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Impact of weather on COVID-19 pandemic in Turkey

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HIGHLIGHTS

• COVID-19 is an infectious disease.
• Correlation of weather and population with COVID-19 considering nine cities in Turkey.
• The highest correlation is observed for population.
• Wind speed 14 days ago and temperature on the day of the case have high impacts on COVID-19 cases.

GRAPHICAL ABSTRACT

ABSTRACT

The coronavirus pandemic, which has numerous global implications, has led people to believe that nothing will be the same as before. The present day is dominated by studies on determining the factors that affect, taking preventive actions, and trying to find an effective treatment on top priority. Meteorological parameters are among the crucial factors affecting infectious diseases. The present study examines the correlation between weather and coronavirus disease 2019 (COVID-19) by considering nine cities in Turkey. In this regard, temperature (°C), dew point (°C), humidity (%), and wind speed (mph) are considered as parameters of weather. Research states that the incubation period of COVID-19 varies from 1 day to 14 days. Therefore, the effects of each parameter within 1, 3, 7, and 14 days are examined. In addition, the population is included as an effective parameter for evaluation. The analyses are conducted based on Spearman’s correlation coefficients. The results showed that the highest correlations were observed for population, wind speed 14 days ago, and temperature on the day, respectively. The study results may guide authorities and decision-makers on taking specific measures for the cities.

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1. Introduction

Coronavirus disease 2019 (COVID-19) is an infectious disease that was initially recognized in Wuhan, China, in late December 2019. The World Health Organization (WHO) has declared COVID-19 as public health emergency after it spread to several countries outside of China. It has spread globally, and there are about 1,279,722 confirmed cases and 72,614 total deaths as on April 8, 2020, worldwide (World Health Organization, 2020).

The situation in Turkey may be different as the first case was declared on March 10, 2020, by the Ministry of Health of the Republic of Turkey. As a result of the 202,845 tests carried out as of April 6, 2020, a total of 30,217 cases were identified, and the number of deaths recorded till then was 649 (World Health Organization, 2020). These data indicate that the ratio of confirmed cases to the total cases is...
about 15%. If this ratio is compared with the average of all the other countries, which is around 13.5%, it shows that the average for Turkey is slightly above the world average. The fatality rate in Turkey is about 2%. Based on the number of tests declared, it can be inferred that this rate is lower than the average global fatality rate (5.85%).

According to the WHO, the common symptoms of COVID-19 infection include fever, tiredness, dry cough, shortness of breath, aches, pains, and sore throat. Owing to its contagious nature, COVID-19 has affected the lives of human beings and prominently restricted their movement. To prevent or minimize the spread of the virus, in Turkey, as in most countries in the world, it is stated that people should not venture out unless it is necessary. Besides, people are not allowed to enter some metropolitan cities except in mandatory situations. Such measures show the severity of the situation and that the virus is carried through mobility. Recent studies confirmed that COVID-19 is transported and propagated through humans (Chen et al., 2020; Li et al., 2020; Wang et al., 2020a). Lai et al. (2020) claimed that COVID-19 has spread via human-to-human transmission through direct contact and respiratory droplets. In this regard, it can be inferred that the people's mobility and crowd accelerate the spread of the virus. Therefore, the population is also considered a potentially significant factor in this study.

In addition to human-to-human transmission, meteorological parameters are thought to be effective factors in terms of the viability, transmission, and range of spread of viruses (Chan et al., 2011; Van Doremalen et al., 2013). Zhu and Xie (2020) analyzed the correlation between temperature and COVID-19 infection in China and claimed that the mean temperature and the number of COVID-19 cases have a positive linear association when the temperature is below 3 °C. Tosepu et al. (2020) examined the association between weather and COVID-19 pandemic in Indonesia and found that the temperature average (°C) is correlated with COVID-19 pandemic. Ma et al. (2020) examined the impact of temperature variation and humidity on COVID-19 deaths and postulated that these parameters affect COVID-19 mortality. Chen et al. (2020) analyzed the association between meteorological parameters and the severity of COVID-19 spread on a worldwide scale and claimed that wind speed, temperature, and relative humidity are effective factors. Wang et al. (2020b) analyzed the impact of temperature on the spread of COVID-19 and claimed that temperature significantly affects the transmission of COVID-19.

The main objective of the present study is to analyze the correlation between meteorological parameters and COVID-19 pandemic. Unlike other studies, this study considers different cities in Turkey rather than only one city. In addition, temperature (°C), dew point (°C), humidity (%), and wind speed (mph) are considered as parameters of weather. Besides, given that the incubation period of COVID-19 varies from 1 day to 14 days, each parameter is evaluated based on four timeframes, namely on the day of the case, within 3, 7, and 14 days of the case. Thus, the study aims to provide insight into the right incubation period.

2. Materials and methods

2.1. The data

The data of COVID-19 cases of Turkey were gathered from the official website of the Ministry of Health of the Republic of Turkey (https://covid19.saglik.gov.tr). Fig. 1 presents the situation (as of April 5, 2020) in Turkey. Although the first COVID-19 case was announced in China in late December 2019, the first case in Turkey was announced on March 10, 2020. In other words, COVID-19 has spread to Turkey after more than two months.

Table 1 lists the cities with the highest COVID-19 cases as of April 3, 2020. The table shows that majority of the cases are located in Istanbul, followed by Izmir, Ankara, Konya, Kocaeli, Sakarya, Isparta, Bursa, Adana, Zonguldak, and Samsun. In other words, nearly 62.5% of the total cases are in Istanbul. Istanbul is the most crowded city in Turkey, and it attracts many domestic visitors and foreigners every year. According to the statistics published by the Ministry of Culture and Tourism of the Republic of Turkey, 962,151 foreigners visited Istanbul and 1,733,112 visited Turkey in February 2020. In other words, Istanbul welcomed nearly 56% of total foreigners in Turkey in February 2020. These statistics may provide some clues on the origin of the first cases.

The weather data were collected from https://www.wunderground.com/. Fig. 2 shows the average temperature in the cities. Sakarya and Zonguldak were not included in the evaluation process because the website showed the weather data of these cities same as Kocaeli. Instead, Samsun, which accounted for 167 cases, was considered. Fig. 2 shows that the average temperature is the highest in Adana, where there are 241 cases. The lowest and highest average temperatures are 11.8 °C and 17.7 °C in Adana.

Fig. 3 illustrates the average dew point in the cities. Dew point is the temperature at which the air is saturated and clouds are formed. In other words, it is the temperature to which the air needs to be cooled for the relative humidity to reach 100%. It can be said that the average dew point in Adana generally rises to the highest level than in other cities. Considering all the cities, the lowest and highest dew points are −3 °C and 12.8 °C.
Fig. 4 shows the change of average humidity in the cities. It can be inferred that the humidity level reaches to the highest level in Kocaeli than in the other cities. The highest level (93.6%) was observed on March 25, 2020, in Kocaeli.

The average change in wind speed of each city in 14 days is shown in Fig. 5. The highest values are observed in Istanbul and Kocaeli in general. In particular, the highest level (30.7 mph) was recorded in Kocaeli on March 26, 2020.

The data of the population were collected on the official website of the Turkish Statistical Institute. Fig. 6 presents the population of each city. Istanbul is seen to be the most crowded, while Isparta is the least crowded city.

2.2. Spearman’s correlation test

Spearman’s rank correlation coefficient ($r_s$) is adopted to determine the correlation between variables. It analyzes how well the association between two variables can be defined using a monotonic function. Given that the data used in this study are not normally distributed, it is appropriate to use correlation coefficients for the analyses. The coefficient can be calculated via the following equation.

$$r_s = 1 - 6 \frac{\sum d_i^2}{n(n^2 - 1)}$$

where $n$ represents the number of alternatives, and $d_i$ is the difference between the ranks of two parameters.

Table 1

| City       | Total cases |
|------------|-------------|
| Istanbul   | 12,231      |
| Izmir      | 1105        |
| Ankara     | 860         |
| Konya      | 601         |
| Kocaeli    | 500         |
| Sakarya    | 337         |
| Isparta    | 289         |
| Bursa      | 259         |
| Adana      | 241         |
| Zonguldak  | 197         |
| Samsun     | 167         |

Fig. 2. Average temperature (°C) of the cities.

Fig. 3. Average dew point (°C) of the cities.
Fig. 4. Average humidity (%) in the cities.

Fig. 5. Average wind speed (mph) in the cities.

Fig. 6. The population of each city.
Table 2
Spearman correlation coefficients.

| Factor                  | Total case |
|------------------------|------------|
| Temperature on the day  | -0.483     |
| Temperature 3 days ago | -0.383     |
| Temperature 7 days ago | -0.350     |
| Temperature 14 days ago| -0.317     |
| Dew point on the day   | -0.400     |
| Dew point 3 days ago   | -0.400     |
| Dew point 7 days ago   | -0.300     |
| Dew point 14 days ago  | -0.300     |
| Humidity on the day    | -0.317     |
| Humidity 3 days ago    | -0.133     |
| Humidity 7 days ago    | 0.017      |
| Humidity 14 days ago   | -0.033     |
| Wind speed on the day  | -0.217     |
| Wind speed 3 days ago  | 0.267      |
| Wind speed 7 days ago  | 0.450      |
| Wind speed 14 days ago | 0.550      |
| Population             | 0.683      |

3. Results and discussion

Table 2 presents the result of Spearman’s correlation analysis. As noted earlier, the five main factors, namely, temperature, dew point, humidity, wind speed, and population, are considered in the study. Four of these factors (temperature, dew point, humidity, and wind speed) are evaluated for four timeframes, namely, on the day, 3 days ago, 7 days ago, and 14 days ago. First, the correlation between temperature and the number of total cases in each city is evaluated. In this context, the temperatures on the day of the case, and within 3, 7, and 14 days of the case are considered. The results indicate that the temperature on the day of the cases has the highest correlation. In other words, the average air temperature on the day of the incident is closely related to the case. The correlation is negative, which implies that as the temperature lowers, the number of cases increases. Second, the dew point on the day and within 3 days has the same correlation with the number of cases. The correlation worsens as the time span considered widens. Third, the association between humidity and the number of cases is the most on the day of the case. Considering the average humidity on the day of the cases is the most reasonable. The correlation is negative, which indicates that an increase in any of these parameters indicates a decrease in the other. Fourth, among meteorological parameters, the average wind speed in 14 days has the highest correlation with the number of cases. The higher the wind speed is, the more the number of cases is. The results also indicate that the most reasonable timespan is 14 days, meaning that the wind speed in 14 days of the case should be considered for determining the right correlation. Finally, as expected, the population of a city is highly correlated with the number of cases in the city.

Fig. 7 is presented to observe the most correlated factors with the number of cases. The impacts of population, wind speed 14 days ago, and temperature on the day on the total cases can be easily observed. To compare the results of this study to those of the other studies, a recent study is considered first. Tosepu et al. (2020) posited that the average temperature is significantly correlated with COVID-19. However, it is claimed that minimum and maximum temperature, rainfall, and humidity are not significantly correlated with COVID-19. In this study, the average temperature is found to be correlated with COVID-19 as well. The correlation coefficient is higher in this study ($r_s = -0.483$) compared with that in the study by Tosepu et al. (2020), in which the coefficient value $r_s = 0.392$. The difference is likely because of the different countries and cities. Unlike in that study, the temperature is evaluated in four timespans in this study. Thus, the impact of average temperature based on different timespans is revealed. Besides, the correlation of humidity on the day with COVID-19 cases ($r_s = -0.317$) is higher in this study. In addition, unlike the other study, wind speed, which is found to be correlated with COVID-19 cases, and population, which is strongly correlated with COVID-19, are also considered in this study. Finally, unlike the other study, nine different cities are included in the analyses that may contribute to the generalization of the results.

In addition, Bi et al. (2007) investigated the correlation between severe acute respiratory syndrome (SARS) transmission and weather in Beijing and Hong Kong in the 2003 epidemic to reveal the impact of weather on SARS transmission. The results of that study reveal that there is an inverse correlation between the number of cases and temperature. This finding is consistent with that in this study, in which the temperature is inversely correlated with the number of COVID-19 cases. Similarly, in another study conducted by Chan et al. (2011), it is claimed that higher temperatures and higher relative humidity (e.g., 38 °C and relative humidity of >95%) eliminate the virus viability. This result is consistent with the result found in the present study, which shows that humidity on the day and temperature are inversely correlated with COVID-19 cases.
The results of the present study can be summarized as follows. First, the temperature on the day is correlated with the number of COVID-19 cases. The impact of temperature is the highest on the day of the case. Second, the impact of the dew point is the same on the day and three days ago of the COVID-19 cases. Third, the effect of humidity is the highest on the day of the COVID-19 cases. Fourth, the wind speed 14 days ago of the COVID-19 cases has the highest correlation with COVID-19. Finally, the population is a prominent indicator of determining or estimating COVID-19 cases.

This study may have some limitations. The results may not reflect the real case of the cities. In some cities, people coming from various countries have been quarantined. These people may lead to increased number of cases in a city because almost all first COVID-19 cases in Turkey have originated abroad. Therefore, not knowing the exact number of these people coming to each city can be considered a limitation. Furthermore, not considering all cities in Turkey may be another limitation. As mentioned earlier, past meteorological data do not exist for all cities.

4. Conclusions

Unlike other studies, the present study analyses the impact of temperature, dew point, humidity, and wind speed within 1 day, 3, 7, and 14 days of the case on COVID-19 cases using data in Turkey. In addition, the correlation between the population and the COVID-19 cases is examined. The results indicate that the crowd in a city is closely related to the higher number of COVID-19 cases. Moreover, the wind speed of the last 14 days, including the day of the incident, represents a positive relationship with the number of COVID-19 cases. In other words, the higher average wind speed in 14 days, the higher is the number of COVID-19 cases. Another interesting result is that temperature on the day of cases has the highest correlation with the cases. In other words, the lower the temperature on a day, the higher is the number of COVID-19 cases on that day.

The availability of weather data of Sakarya and Zonguldak, where the density of COVID-19 cases may be considered as high, could help improve the accuracy of the results. Furthermore, the updated detailed COVID-19 cases for each city could help broaden the results. Besides, the exact number of people, who have come from abroad and have been quarantined in cities, could enhance the accuracy of the analyses. For future research, these points may be considered. In addition, different cities from different countries could help to generalize the results.

CRediT authorship contribution statement

Mehmet Şahin: Writing - original draft.

Declaration of competing interest

The author declares no conflict of interest. Mehmet Sahin conducted all work.

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