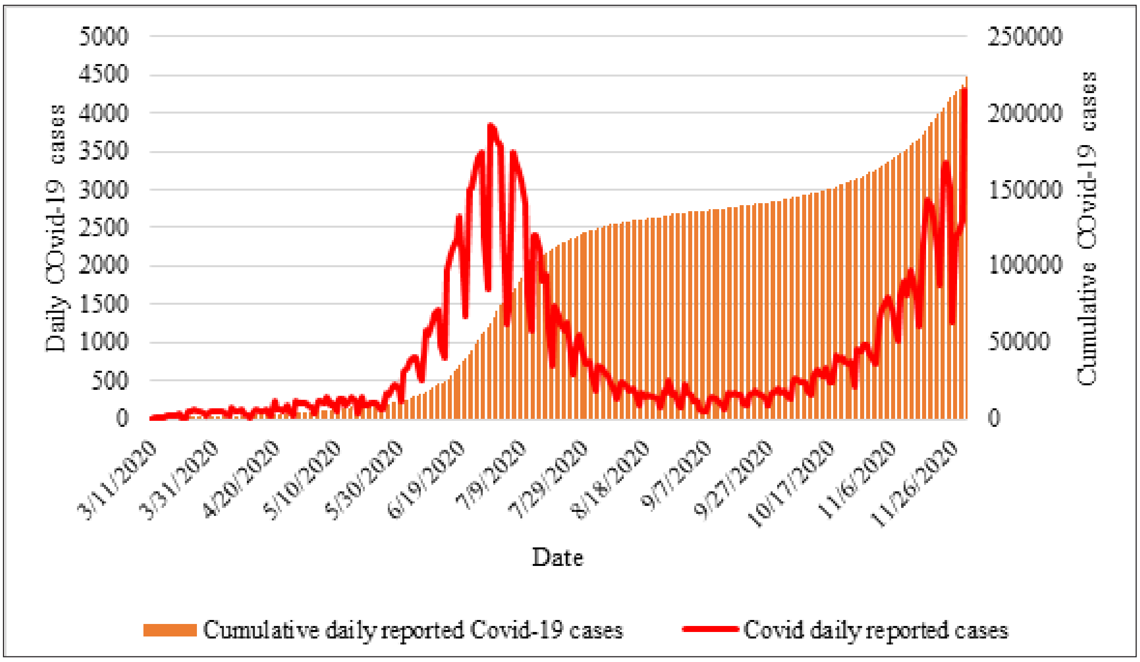

Figure 2. Daily COVID-19 cases and cumulative daily patients.

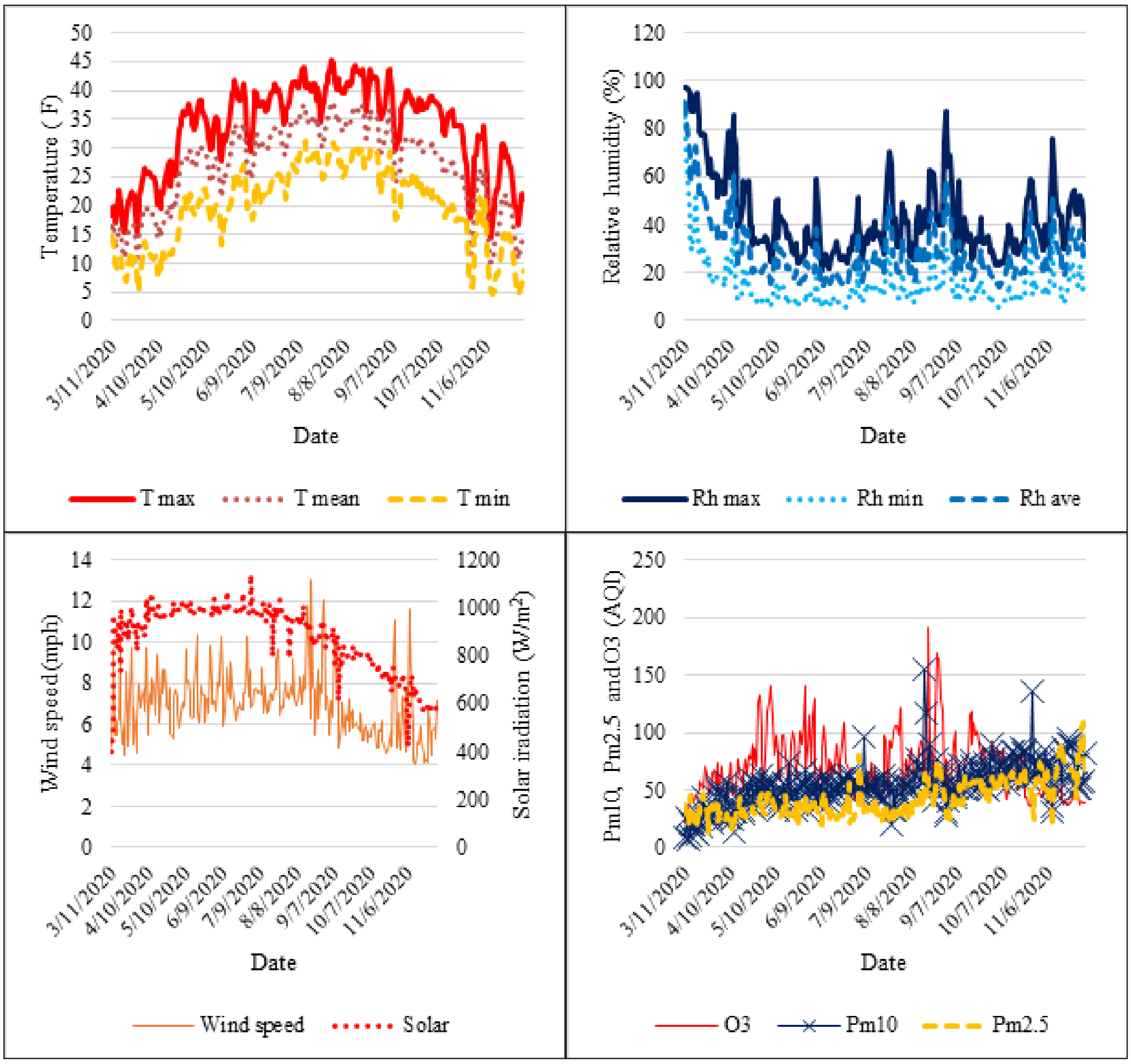

Figure 3. Climate and Air quality parameters from March 30, 2020,to November 30, 2020. a) Maximum, mean, and minimum daily air temperature (˚C), b) maximum, mean, and minimum daily relative humidity (%), c) daily wind speed (m/s) and solar radiation (W/m2) and d) daily PM10, PM2.5, and O3 AQI.

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Table 1. Upper and lower limits of climate and air quality parameters from March 11 to November 30, 2020.

Variable	Upper limit	Lower limit
T_{max} (˚C)	45.15	14.3
T_{mean} (˚C)	38.12	9.98
T_{min} (˚C)	31.16	4.58
Rh_{max} (%)	97.3	21
Rh_{mean} (%)	91.22	13.88
Rh_{min} (%)	85.28	5.5
Wind speed (m/s)	13.06	4.06
Solar radiation (W/m^2)	1142.7	401.65
Pm_{10} AQI	155	7
$Pm_{2.5}$ AQI	109	14
O_3 AQI	192	22

T_{max}: Maximum air temperature, T_{mean}:mean air temperature,T_{min}:minimum air temperature, Rh_{max}:maximum relative humidity, Rh_{mean}:mean relative humidity, Rh_{min}:minimum relative humidity, AQI: Air Quality Index

(Table 2) shows the correlation coefficients between the parameters and the number of patients reported per day.

Regarding the parameters examined, only the wind was not correlated, while other parameters showed a significant correlation with the number of patients per day. The T_{max}, T_{mean}, T_{min}, PM_{10}, and $PM_{2.5}$ AQI had a significant ($P<0.001$) and positive correlation with the number of patients per day. At the same time, O_3 AQI and Solar radiation showed a negative and significant ($P<0.05$) correlation with the numbers of cases per day.

Table 2. Spearman's rank correlation results.

Variable	Spearman's rank correlation	P-value
T_{max}	0.271	<0.001
T_{mean}	0.265	<0.001
T_{min}	0.258	<0.001
Rh_{max}	-0.364	<0.001
Rh_{mean}	-0.333	<0.001
Rh_{min}	-0.246	<0.001
Wind speed	-0.042	0.499
Solar radiation	-0.132	<0.05
Pm_{10} AQI	0.488	<0.001
$Pm_{2.5}$ AQI	0.235	<0.001
O_3 AQI	-0.170	<0.01

T_{max}: Maximum air temperature, T_{mean}:mean air temperature,T_{min}:minimum air temperature, Rh_{max}:maximum relative humidity, Rh_{mean}:mean relative humidity, Rh_{min}: minimum relative humidity, AQI: Air Quality Index

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Since Rh_{mean}, Rh_{min}, and Rh_{max} had more than 0.85 the correlation to each other and T_{max}, T_{min} and T_{mean} had more than 0.95 correlation to each other, only one parameter of each group entered the linear regression. Rh_{mean} and T_{mean} were chosen from each group as they were indicators of either minimum and maximum data. The linear regression indicated that five parameters of solar radiation, T_{mean}, Rh_{mean}, PM_{10}, and O_3 AQI can explain 16% of the variance in the daily COVID-19 cases (R2=0.16, F (5,207)=8.14, P<0.001),the results of which are summarized in (Table 3). It was found that O_3 (β=-15.16, P<0.001) and T_{mean} (β=18.47, P<0.01) significantly predicted daily COVID-19 cases.

Table 3. Linear regression analysis of parameters that had significant Spearman's ranked correlation with the COVID-19 daily patients

Variable	Unstandardized beta	Standardized beta	P-value
T_{mean}	18.47	0.267	<0.01
Rh_{mean}	-13.82	-0.086	0.252
Solar radiation	-0.99	-0.233	0.065
Pm_{10} AQI	6.71	0.146	0.14
O_3 AQI	-15.16	-0.34	<0.001

T_{mean}: Mean air temperature, Rh_{mean}: mean relative humidity, AQI: Air Quality Index

Discussion

In this study, T_{max}, T_{mean}, and T_{min} had a significant positive correlation with the spread of COVID-19 (P<0.01); accordingly, the linear regression analysis showed a unit increase in T_{mean} can cause an increase of 18 new daily COVID-19 cases. These results were consistent with those of a study performed by Bashir et al. (2020) in New York (30) which showed a positive correlation between moderate and minimum temperatures. Ahmadi et al., (2020) in the arid and semi-arid country of Iran and Tosepu et al., (2020) in Indonesia, a country with a tropical climate, also observed a positive correlation between temperature and the spread of COVID-19(39-40). However, the findings of most studies in this regard indicated a negative correlation between temperature and the spread of COVID-19 (29).

In addition, viruses similar to SARS and MERS survive for longer periods at low temperatures and are more susceptible to high temperatures (41-42); accordingly, as most studies show, the prevalence of the disease is likely to decrease with an increase in the temperature. Although the SARS-COV-2 virus is said to be a cold-loving virus that has a long shelf life at 4 ^{o}C and is susceptible to higher temperatures, no specific reason or clear clue can be given for the decrease in daily patients at high temperatures (18-29).

The positive correlation between the number of patients and temperature in Maricopa could be due to high daily temperatures. The mean temperature from May to early October 2020 was more than 30 ˚C with the maximum temperature reaching above 40 ˚C (Figure 2). High temperatures are observed in this county for 6months of the year (32), and people tend to stay indoors in such conditions. Due to the intense heat outside, natural and clean air is less allowed to enter the closed spaces. These two issues cause interaction between infected and healthy people in closed environments and may lead to an increase in the number of infected patients and the spread of the disease. Moreover, it may justify the positive correlation between temperature and the number of daily patients in this study. More detailed studies of the relationship between temperature and the number of cases are needed to explain this further.

The number of patients per day had a significant negative correlation (P<0.01) with Re_{max}, Rh_{min}, and Rh_{mean}. The findings of this study are in line with those of most studies that have indicated a

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negative correlation between relative humidity and the number of patients (29-40-43). This negative correlation is due to the short survival time of the SARS-COV-2 virus or similar viruses, like SARS, in environments with high relative humidity (41-44-45) as such conditions cause the virus to become inactive. Additionally, high environmental humidity leads to the emission of larger airborne droplets (46) and the settlement of more airborne droplets. As a result, less virus remains in the environment(47-48). Since the most crucial transmission route of the SARS-COV-2 virus is through respiratory droplets (16), settling the respiratory droplets containing the virus as soon as possible helps prevent the spread of the disease.

A negative correlation was observed between the wind speed and the number of COVID-19 cases, although it was insignificant. Extensive studies on the association between the prevalence of COVID-19 disease and wind speed have not yet been conducted, and the results of few studies performed in this regard have not been similar (29). However, wind speed is expected to help reduce the spread of the virus by replacing polluted air with clean air (49) which could lead to a negative correlation between wind and the spread of COVID-19.

The results of the present study are consistent with those of the research carried out by Rosario et al. (2020) in Rio de Janeiro in a tropical region and Ahmadi et al. (2020) performed in the hot and arid parts of Iran as they indicated a negative correlation between solar radiation and the prevalence of COVID-19 disease(40-50). It can be due to ultraviolet radiation of the sunlight since these rays are useful for rendering the coronavirus inactive and are used as a method of disinfecting surfaces and objects (51). Nevertheless, it must be noted that the use of these rays requires a specific dose and distance, and also there should be no barrier between ultraviolet radiation and the virus (52).

Most of the ultraviolet radiation reaching the surface of the earth are UV-A and UV-B which are less effective in rendering the viruses inactive than UV-C. However, the effect of solar radiation on reducing the spread of similar viruses, such as influenza, SARS, and coronaviruses has been observed and recognized (53-54). In addition, solar radiation produces and increases the level of vitamin D in the body (55) which is introduced as an effective factor in the fight against COVID-19(56). A positive and significant correlation was observed between the PM10 and Pm2,5 particles AQI; this is consistent with the results of studies conducted in 120 cities in China and Milan, where COVID-19 disease is widespread (57-58). One of the reasons for the spread of COVID-19 in Milan was recognized to be the concentration of environmental pollutants, such as PM10, which exceeded their limits (59-60). This could be because the particles of the COVID-19 virus attach to the contaminants and use them as a carrier to be transported.

This hypothesis was confirmed by the discovery of COVID-19 virus particles on PM_{10} particles in Bergamo, Italy (61). In this way, the virus particles can float in the air for an extended period, move by the wind and, and at the same time, enter the body with PM_{10} or $PM_{2.5}$ particles. Furthermore, PM_{10} and $PM_{2.5}$ particles can damage the respiratory system and lungs by themselves (62-63), which makes healthy people more vulnerable to COVID-19 and also helps spread the virus.

A linear regression test showed that O_3 significantly predicted daily COVID-19 cases. The increase in the O_3 AQI had a significantly negative correlation with the number of new daily patients. The linear regression also revealed that a unit increase in O_3 can decrease 15 new daily cases. This may be due to the antiseptic properties of O_3. This gas is a strong disinfectant used for disinfecting water, food, and medical equipment (64-67). Although the presence of ozone in the atmosphere is advantageous and blocks solar UV radiations, its presence near the surface of the earth is harmful to humans (68); however, in this case, it came to the aid of mankind. Ozone with its oxidizing properties may help the fight against COVID-19 and render suspended viruses inactive (69), thereby reducing the spread.

In this study, the relationship between climatic variables and the spread of COVID-19 disease was investigated using the Spearman correlation and simple linear regression to determine their contribution to the pandemic. A significant correlation was found between the variables and the number of daily patients which can be justified. Nevertheless, it cannot be said with certainty how these factors affect the spread of the disease, but it can only be said that there is an association between them. The spread of COVID-19 disease depends not only on climatic parameters but also on other factors and even existing laws in the community, each of which affects the prevalence of the diseases.

Conclusion

Climatic parameters influence the spread of COVID-19 disease and should be addressed efficiently for similar situations in the future to suppress the trauma. Among climatic parameters in Maricopa county, maximum, mean, and minimum temperatures, as well as PM10 and PM2.5 AQI, correlated positively and significantly with the number of new daily patients. It must be mentioned that the PM10 AQI had the greatest effect on the spread of the virus. Moreover, minimum, maximum, and mean relative humidity parameters, together with solar radiation and O3 AQI, had a negative impact on the spread of COVID-19. In addition, maximum relative humidity had the greatest negative correlation with the epidemic.

The linear regression also revealed Tmean can significantly predict daily COVID-19 cases. It also showed that a unit increase in O3 AQI can reduce daily new COVID-19 cases by 15 (cases). Wind speed was not significantly correlated with the spread of COVID-19 disease in Maricopa County. The results of this study can be used to prevent the spread of COVID-19 or similar diseases based on climatic conditions.

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Conflicts of interest

There is no conflict of interest.

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