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Correlation between weather conditions and COVID-19 pandemic in the southeast area of Iran

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Abstract

The Coronavirus disease 2019 (COVID-19) has influenced the life of all people around the world. This study analyzed the relationship between the weather elements (daily temperature, wind speed and humidity) and daily active, recovered and dead cases of COVID-19 in Rafsanjan, southeast area of Iran. COVID-19 data and meteorological variables were obtained from 29 February 2020 to 20 March 2021 (386 days) from Rafsanjan University of Medical Sciences and Meteorological Organization of Iran, respectively. The results showed that there is a significant inverse association between daily average temperature with the number of daily active cases (r: −0.293), recovered cases (r: −0.301) and dead cases (r: −0.198) of COVID-19 ($p<0.01$). With decreasing the average wind speed, the number of daily active cases (r: −0.224), recovered cases (r: −0.232) and dead cases (r: −0.169) of COVID-19 has been increased ($p<0.01$). A non-significant positive correlation was observed between daily humidity and active cases (r: 0.033, $p=0.518$) and recovered cases (r: 0.044, $p=0.390$), and significant positive correlation with the daily dead cases (r: 0.254, $p<0.01$). Therefore, temperature and wind speed can be considered as affective factors in COVID-19 transmission as an auxiliary solution.

Keywords COVID-19 · Humidity · SARS-COV-2 · Temperature · Weather

1 Introduction

The COVID-19 is an infectious illness caused by severe acute respiratory disease coronavirus 2 (SARS-CoV-2) [1]. SARS-CoV-2 belongs to the Coronaviridae family and contains a single-stranded RNA as its genetic material [2]. Fever, cough, and breathlessness have been reported as common clinical symptoms of the disease; however, this virus, similar to other coronaviruses, has the potential to cause Severe Acute Respiratory Syndrome (SARS) [3]. SARS-CoV-2 is transmitted from human to human through respiratory droplets or aerosol [4]. The people with pre-existing ailments, including diabetes mellitus, asthma, hypertension, and cardiovascular disease, as well as the elderly and males, are more susceptible to COVID-19 disease or have more severe symptoms [5]. Due to the fast outbreak of the disease globally, it has become a serious public health threat, and the World Health Organization (WHO) has announced this disease as a pandemic [6]. More than 758,390,564 confirmed cases and 6,859,093 deaths around the world have been reported until 28 February 2023 [7].

Several different factors, including demographic and environmental, can play important role in the course of a

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pandemic therefore, it is essential to find out the effect of these factors [8]. Weather conditions (e.g., temperature and humidity) are important in the transmission of viruses. High temperature and humidity decrease the stability of the virus, while low temperature and humidity can increase the half-life of SARS-CoV-2 [9]. Several mechanisms can be important in explaining the relationship between temperature, humidity and SARS-CoV-2 transmission. Due to a lipid envelop of SARS-CoV-2, this virus is sensitive to temperature, humidity and solar radiation in laboratory conditions [10]. Laboratory studies have suggested that the viability of SARS-CoV-2 has been reduced by increasing temperature (4 °C, 22 °C, and 37 °C) [11]. Seasonal changes can influence on immune system functions, for example, low ultraviolet B exposure during winter can affect the required production of vitamin D in human bodies which might affect the antiviral immune defenses and impact covid-19 transmission [12]. Also, Interferons functions which are important in innate immune response against viruses might be impaired at low relative humidity [13]. Weather conditions influence on people mobility, and contact patterns, spending more time in enclosed spaces due to very hot or very cold conditions can increase the risk of SARS-CoV-2 transmission [14].

Weather factors impact the transmission of COVID-19; however, their influences are different among different regions. Recently, studies have shown a strong relationship between humidity, temperature, and COVID-19 outbreak in different countries worldwide [15]. During the first months of the pandemic, temperature was considered as a main factor in COVID-19 transmission and lower incidences of infection was reported in highest temperatures regions of Spain [16]. Infection rate decreased by increasing temperatures over 25 °C [17]. A non-linear association between the effective reproduction number and mean temperature, has been found [18]. A linear relationship between mean temperature and daily number of the COVID-19 confirmed cases in the temperature lower than 3 °C was shown [19]. A positive correlation between temperature and COVID-19 spread in Singapore, Brazil, Indonesia, Japan, and Norway [20–24] and a significant negative correlation in New York City, Iran, Bangladesh, and China have been reported [9, 25–27].

Some researches indicated the relationship between humidity and SARS-CoV-2 transmission and growth [19]. In a study, a significant relationship between relative humidity and the spread of COVID-19 was shown [28]. One study concluded that there was no significant relationship between absolute humidity and COVID-19; however, temperature could influence on COVID-19 spread [29]. The results of another study showed no relationship between rainfall amount and humidity with COVID-19 spread [24]. The number of daily confirmed cases of COVID-19 increased (1.7 ~ 3.7%) for 1% rise in relative humidity [30]. A positive correlation between relative air humidity in Brazil and Singapore has been reported [20, 21]. A research showed a significant correlation between temperature and the transmission of COVID-19 and reported that every 1℃ rises in the minimum temperature and 1% increase in humidity, lead to a reduction in the number of cases and reduced the virus transmission [31].

Wind is another climate factor influence COVID-19 transmission. Under high-speed wind conditions, respiratory droplets including virus can be transmitted on the wind direction and as a result the risk of SARS-CoV-2 transmission increases [32]. Researches in United States and Bangladesh reported a significant association between wind speed and COVID-19 spread [33, 34]. A significant association between the number of COVID-19 cases and low wind speed was indicated in Iran [9]. The high wind speed has increased the prevalence of COVID-19 in Turkey [35] but did not impact the outbreak in Singapore [23].

Regarding the effect of weather indicators, such as humidity, temperature, and wind speed, on the spread of COVID-19 disease in different countries, the investigation of the impact of climatology factors can be helpful to limit and control the spread of SARS-CoV-2. Also, due to need to the growing literature and evidence on the relationship of weather conditions and COVID-19 transmission, and the effect of climate factors on the spread of COVID-19 has not been explored in Rafsanjan city; therefore, the main goal of the current study is to investigate the correlation between the numbers of new positive daily cases of this disease and three environmental factors, including temperature, humidity, and wind speed, in this city.

2 Material and methods

2.1 Study area

This study was conducted as a case and ecological study in Rafsanjan city which is located in the north of Kerman province, Iran (Fig. 1). This city is situated at a longitude of 55° 59′ 30″ E and latitude of 31° 13″ N. The maximum and minimum annual temperature and humidity in Rafsanjan are − 8 and 43 °C, and 7 and 94%, respectively. The annual rain fall is ≤ 100 mm and the climate is arid and hot. The total population of the city is 311,214 people [36].

2.2 Data collection

The present study investigates, the relationship between weather variables and daily COVID-19 cases (confirmed positive, recovered and dead cases). Data from 29 February 2020 to 20 March 2021 (386 days) in Rafsanjan were collected, including daily number of COVID-19 confirmed positive cases (through real-time reverse-transcriptase–polymerase-chain-reaction (RT-PCR)), improved cases, dead cases and meteorological data. COVID-19 data were obtained from Rafsanjan University of Medical Sciences,

Fig. 1 A location map of the study area in Rafsanjan, Kerman, Iran

Table 1 Spearman correlation between COVID-19 and weather parameters

Climate variable	New cases	Recovered cases	Dead cases
Temperature maximum	−0.235**	−0.245**	−0.184**
Temperature minimum	−0.330**	−0.338**	−0.182**
Temperature average	−0.293**	−0.301**	−0.198**
Humidity average	0.033	0.044	0.254**
Wind speed average	−0.224**	−0.232**	−0.169**

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

in the southeast of Iran. while weather variables including daily average temperature, daily average wind speed, daily average humidity, daily maximum and daily minimum temperatures were obtained from Meteorological Organization of Iran (https://irimo.ir/eng/index.php).

The ethical code for this research (IR.RUMS.REC.1399.264) was obtained from Rafsanjan University of Medical Sciences, Rafsanjan, Iran before the data collection.

2.3 Data analysis

In order to find the associations between weather condition including daily average temperature, wind speed and humidity, and daily number of COVID-19 confirmed positive cases, improved cases and dead cases, Statistical Package for the Social Sciences (SPSS-22) software was used to calculate Spearman's correlation analysis. A p-value of < 0.05 considered a statistically significant relationship.

3 Results

During the study period (29 February 2020 to 20 March 2021), 11,436 active cases were reported, of which 11,104 cases and 332 cases were deaths in Rafsanjan. The spearman's correlation analysis between whether variables and the daily active cases, recovered cases and dead cases of COVID-19 are presented in Table 1.

3.1 COVID-19 and temperature

The daily trends of new, recovered and dead cases of COVID-19 and temperature changes during the study period are shown in Fig. 2. According to Fig. 2, and (Table 1), there is a significant inverse correlation between daily temperature average with the number of daily active cases (r: −0.293, $p < 0.01$), recovered cases (r: −0.301, $p < 0.01$) and dead cases (r: −0.198, $p < 0.01$), which means by decreasing daily temperature average, the total daily numbers of COVID-19 cases are increased.

3.2 COVID-19 and humidity

According to Fig. 3 and Table 1, there is a positive correlation between the number of COVID-19 cases and daily average humidity, indeed by increasing daily average humidity, the number of daily active cases (r: 0.033, $p = 0.518$), recovered cases (r: 0.044, $p = 0.390$) and dead cases (r: 0.254, $p < 0.01$) with a slight slope are increased. It can be seen from the data in Table.1 that only the association between daily average humidity with daily mortality is significant.

3.3 COVID-19 and wind speed

According to Fig. 4, there is a slight decline in the number of daily active cases (r: −0.224, $p < 0.01$), recovered cases (r: −0.232, $p < 0.01$) and dead cases (r: −0.169, $p < 0.01$) as average wind speed is increased. A significant negative correlation between the number of COVID-19 cases and daily average wind speed is shown in Table 1.

4 Discussion

The *COVID-19* disease is a global pandemic since the onset of which the world has altered. This pandemic has negatively affected economic activities and human health [37]. In the present study, the correlation of five main weather variables, including daily average temperature, wind speed, humidity,

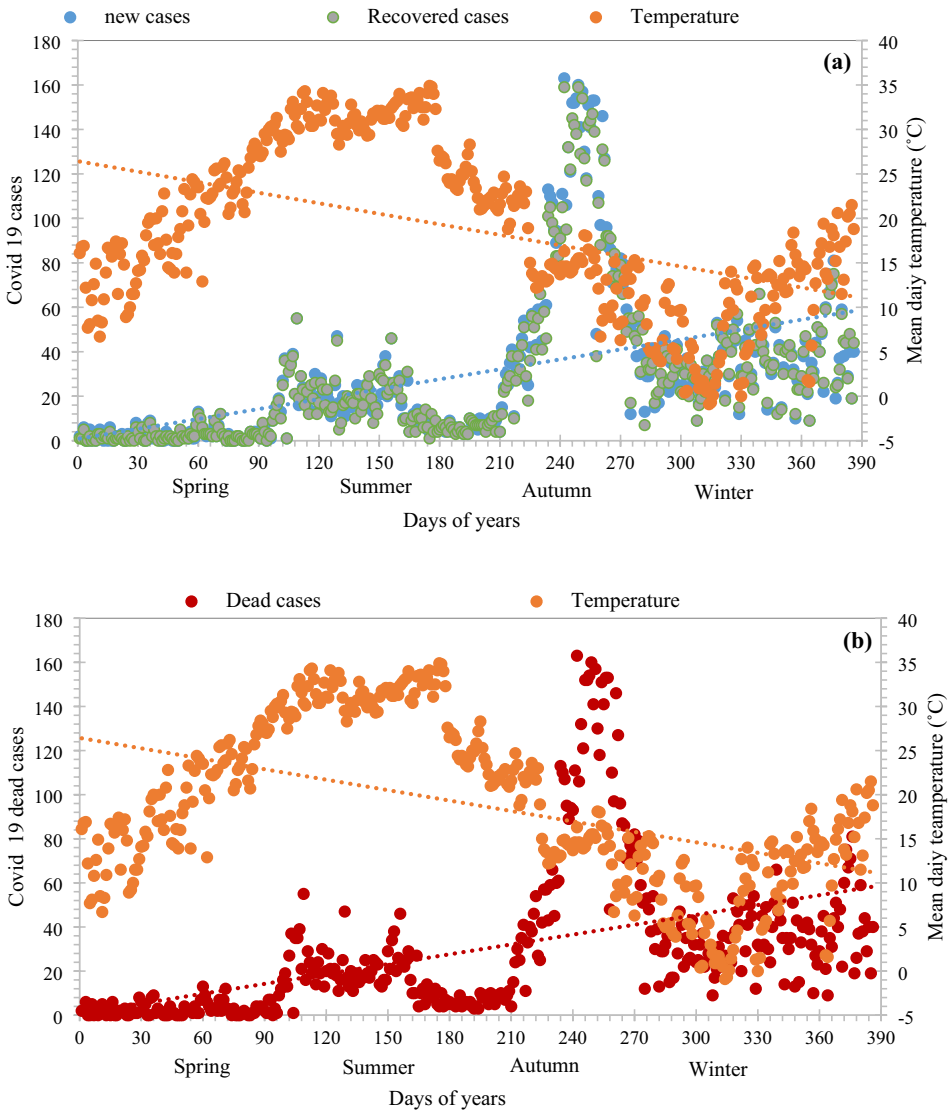

Fig. 2 Trend of COVID-19 daily new, recovered (**a**) and dead cases (**b**), and temperature changes during the study period

maximum temperature, and minimum temperature, with the number of daily active, recovered, and death cases of COVID-19 is investigated. Among weather elements, the effect of temperature has been the most studied [24]. A significant negative correlation between COVID-19 cases and temperature is found in this study. This result seems to be consistent with other researches. Adekunle et al. indicated temperature average to be related inversely to COVID-19 growth in Africa [38]. A moderate negative correlation between average temperature, maximum temperature, and the number of COVID-19 infections in the State of Rio de Janeiro, Brazil, was reported by Rosario et al. [39]. According to the study by Alkhowailed et al., as the average and maximum temperature increased, the number of COVID-19 positive cases decreased in Saudi Arabia [40]. In a study from eight South American locations, Zhu et al. observed a negative association between average temperature and COVID-19 confirmed cases [41]. In a comprehensive study in 166 countries, the authors reported the number of daily positive cases and new deaths of COVID-19 to be reduced for every1°C rise in temperature [42]. In another study in Brazil, Prata et al. reported that when the temperature was below 25.8 °C, every 1 °C increase in temperature led to a 4.9% decrease in COVID-19 cases [43]. According to Wu et al., with increasing 1 °C temperature, the daily new cases and dead were decreased by 3.08% and 1.19% [42]. Other studies have reported conflicting results. Bashir et al. pointed out a positive correlation between minimum and average temperature with COVID-19 cases in New York City [25]. In another study from Wuhan, Ma et al. suggested diurnal temperature ranges be significantly associated with the number of COVID-19 daily deaths [44]. Xie and Zhu illustrated that when the average temperature was below 3 °C, the number of daily confirmed cases of COVID-19 was increased for every 1 °C increase in temperature in 122 cities in China [19]. A significant positive correlation for both minimum

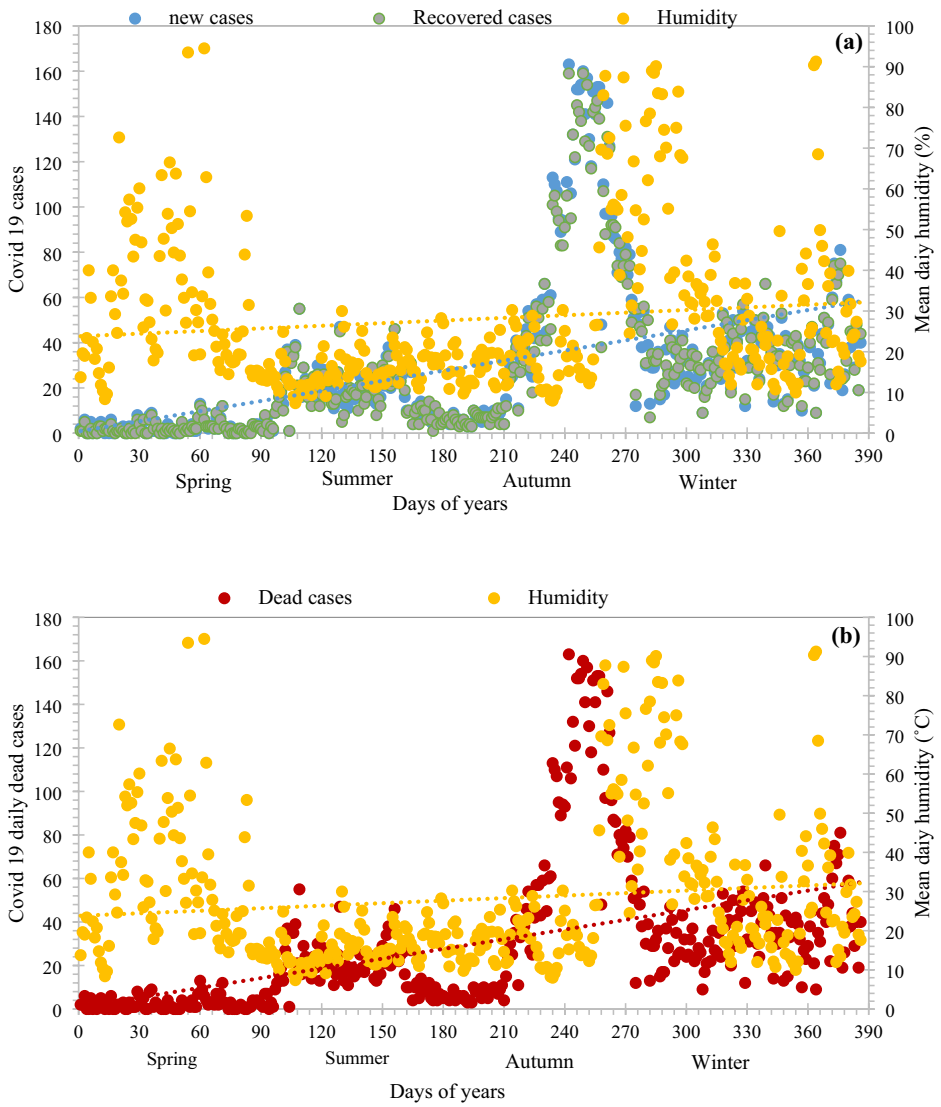

Fig. 3 Trend of COVID-19 daily new, recovered (**a**) and dead cases (**b**), and humidity changes during the study period

temperature and mean temperature with daily new COVID-19 cases was reported in Singapore by Pani et al. [23]. The possible explanation for our results might be that an elevated temperature has the potential to damage the virus lipid membrane and consequently diminishes the stability and transmission rate of viruses [45]. Also, in hot weather, viral load in the air and surfaces can be decreased due to exposure of pathogens to ultraviolet (UV-A) and infrared (IR) rays of the sun; as a result, they are damaged, inactived, or degraded, thus decreasing the transmission [37]. Cold weather in winter can reduce blood supply, thus decreasing immune cells in the nasal mucosa and innate human immunity. However, differences in minimum and maximum temperatures, characteristics of the participants in different area, and other factors such as overcrowding and non-compliance with hygiene tips, recommended by WHO, can also cause differences in study results [24].

The wind is considered a crucial climatic factor in transmitting infectious respiratory ailments since it may modulate the dynamics of various vectors and pathogens [37]. The data of the present study demonstrated that the number of COVID-19 positive, recovered, and dead cases elevated due to the decrease of wind speed; studies on this element are scarce. Pani et al. founded that wind speed decrease was associated with an elevated incidence of COVID-19 [23]. Alkhowailed et al. also reported a significant reverse correlation between daily confirmed cases and wind speed [40]. Moreover, another study from Iran indicated that in provinces such as Golestan, Mazandaran, Gilan, and Tehran, where the wind speed was low, the outbreak rate of COVID-19 disease was much higher [9]. Research by Rendana revealed that wind speed was negatively correlated with the number of total cases of COVID-19 (new and dead cases) [32]. A significant negative correlation between confirmed cases and wind speed was reported when its speed

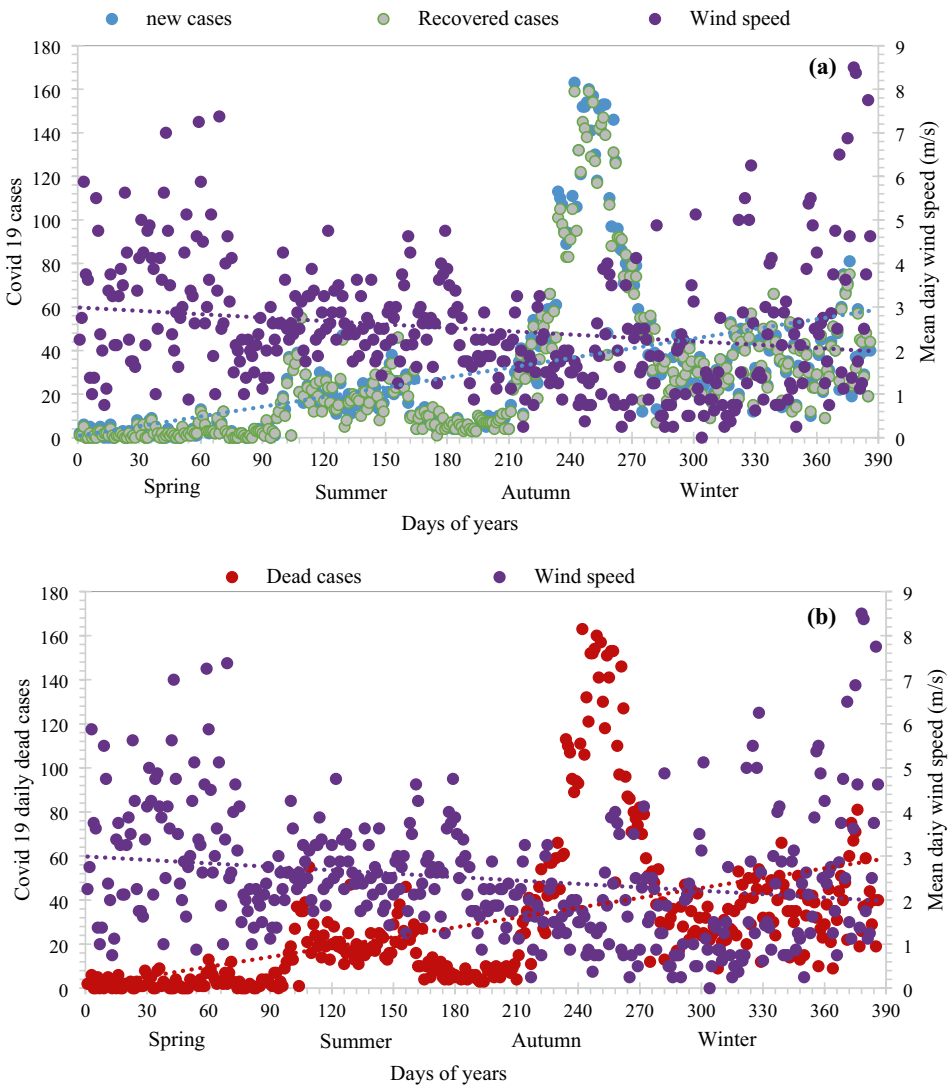

Fig. 4 Trend of COVID-19 daily new, recovered (**a**) and dead cases (**b**), and wind speed changes during the study period

was below 7 m/s in 127 countries [46]. These results are in line with those of the present research. However, the current study does not support the earlier researches reporting a significant positive association between wind speed and COVID-19 cases [38]. One of the main factors to explain the negative correlation between daily confirmed cases and wind speed is that the wind speed has the potential to spread suspended particles in the air, and higher wind speed results in less particle density and contamination [47]. Due to the small size of SARS-COV-2 (50–200 nm), it is transmitted via droplets and aerosols; Therefore, higher and stronger wind speed reduces the concentration of the SARS-COV-2 virus in the air, thus reducing the transmission potential of the virus [48].

In this study, daily average humidity was found to be positively but insignificantly related to daily new confirmed cases and daily recovered cases, while it was positively and significantly associated with daily dead cases. These results are in line with those of other studies, which reported no significant association between humidity and COVID-19 [24, 25, 38]. A significant positive correlation between the number of COVID-19 cases and relative humidity was reported in the US [33], China [6], and Saudi Arabia [40]. Experimental studies showed that viral inactivation could occur due to viral capsids accumulation at the air–water surface, leading to viral cell structural damage [40]. However, the studies from China [49] and Spain [50] found a significant negative relationship between humidity and COVID-19 incidence. Currently, the COVID-19 pandemic shows a non-stable trend in different areas of the world, and it is expanding rapidly; thus, the effect of meteorological factors, such as temperature, wind speared, and humidity, on COVID-19 is not enough to control it.

5 Conclusion

This project was undertaken to determine the association between weather elements and the number of COVID-19 cases in Rafsnjan, Iran. It indicated temperature and wind speed to be important factors affecting the COVID-19 infectivity. As the temperature and wind speed increased, the number of COVID-19 cases was decreased. Moreover, no significant association between humidity and COVID-19 incidence was found. Taken together, these results suggested that weather might be an important factor in determining the incidence rate of COVID-19. This study had few limitations: firstly, the number of daily confirmed cases was based on the results of PCR test, and also, patients infected by the SARS-COV-2 virus but did not go to health-care centers or hospitals were not reported. Secondly, the effect of important factors, including medical resources and government interventions, on the COVID-19 mortality were ignored; thus, future studies should focus on their effect. Finally, due to the effect of multiple factors such as medical resources and demographic variations on the spread of the virus, they should be analyzed in future researches. Also, this study data and results related to ambient air and therefore, indoor air needs to future studies for this relation.

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Declarations

Competing interests The authors have no conflicts of interest to declare that are relevant to the content of this article.

Ethics approval This work is the result of a research project (99254) with an ethics code IR.RUMS.REC.1399.264 approved by Rafsanjan University of Medical Sciences.

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