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Research Article

Impact of environmental factors on COVID-19 cases and mortalities in major cities of Pakistan

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ABSTRACT

Introduction: Climate factors play an important role in the transmission of viruses, such as influenza viruses, MERS-CoV, and SARS-CoV-1. This study aimed to determine the relationship between changes in temperature, humidity, rainfall, and SARS-CoV-2 contagion. Five ecologically and climatically distinct regions were considered—Karachi, Lahore, Islamabad, Peshawar, and Gilgit-Baltistan.

Method: Data on daily COVID-19 cases and deaths were retrieved from government officials, while meteorological information was collected from Pakistan Meteorological Department. Statistical analysis was performed using SPSS version 20 and the Spearman rank correlation test was used to analyze the correlation between the meteorological factors and COVID-19 cases and deaths.

Result: Positive correlation of COVID-19 incidence was observed with all the temperature ranges (maximum, minimum and average) and negative correlation was seen with humidity, DTR and rainfall. COVID-19 deaths were positively associated with temperature and were negatively associated only with humidity. Linear regression showed that for every unit increase in humidity, there was a −3.345 daily significant decrease in COVID-19 cases, while in Karachi for every unit increase in humidity, there remained a 10.104 daily significant increase in cases. In Gilgit-Baltistan, for every unit increase in average temperature and rainfall respectively, significant increases of 0.534 and 1.286 in daily cases were found.

Conclusion: This study signifies the effect of climate factors on COVID-19 incidence and mortality rate, but climate factors are not the only variable and several other interlinked factors enhance the spread of COVID-19. Hence, effective mitigation policies, enhancing testing capacities, and developing public attitudes toward adopting precautionary measures are important to overcome this overwhelming pandemic.

1. Introduction

The COVID-19 pandemic that started in late December 2019[1] is at its second peak and as of January 2021, the pandemic has seen 90,335,008 confirmed cases and 1,954,336 deaths globally.[2] The current outbreak of this coronavirus related respiratory infection is the third recorded overflow of an animal coronavirus to people in just two decades and has been recognized as a zoonotic coronavirus, like SARS-CoV-1 and MERS CoV.[3] Besides person-to-person transmission through direct, indirect, or aerosol contact, studies have revealed that environmental factors play a significant role in the transmission and survival of coronaviruses.[4,5] For instance, changes in temperature play a pivotal role in the transmission rate by influencing the stability of coronaviruses on surfaces.[6]

The coronavirus infection poses flu-like symptoms and is least likely to be transmissible in hot and humid environment.[6] Because of the familial relationship of COVID-19 with SARS-CoV-1 and other flu infections, health experts were of the opinion that higher temperatures in the coming seasons will limit the spread of COVID-19 since the breakdown of the lipid layer of the infectious agents happens at higher temperatures.[7] Since the emergence of COVID-19, numerous studies have centered their endeavors in understanding the influencing and transmission favoring factors of this infection.

These studies are inspired by past research on other viral infections, such as SARS CoV-1 and influenza. SARS is another type of coronavirus that showed up in 2002, and caused a pandemic accounting for 8000 cases in 26 countries.[8] A perceptible relationship was noted between the SARS cases and the ecological temper-

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ature[9] as SARS transmission appeared to be reliant on temperature changes, i.e. positive co-relation was observed between low temperature and low humidity on the stability of SARS-CoV-1.[10] SARS-CoV-1 has been found to remain viable for up to 5 days at 22 to 25 °C and its stability lessens as there is an increase in temperature and humidity,[11] Similar findings were observed in the case of MERS-CoV.[12]

MERS-CoV is the second most significant zoonotic virus of the coronavirus family that showed its presence in 2012, with more than 1000 confirmed cases across 27 countries. MERS-CoV shared the same stability features as SARS-CoV-1, with more pronounced stability at low temperature and humidity and significant loss of steadiness as temperature and humidity rises.[12] It has previously been suggested that climatic conditions (temperature, humidity, and diurnal temperature range) and populace density may have influenced the spread and broadening of influenza viruses.[13] Hence, it would not be surprising to seek a relationship between COVID-19 and climatic variables.

Some investigations have exhibited that there is a relationship between meteorological variables, for example, temperature and humidity, and the transmission of COVID-19.[5] Some of these studies have demonstrated a noteworthy positive relation between diurnal temperature range (DTR) and the day wise mortality of COVID-19[14] and a critical negative relationship between COVID-19 mortality and temperature and absolute humidity.[14] Another study demonstrated that only average temperature effects corresponded with COVID-19.[15] However, studies have also demonstrated that temperature and humidity are not strongly associated with the transmission of COVID-19.[16] This logical inconsistency indicates a requirement for additional investigation on this matter. Hence five environmentally distinct cities were chosen to probe any association between climate changes and COVID-19 spread.

Islamabad has a muggy subtropical atmosphere, while the climate of Karachi is dominated by a hot and humid summer season, moderated by cool sea breezes from the Arabian Sea. Peshawar has a semi-arid climate with low precipitation throughout the year. Lahore faces a semi-dry climate, while the atmosphere of Gilgit-Baltistan varies considerably, as it encompasses mountain ranges that cause sharp variations in climate. The eastern part has the damp zone of the Western Himalayas but going towards Karakoram and Hindu Kush, the atmosphere becomes significantly drier.

2. Methodology

A retrospective data analysis was performed at the National Institute of Health (NIH), Islamabad, from February 26 to July 31, 2020. The line list of confirmed cases was retrieved from the provincial and national COVID-19 data repository. This study period was considered because the first case was reported on February 26 and Pakistan witnessed the first peak of COVID-19 cases during the months of June-July 2020. Data were gathered from the COVID-19 Health Advisory Platform by the Ministry of National Health Services Regulation and Coordination.

Daily meteorological data, including the maximum, minimum, and average temperature, humidity, and rainfall of each city were obtained from the Pakistan Meteorological Department.

The Institutional Review Board of the NIH was approached for ethical approval of the study. No human participants were involved and departmental permission was sought from every province.

Data were compiled using Microsoft Excel, and all identities were removed before analysis. The impact of meteorological factors on COVID-19 cases and deaths was analyzed and the Spearman rank correlation test was used to check this correlation. A linear regression model was used to validate the association between COVID-19 incidence, mortality, and climatic factors. SPSS version 20 was used for all analyses, with a P value less than 0.05 considered as significant.

3. Result

Data analysis revealed that Lahore had the highest average temperature (33.99 °C), while Gilgit-Baltistan showed the lowest (1.868 °C). Karachi recorded the highest mean value of humidity 61.47%, while the rainfall trend remained fluctuating in all the cities with the highest mean value of 3.481 mm in Islamabad during the defined study period (Table 1, Fig. 3).

Daily confirmed COVID-19 cases are shown in Fig. 1, with Karachi and Gilgit Baltistan having the highest and lowest incidence of COVID-19 cases, respectively. The highest number of cases was observed in June 2019 in all the cities included in the study, with the highest daily confirmed deaths being reported in Karachi. (Fig. 2.)

The Spearman rank correlation test was used to check the correlation between daily cases, deaths, and meteorological factors (Table 2).

The daily confirmed cases from all the cities manifested a positive correlation with the maximum, minimum, and average temperatures. Humidity was negatively correlated in almost all cities except Karachi, where it had a positive impact on the number of new cases. A negative association between rainfall and COVID-19 cases was found only in Islamabad and Peshawar. The diurnal temperature range (DTR) was negatively correlated with COVID-19 cases in Lahore and Karachi, while DTR showed a positive impact in Gilgit Baltistan. Tables 2 and 3 show the Spearman correlation coefficients between the total daily cases, deaths, and meteorological factors.

The impact of meteorological factors on mortality rate demonstrated a positive relationship with the maximum, minimum, and average temperatures, while it remained negatively linked to humidity in all the studied cities. Lahore and Peshawar remained the only cities to show a positive correlation with the diurnal temperature range (DTR), while rainfall was the only meteorological factor that showed no significant effect on the COVID-19 mortality rate.

The linear regression analysis between the climate variables and COVID-19 cases revealed that in Islamabad, for every unit increase in humidity, there was a −3.345 daily significant decrease in COVID-19 cases and −0.036 decrease in mortality rate, while in Karachi for every unit increase in humidity, there remained a 10.104 daily significant increase in cases. In Gilgit-Baltistan, for every unit increase in average temperature and rainfall, a significant increase of 0.534 and 1.286 in daily cases was found, while all the other variables remained constant. Statistical significance was set at $p < 0.05$ (Table 4). R-values showed a moderate correlation. Due to the multiple data points, R-squared values showed less variation in the case of COVID-19 incidence in Islamabad, while 45% variation was seen in Karachi COVID-19 cases and 42% in Gilgit-Baltistan COVID-19 cases (Table 5).

4. Discussion

Pakistan lies in a temperate zone and enjoys an immense variety of atmospheric conditions across the country. Recently, Ali Raza and his colleagues investigated the correlation between meteorological factors and incidence rates among provinces in Pakistan and found a positive association between these variables.[17] In our study, we found an association between the COVID-19 incidence, mortality rates and meteorological factors

Table 1
Description of the daily confirmed COVID-19 cases, daily mortality and the meteorological factors.

Cities	Max-T	Min-T	Avg	Rainfall	Humidity	DTR	Cases	Deaths
Islamabad	33.08	23.14	28.108	3.481	42.14%	9.99	15,038	167
Lahore	39.65	28.55	33.99	0.17	32.16%	11.1	47,322	781
Karachi	33.65	26.09	29.86	0.103	61.47%	7.56	88,543	2376
Peshawar	36.62	26.58	31.57	0.35	60.23%	10.03	12,825	572
Gilgit Baltistan	4.84	−4.01	1.869	0.928	51.71%	−0.03	2125	53

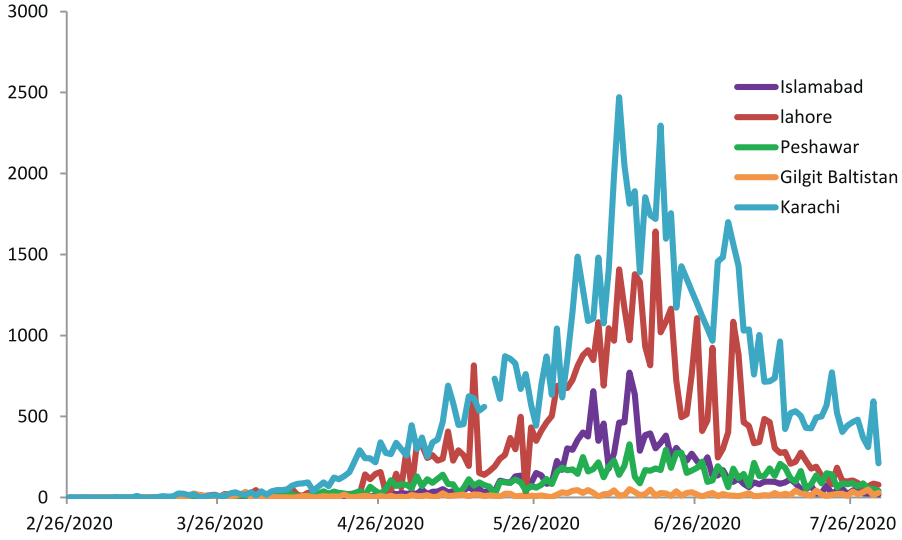

Fig. 1. Daily confirmed COVID-19 cases in Islamabad, Lahore, Karachi, Peshawar and Gilgit-Baltistan.

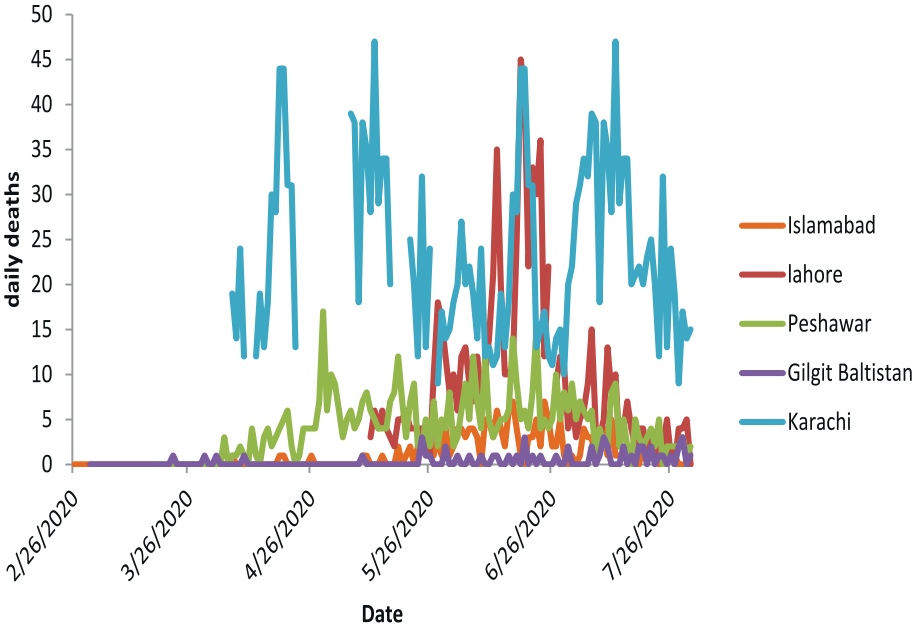

Fig. 2. Daily confirmed COVID-19 deaths in Islamabad, Lahore, Karachi, Peshawar, and Gilgit-Baltistan.

among major cities in Pakistan. The cities selected for the study represent provincial capitals and reported the highest number of COVID-19 cases in Pakistan. Islamabad is the capital of Pakistan while Karachi, Lahore, Peshawar are the capitals of the Sindh, Punjab and Khyber-Pakhtunkhawa provinces respectively. Hence these cities contributed the major bulk bkunkof COVID-19 cases and deaths in Pakistan. Therefore, the daily environmental data of these cities were used to relate with new COVID-19 cases and deaths to find any possible positive or negative association between them.

As per the findings of our study, a positive relationship between temperature and new cases of COVID-19 was observed in all the cities, which was consistent with similar findings in researches conducted in the Middle East Region[18] and India.[19] India reported

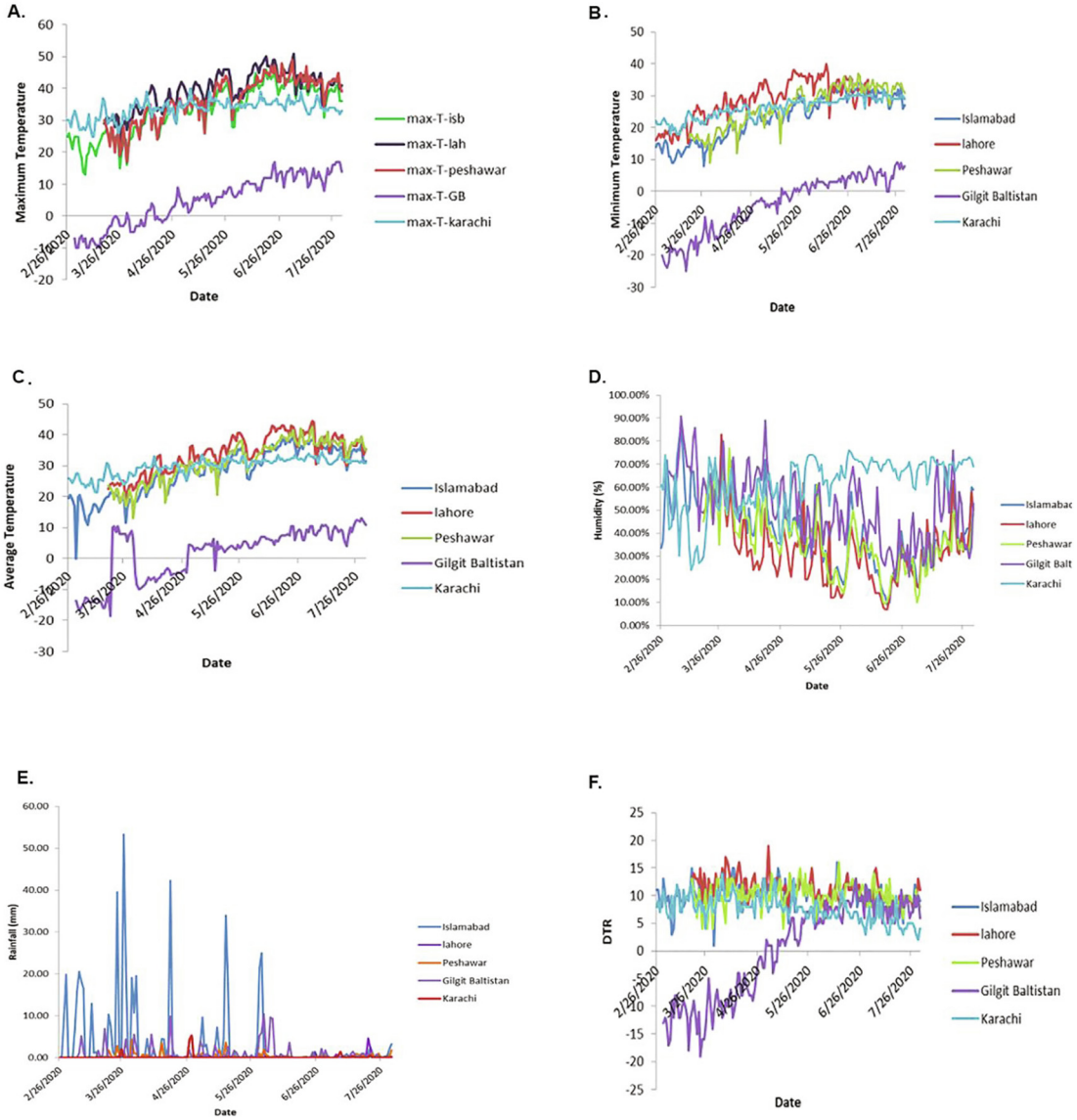

Fig. 3. Meteorological variables variation among all the studied cities A) Maximum temperature B) Minimum temperature C) Average temperature D) Humidity E) Rainfall F) DTR.

Table 2
Spearman correlation coefficient of COVID-19 confirmed cases and meteorological factors.

	Cities	Maximum Temperature	Minimum temperature	Average Temperature	DTR	Humidity	Rainfall
Spearman correlation coefficient	Lahore	0.74*	0.76*	0.77*	−0.3*	−0.57*	0.03
	Peshawar	0.69*	0.71*	0.71*	0.09	−0.57*	-0.05
	Karachi	0.62**	0.79**	0.80**	-0.40**	0.59**	0.124
	Islamabad	0.83*	0.83**	0.84*	0.03	-0.72**	-0.26*
	Gilgit-Baltistan	0.66*	0.66*	0.66*	0.61*	-0.42*	0.081

** significance level < 0.01.
*significance level < 0.05.

a similar increase in COVID-19 incidence in the summer season, and this depicta that the virus is temperature independent.[20,21] Sahoo et al. reported that the earllier phase of the COVID-19 outbreak in colder regions could have been mere coincidence considering the findings of multiple other studies that reported the positive correlation between temperature and increase in COVID-19 cases.[22] However, on the other way round, a negative correlation was sought between temperature variations and COVID-19 case growth rate in studies conducted in China[23] and Bangladesh.[24] similar to the observations of a study that additionally explained human mobility as an intermediate variable between high temperature and COVID-19 transmission.[25]

As per the results of our study, a positive association was observed between temperature and COVID-19 mortality rate, con-

Table 3
Spearman correlation coefficient of COVID-19 deaths and meteorological factors.

	Cities	Maximum Temperature	Minimum Temperature	Average Temperature	DTR	Humidity
Spearman correlation coefficient	Lahore	0.381**	0.278*	0.33**	0.259**	−0.353**
	Peshawar	0.43**	0.44**	0.443**	0.090	−0.498**
	Karachi	0.042	−0.070	−0.005	0.079	0.107
	Islamabad	0.607**	0.647**	0.631**	−0.124	−0.557**
	Gilgit-Baltistan	0.418**	0.418**	0.399**	0.379**	−0.226**

** significance level < 0.01.
*significance level < 0.05.

Table 4
Multivariate Linear Regression.

Cities	Climate variables	Regression coefficient (β)	SE	t-value	p-value
Islamabad cases	Humidity	−3.345	1.327	−2.521	0.013*
Islamabad deaths	Humidity	−0.036	0.015	−2.324	0.02*
Karachi cases	humidity	10.104	3.97	2.545	0.012*
Gilgit-Baltistan cases	average temperature	0.534	0.187	2.861	0.005*
	Rainfall	1.286	0.471	2.731	0.007*

*significance level < 0.05.

Table 5
R-squared results.

Model	R	R- square	Adjusted R-square
Islamabad	0.573	0.329	0.311
Karachi	0.67	0.449	0.431
Gilgit-Baltistan	0.647	0.419	0.395

sistent with the findings of research conducted in Bangladesh[18] and India[19]; however, another recent study revealed a negative correlation between high temperature and COVID-19 deaths, a finding observed in nine of the most COVID-19 infected cities worldwide.[26]

Furthermore, the results of our study found a negative correlation between COVID-19 daily cases and DTR in Lahore and Karachi, while the effects of DTR on COVID-19 mortality rate remain positively linked in the case of Lahore and Gilgit-Baltistan. These findings are similar to those of previous studies conducted in China.[5,14]

Similar to other research ,[27] our study revealed an inverse effect of humidity on COVID-19 daily cases except in Karachi, where a positive relationship between humidity and COVID-19 cases was found, and this unique finding goes consitent to the result of a study conducted in the U.S.[28] While an inverse impact of humidity was revealed with mortality rate in all of our studied cities, which supports the results of previous studies.[5,14]

Although contrary findings have been observed in various studies on temperature, humidity, and COVID-19 correlation, the impact of precipitation on COVID-19 incidence has remained null. While the study conducted by Ali Raza showed insignificant regression coefficients between COVID-19 cases and rainfall in Pakistan,[17] our study found a negative correlation between COVID-19 cases and rainfall in Islamabad (Table 2). Rainfall did not show any specific trend during the study period; therefore, linear regression indicated a weak correlation between rainfall and the incidence of COVID-19 in Gilgit-Baltistan (Fig. 4).

Our findings indicate that high temperatures did not suppress COVID-19 cases. This is surprising because coronaviruses are normally cold-loving viruses. One possible explanation for this unusual behavior could be its irresistible nature, unlike the other viruses that could not survive under hot conditions.[29] One study demonstrated that SARS-CoV-2 can survive from a few hours to days in aerosols and on surfaces, that is, in aerosol for up to 3 h, up to 4 h on copper, up to 24 h on cardboard, and up to 2–3 days on plastic and stainless steel.[30] These outcomes provide considerable information about the stability of this strain and propose that individuals may be infected by direct or indirect means, and individuals who remain asymptomatic can likewise spread the disease.[31] Hence, the spread of this coronavirus, quicker than its two predecessors SARS-CoV and MERS-CoV,[32] is most likely due to the high transmission rate posed by asymptomatic carriers. Another reason could be the negligence in procuring precautionary measures due to the ease of lockdown strategies during the study period. Although environmental factors were found to be associated with the surge of COVID-19 cases and mortality in our study, various other factors would have played a significant role in the expansion of COVID-19 cases as well, such as the ease of the lockdown, easy attitude of the people, and failure to abide by standard operating procedures (SOPs) in work and crowded places. The government called off the lockdown on May 9, 2020 and this was followed the peak in COVID-19 cases in Pakistan. This could be explained by the overwhelming crowding that took place in the markets for the upcoming event of Eid-ul-fitar (Muslim festival) once the lockdown ended. Nevertheless, the containment of this rapid surge of COVID-19 cases was successfully managed by implementing Smart Lockdown across the country, posing restrictions in areas with a higher number of cases and establishing quarantine facilities for international travelers (importation containment).

5. Limitations

This study can help policymakers understand the spread of COVID-19 and its relationship with meteorological variables. However, the study may have a few limitations. First, a large number of asymptomatic positive unknown cases in the community are another influencing factor that can change the result significantly in terms of the metrological influence on COVID-19. In addition, the restricted day-to-day testing limit may impact the quantity of confirmed new cases.

6. Conclusion

The positive correlation of temperature with the COVID-19 cases in the studied cities and the observance of the highest peak of cases in the month of July signifies the resistible and adapting

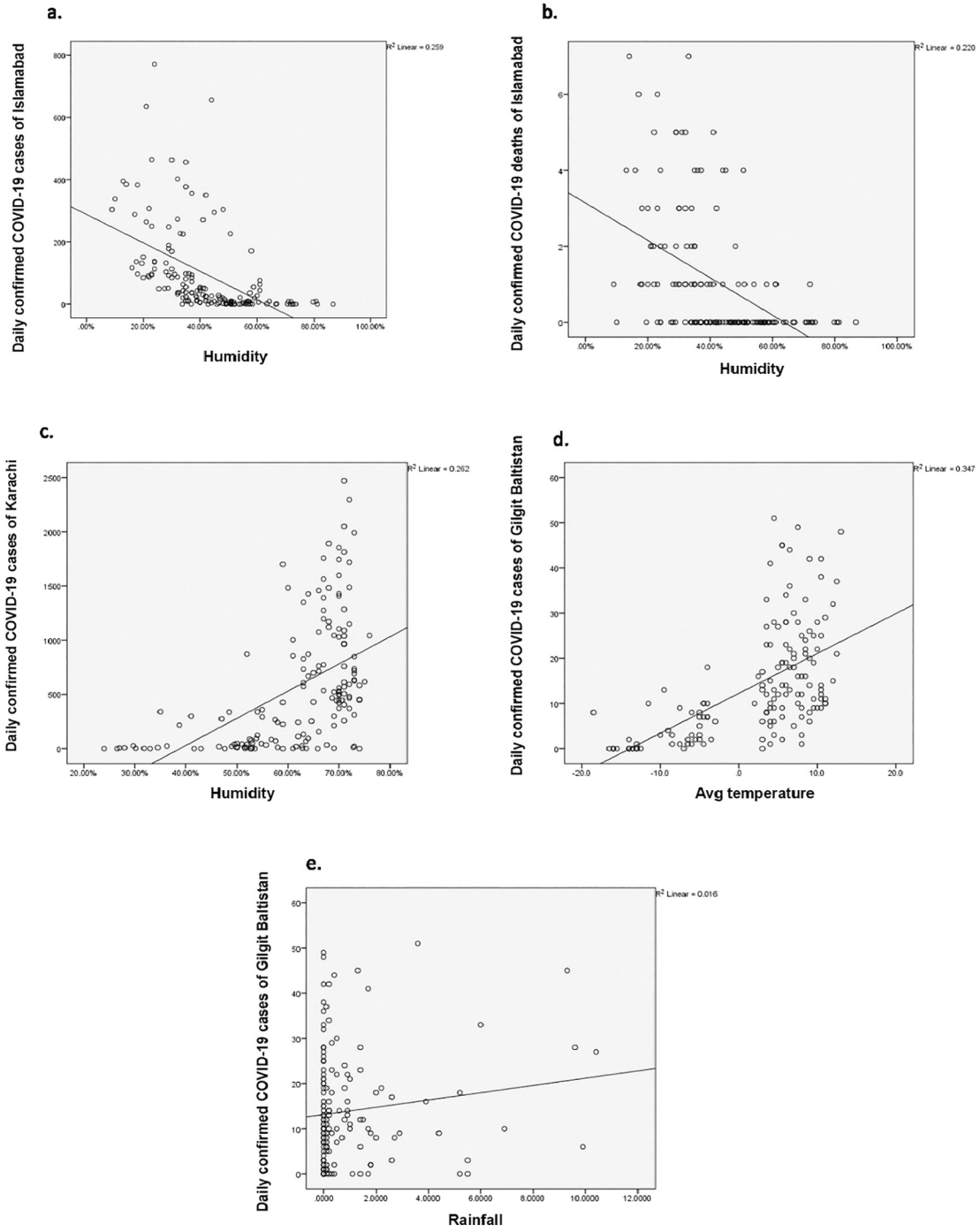

Fig. 4. Association of daily confirmed a) COVID-19 cases in Islamabad with humidity b) COVID-19 deaths in Islamabad with humidity c) COVID-19 cases in Karachi with humidity d) COVID-19 cases in Gilgit-Baltistan with average temperature e) rainfall.

nature of the SARS-COV-2. However, climatic factors are not independent variables. Several other contributing factors are interlinked to create a favorable environment for SARS-CoV-2 to flourish and produce devastating effects on the masses. Mitigation policies, testing capacities, and public attitudes toward adopting precautionary measures may also affect the spread of this virus. Hence, active measures must be adopted to halt the infection, block its transmission, and prevent further proliferation of COVID-19. Therefore, there is still a dire need for the strict implementation of standard operating procedures (SOPs), as recommended by the World Health Organization (WHO), in Pakistan.

Conflict of interest

The authors declare no conflicts of interest.

CRediT authorship contribution statement

Rabia Basray: Conceptualization, Methodology, Investigation, Writing - original draft. **Amber Malik:** Formal analysis, Investigation, Visualization. **Wajiha Waqar:** Investigation, Writing - original draft. **Ambreen Chaudhry:** Writing - review & editing, Supervision.

Muhammad Wasif Malik: Supervision. **Mumtaz Ali Khan:** Supervision. **Jamil A. Ansari:** Resources, Writing - review & editing, Supervision. **Aamir Ikram:** Supervision.

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