Original Article

The Impact of Meteorological Factors on the Spread of COVID-19

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Abstract

Background: Clinical studies suggest that warmer climates slow the spread of viral infections. In addition, exposure to cold weakens human immunity. **Aim:** This study describes the relationship between meteorological indicators, the number of cases, and mortality in patients with confirmed coronavirus disease 2019 (COVID-19). **Patients and Methods:** This was a retrospective observational study. Adult patients who presented to the emergency department with confirmed COVID-19 were included in the study. Meteorological data [mean temperature, minimum (min) temperature, maximum (max) temperature, relative humidity, and wind speed] for the city of Istanbul were collected from the Istanbul Meteorology 1st Regional Directorate. **Results:** The study population consisted of 169,058 patients. The highest number of patients were admitted in December (n = 21,610) and the highest number of deaths (n = 46) occurred in November. In a correlation analysis, a statistically significant, negative correlation was found between the number of COVID-19 patients and mean temperature ($rho = -0.734$, $P < 0.001$), max temperature ($rho = -0.696$, $P < 0.001$) or min temperature ($rho = -0.748$, $P < 0.001$). Besides, the total number of patients correlated significantly and positively with the mean relative humidity ($rho = 0.399$ and $P = 0.012$). The correlation analysis also showed a significant negative relationship between the mean, maximum, and min temperatures and the number of deaths and mortality. **Conclusion:** Our results indicate an increased number of COVID-19 cases during the 39-week study period when the mean, max, and min temperatures were consistently low and the mean relative humidity was consistently high.

Keywords: *COVID-19, humidity, meteorological indicators, temperature, wind speed*

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Introduction

In December 2019, cases of atypical pneumonia of an unknown etiology were reported in Wuhan, Hubei, China. In January 2020, a novel coronavirus not previously detected in humans was identified as the causative agent. The World Health Organization (WHO) named the virus the 2019 novel coronavirus.[1] In February 2020, countries with domestic contamination emerged. By March 2020, the coronavirus disease 2019 (COVID-19) had spread to more than 100 countries,[2,3] such that on March 11, 2020, the WHO defined the outbreak as a pandemic.[4]

Analyzing the relationship between viral infections and meteorological conditions can provide a better understanding of virus behavior. Clinical studies suggest that warmer climates slow the spread of viral infections.[5] In addition, exposure to cold weakens human immunity. Cold weather is associated with a reduced blood supply to the nasal mucosa, in turn reducing the movement of immune cells to the entire upper respiratory tract. Consequently, people are more vulnerable to microbial infections during the winter. In

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addition, as they also typically spend more time indoors, the risk of transmission of pathogenic microorganisms between hosts is higher.[6]

SARS-CoV, responsible for the 2002–2004 SARS outbreak, was shown to survive longer on surfaces when both the temperature and the relative humidity were low.[5] However, whether the spread of SARS-CoV-2, the virus responsible for COVID-19, is facilitated by temperature is thus far unclear.[7–10] Wang *et al*.[7] conducted a study of 26 countries that had reported SARS-CoV-2 cases and found a significant relationship between viral spread and temperature. However, a study of 15 European countries with reported SARS-CoV-2 cases showed that a 1°C increase in air temperature reduced COVID-19 transmission by 0.9%.[8] In another study, which analyzed the relationship between COVID-19 and meteorological indicators in New York City, USA, average temperature, minimum (min) temperature, and air quality were shown to correlate significantly with the city's COVID-19 outbreak.[9] Possible environmental effects in the spread of COVID-19 were also investigated in a Chinese study, which concluded that a high air quality index may have a positive effect on the spread of COVID-19, with transmission accelerated by a low relative humidity.[10] However, Dutta *et al*.[11] found that high relative humidity in Delhi, India during the first wave of the COVID-19 pandemic was related to a decrease in both patient numbers and mortality. The relationship between the spread of COVID-19 and meteorological factors is thus far unclear. It is necessary to conduct additional research to clarify the limited and conflicting evidence on the association between the spread of COVID-19 and meteorological factors.

In this study, therefore, we investigated the relationship between meteorological indicators (air temperature, humidity, and wind speed) and the number of COVID-19 cases as well as the mortality of patients with confirmed COVID-19 who were consecutively admitted to our tertiary hospital during the 39-week period.

Patients and Methods

Ethics committee approval and patient consent

This study was conducted in accordance with the 1989 Declaration of Helsinki. Approval was obtained from the Turkish Ministry of Health Scientific Research Platform (form number 14; 16/08/2021) as well as from the Clinical Research Ethics Committee of the Haseki Training and Research Hospital, Istanbul, Turkey (decision number 54–2021 dated 25/08/2021). Patient consent to review the medical records was not required by the IRB because all data were deidentified.

Data collection

This was a single-center, retrospective, descriptive, cross-sectional, and clinical observational study. The data for this study were obtained from the Turkish Ministry of Health's Public Health Management System and included the number of daily and cumulatively confirmed COVID-19 cases by real-time polymerase chain reaction (RT-PCR). Meteorological data (mean temperature, min temperature, maximum (max) temperature, relative humidity, and wind speed) for the city of Istanbul were collected between June 01, 2020, and February 28, 2021, during the 39-week study period from the Istanbul Meteorology 1st Regional Directorate.

Adult patients, ≥18 years of age, who presented to the emergency department with COVID-19 symptoms confirmed by RT-PCR were included in the study. Patients, <18 years of age or those with pneumonia of other types not confirmed by RT-PCR, were excluded from study participation.

Study design

This study investigated the hypothesis that high temperature and low relative humidity reduce COVID-19 transmission and mortality. As a primary objective, we evaluated the relationship between patient numbers and meteorological factors. Our secondary objective was to reveal the relationship between meteorological factors and COVID-19-related mortality.

A correlation analysis between meteorological indicators and both the number of COVID-19 cases and disease severity was performed. A possible correlation between weekly and monthly patient numbers and meteorological parameters was also examined. The seasonal distribution [summer (June, July, and August), autumn (September, October, and November), and winter (December, January, February)] of the number of COVID-19 cases and deaths was determined as well.

Data analysis

SPSS 15.0 for Windows was used for the statistical analyses. Descriptive categorical variables were expressed as numbers and percentages, and numerical variables as the mean, standard deviation, min, max, median, and interquartile range (IQR). The relationship between the COVID-19 parameters of interest and non-normally distributed meteorological data (mean, min and max temperatures, mean relative humidity) was assessed using Spearman's rank correlation test. In the case of normally distributed data (wind speed), Pearson's correlation test was used. A statistical alpha significance level was defined as $P < 0.05$.

Results

The study population consisted of 169,058 patients, of which 89,091 (52.70%) were male and 79,967 (47.30%) were female. The mean age of the patients was 39.74 ± 11.60 (range, 18–92) years. From the initial group, 354 patients died, resulting in a mortality rate of 0.21%.

The meteorological parameters are shown in Table 1. The daily mean, max, and min temperatures were 16.4 ± 6.9°C, 21.8 ± 7.5°C, and 12.4 ± 6.3°C, respectively. In addition, the mean relative humidity was 81.8 ± 6.9% and the mean wind speed was 3.02 ± 0.80 m/s.

The largest number of patients (n = 21,610) was admitted in December, but the largest number of deaths (n = 46) occurred in November. The lowest number of patients (n = 15,345) occurred in June, as did the lowest number of deaths (n = 30). A comparison of the number of patients with the number of deaths according to the season showed that the largest number of patients occurred in winter (n = 63,544), and the largest number of deaths in autumn and winter (n = 129 and 127). The total number of patients and the distribution of patient deaths by month and season are shown in Table 2 and Figure 1.

In the correlation analysis, a statistically significant, negative relationship was found between the number of COVID-19 patients and mean temperature (*rho* = −0.734, P < 0.001), max temperature (*rho* = −0.696, P < 0.001) or min temperature (*rho* = −0.748, P < 0.001), as shown in Table 3 and Figure 2. In addition, the total number of patients correlated significantly and positively with the mean relative humidity (*rho* = 0.399 and P = 0.012) [Table 3 and Figure 2]. However, there was no significant correlation between the total number of patients and the wind speed (*rho* = 0.214 and P = 0.190) [Table 3 and Figure 2].

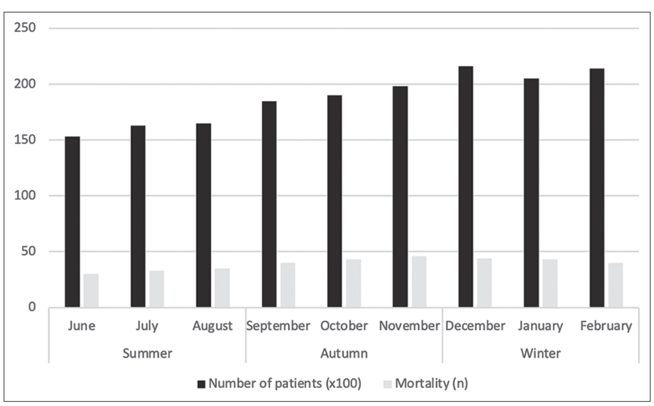

Figure 1: Distribution of the total number of COVID-19 patients and COVID-19-related deaths by month and season

Table 1: Meteorological data during the 39-week study period collected from the Istanbul Meteorology 1st Regional Directorate

Meteorological factors	Mean±SD (min-max)	Median (IQR)
Temperature (°C)	16.4±6.9 (1.7–24.7)	18.6 (10.3–22.8)
Maximum temperature (°C)	21.8±7.5 (5.1–30.6)	25.8 (14.8–28.8)
Minimum temperature (°C)	12.4±6.3 (−1.2–20.4)	13.6 (7.4–18.1)
Relative humidity (%)	81.8±6.9 (70.4–98.0)	81.0 (77.5–86.5)
Wind speed (m/s)	3.02±0.80 (1.53–5.10)	2.87 (2.46–3.58)

Data were given as numbers, mean±standard deviation (SD), minimum, maximum, median, and interquartile ranges (IQR)

Table 2: Distribution of the total number of patients with COVID-19 and COVID-19-related deaths by month and season

Month	Patients *n* (%)	Deaths *n* (%)
June	15,345 (9.08)	30 (8.47)
July	16,389 (9.69)	33 (9.32)
August	16,499 (9.76)	35 (9.89)
September	18,480 (10.93)	40 (11.30)
October	18,972 (11.22)	43 (12.15)
November	19,829 (11.73)	46 (12.99)
December	21,610 (12.78)	44 (12.43)
January	20,552 (15.54)	43 (12.15)
February	21,382 (12.65)	40 (11.30)
Season		
Summer	48,233 (28.53)	98 (27.68)
Autumn	57,281 (33.88)	129 (36.44)
Winter	63,544 (37.59)	127 (35.88)

Data were given as numbers and percentages (%)

Table 3: Correlation analysis of the relationship between meteorological variables and the number of COVID-19 patients, the number of COVID-19-related deaths, and the related mortality

	Patients	Deaths	Mortality during the 39-week
Mean temperature			
rho	−0.734	−0.654	−0.375
P	<0.001	<0.001	0.019
Maximum temperature			
rho	−0.696	−0.675	−0.429
P	<0.001	<0.001	0.006
Minimum temperature			
rho	−0.748	−0.646	−0.352
P	<0.001	<0.001	0.028
Mean humidity			
rho	0.399	0.239	0.158
P	0.012	0.142	0.337
Wind speed			
rho	0.214	0.031	0.003
P	0.190	0.850	0.988

Note: *rho*, correlation coefficient as determined in a Pearson's correlation test

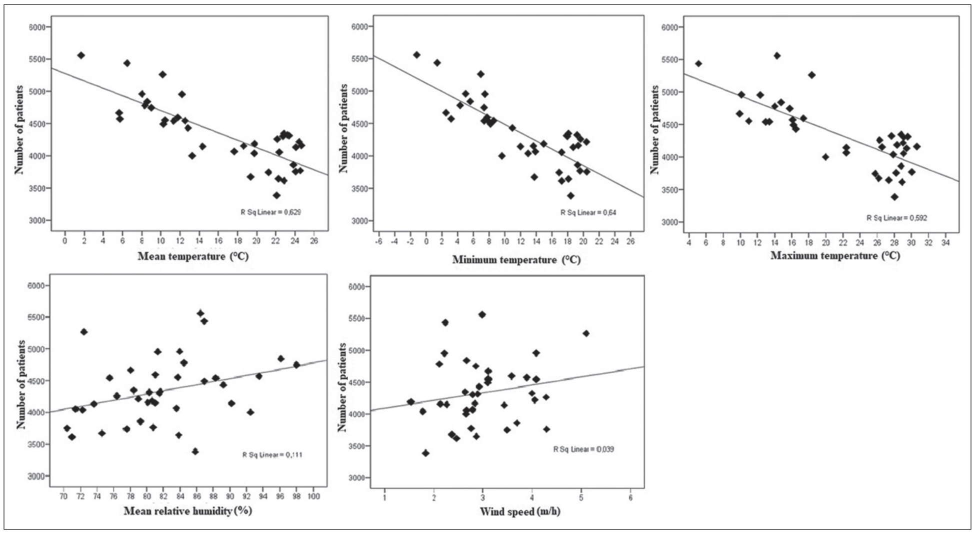

Figure 2: The relationship between meteorological variables and the number of COVID-19 patients

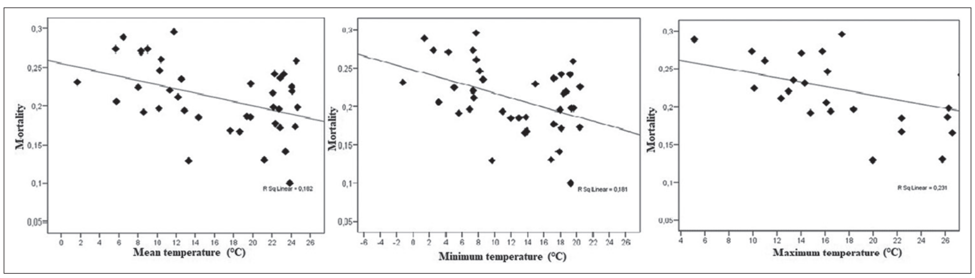

Figure 3: The relationship between mean temperature, maximum temperature, and minimum temperature and mortality due to COVID-19

Similarly, the number of deaths correlated significantly and negatively with the mean (*rho* = −0.654, *P* < 0.001), max (*rho* = −0.675, *P* < 0.001), and min (*rho* = −0.646, *P* < 0.001) temperatures as shown in Table 3. However, there was no significant correlation between the number of deaths and either the mean relative humidity (*rho* = −0.239, *P* = 0.142) or the wind speed (*rho* = 0.031, *P* = 0.850) [Table 3].

A statistically significant, negative relationship was determined between mortality and the mean (*rho* = −0.375, *P* = 0.019), max (*rho* = −0.429, *P* = 0.006), and min (*rho* = −0.352, *P* = 0.028) temperatures [Table 3 and Figure 3]. There was no significant correlation between mortality and either the mean relative humidity (*rho* = 0.158, *P* = 0.337) or the wind speed (*rho* = 0.003, *P* = 0.988) [Table 3].

Discussion

Understanding the factors that contribute to the spread of SARS-CoV-2 will play an important role in controlling the spread of COVID-19 and help combat other possible epidemics. Infectious agents, together with host and environmental factors, are the main determinants of the epidemiology and pathogenesis of infectious diseases.[12]

Recognizing the relationship between COVID-19 and environmental factors such as meteorological variables can help in planning appropriate management of an outbreak. Low relative humidity and cold weather conditions provide a favorable environment for SARS-CoV-2.[5,6] In addition, clinical studies have shown a slower spread of respiratory diseases during warm seasons and a faster spread during cold seasons.[5,6,12,13] However, the relationship between the spread of SARS-CoV-2 and meteorological variables is still unclear.[7–10]

This study investigated potential predictive factors for mortality and disease spread in patients with confirmed COVID-19 who were consecutively admitted to our tertiary hospital of the emergency department. The key findings are summarized below.

The highest number of patients in our study were admitted in December (*n* = 21,610) and the highest number of deaths (*n* = 46) occurred in November. The smallest number of patients (*n* = 15,345) were admitted in June, which was also the month with the lowest number of deaths (*n* = 30). When disaggregated according to season, the highest number of patients (*n* = 63,544) was in winter, and the highest number of deaths was in autumn and winter (*n* = 129 and 127). In a correlation analysis based on the total number of patients and the meteorological indicators, a statistically significant, negative correlation was found between the mean, max, and min temperatures, and a significant, positive correlation between the total number of patients and the mean relative humidity. The correlation analysis also showed a significant negative relationship between the mean, max, and min temperatures and the number of deaths and mortality. Finally, there was no significant relationship between wind speed and the total number of COVID-19 patients, the number of COVID-19-related deaths, or COVID-19-related mortality.

In their study of 16 different geographical regions in Poland conducted between April and October 2020, Bochenek *et al*.[14] reported a statistically significant negative correlation between the spread of COVID-19 and the daily max temperature in all regions. Bashir *et al*.[9] identified an association between the min and average temperatures and the spread of COVID-19 in New York City. In a study conducted in China that examined 80,981 COVID-19 cases, the rate of disease transmission was shown to decrease with increasing temperature.[15] In a large-scale study involving 1,908,197 patients and 190 countries, Guo *et al*.[16] used a nonlinear distributed lag model with the random intersection at the city/country level and reported a statistically significant, negative correlation between the mean temperature and the number of patients. In accordance with those studies, we determined a statistically significant, negative relationship between the total number of COVID-19 patients and the mean, max, and min temperatures. This result is consistent with our findings that the number of patients was highest (lowest) in December (June), and during winter (summer) when the air temperature was lowest (highest).

A study conducted in Shanghai, China, from January 1 to March 31, 2020, found that a 1% increase in relative humidity resulted in a 1.7%–3.7% increase in the daily number of patients with confirmed COVID-19.[17] Zhou *et al*.[18] investigated the effects of air pollutants and meteorological factors on the number of confirmed cases in 120 cities in China. They determined that the rate of COVID-19 transmission increased with an increase in relative humidity. Similarly, our study identified a positive correlation between the relative humidity and the total number of patients. However, there was no statistically significant relationship between the relative humidity and the number of deaths. By contrast, in a study conducted in India, Dutta *et al*.[11] reported that high relative humidity in Delhi during the first wave of the epidemic was related to a decrease in both patient numbers and mortality. Larger studies on the effect of relative humidity on the spread of COVID-19 and COVID-19-related mortality are needed.

Laboratory studies showed that low temperature and high humidity create a favorable environment for SARS-CoV. In addition, cold weather conditions reduce host immunity.[5,19] Cold air reduces both blood flow and immune cell infiltration to the nasal mucosa, which is the first protective barrier against SARS-CoV.[6,19] Consequently, people are more vulnerable to microbial infections during the cold seasons. In addition, as they also typically spend more time indoors, the social distance between people is decreasing. Therefore, the virus spreads more easily between hosts[6]. An epidemiological study that analyzed data on influenza between 1972 and 2002 in the USA showed that changes in relative humidity and temperature were closely associated with an increase in the number of deaths associated with respiratory viral disease.[20] In our study, the death rate was the highest in autumn and winter (129 and 127), corresponding to cold weather conditions. This finding is in line with clinical studies.

In a Chinese study carried out in March–November 2021, Han *et al*.[21] found a significant correlation between the total number of patients and wind speed. A study from Brazil that examined the relationship between meteorological variables and the number of COVID-19 patients reported a statistically significant relationship between air temperature, humidity, wind speed, and the number of patients.[22] In contrast to these reports, in our study, there was no correlation between wind speed and either the total number of patients, the number of deaths, or mortality.

The data we obtained have practical implications for healthcare providers. During cold seasons when meteorologic conditions are favorable for COVID-19 transmission, preventative precautions must be increased. In addition, information on meteorological conditions favorable for SARS-CoV-2 transmission might be incorporated in media weather forecasts. The availability of such information might help develop specific regional measures in areas at high risk of COVID-19. Moreover, early prediction of weather-related patient surges may improve hospital bed occupancy management.

The limitations of our study were as follows: first, the cumulative number of confirmed cases rather than the daily number of confirmed cases was used in the analyses, and the individual characteristics of the patients were not taken into account. Therefore, the effects of potential factors affecting COVID-19 infection, such as age, sex, comorbidities, and smoking status could not be evaluated. Similarly, the effects on the number of COVID-19 patients of either socio-cultural/socio-economic status or the means of access to healthcare services were not considered. Lastly, the effect of restrictive measures, such as lockdowns, during the study period was not examined.

Conclusion

Our study identified a statistically significant, negative relationship between the death rate from COVID-19 and the mean, max, and min temperatures. Furthermore, the mean relative humidity correlated with the number of cases, but not with mortality. Finally, wind speed values did not affect the number of COVID-19 patients nor COVID-19-related death. We conclude that the meteorological variables, including the mean air temperature and the mean relative humidity, have an impact on the initial spread of COVID-19 cases and deaths, respectively. Overall, this study can enhance our understanding of COVID-19 transmission dynamics and inform more effective public health interventions, incorporating meteorological variables. The findings suggest interventions according to local weather conditions such as promoting outdoor activities in warmer weather and implementing indoor ventilation strategies during low relative humidity. Further studies are needed to investigate the effects of meteorological variables on COVID-19 transmission and mortality.

Ethics approval and consent to participate

Approval was obtained from the Turkish Ministry of Health Scientific Research Platform (form number 14; 16/08/2021) as well as from the Clinical Research Ethics Committee of the University of Health Sciences, Haseki Research and Training Hospital, Istanbul, Turkey (decision number 54-2021 dated 25/08/2021). Patient consent to review the medical records was not required by the IRB because all data were deidentified.

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Nil.

Conflicts of Interest

There are no conflicts of interest.

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