

Will weather stem the spread of the COVID-19 in Pakistan?

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Abstract. The pandemic of COVID-19 started spreading more exponentially across Pakistan since the end of February 2020. Numerous models and factors have been used to estimate predictions of the prevalence and severity of COVID-19 infections around the globe. While many factors play a role in the spread of COVID-19, climate and weather conditions are considered key elements in the transmission of COVID-19. Many researchers believe that recent increases in COVID-19 cases correlate strongly with local temperatures and factors (such as humidity, weather conditions, etc.) related to it. In this manuscript we test the hypothesis that SARS-CoV-2 spread is temperature-dependent by using the available data derived from Pakistan. The present review focuses on the relationship between temperature and COVID-19, examining the virus's viability and infectivity under various conditions. Our findings indicate that the trough and crest of the COVID-19 wave observed in 2020 are likely to repeat in the summer and winter of 2021, respectively. In Pakistan, temperatures, and humidity significantly affect the COVID-19 transmission and incidence. Like other types of beta-coronaviruses (β -CoVs), the spread of COVID-19 may depend upon a great deal on temperature.

Key Words:

COVID-19, Incidence, Climate, Temperature, Humidity.

Introduction

The public health sector and the global economy are facing the challenges of the third major epidemic of Coronavirus (CoV) due to the outbreak of Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) since December 2019. Coro-

naviruses are positive-sense single-strand RNA viruses that infect both humans and animals¹. Early viruses in this family, such as human coronavirus (HCoV)-229E, HCoV-NL63, HCoV-OC43, and HCoV-HKU1, are usually known to cause the common cold or mild-to-moderate upper respiratory tract infections; however, three newly emerged viruses (SARS-CoV, SARS-CoV-2, and MERS-CoV) can be lethal²⁻⁵. In addition, SARS-CoV and MERS-CoV led to widespread epidemics, and SARS-CoV-2 emerged as a pandemic (Table I). The outbreak of SARS-CoV-2 was initially reported from Wuhan, Hubei Province, China. The World Health Organization (WHO) declared the Coronavirus Disease-2019 (COVID-19) a pandemic in March 2020⁶⁻⁸. SARS-CoV-2 has spread globally, rapidly, and more effectively than its predecessor (SARS-CoV). The first confirmed case of COVID-19 in Pakistan was reported on February 26th, 2020. Since then, SARS-CoV-2 has spread exponentially, with 1.19+ million laboratory-confirmed cases and 26k+ deaths throughout the country (as of September 8, 2021).

The transmission dynamics of the SARS-CoV-2 depend upon environmental factors⁹, including climate and humidity¹⁰⁻¹². Recent research focuses on the role of temperature on the transmission of SARS-CoV-2, but still, the association of weather conditions and SARS-CoV-2 is unclear¹³. Many studies^{9,14-16} observe that higher temperature and humidity significantly reduces COVID-19 transmission and viability, similar to the influenza virus. Few other preprint studies also confirmed that higher temperature is not suitable for COVID-19 transmission¹⁷⁻¹⁹. The studies demonstrated that sunlight inactivates SARS-CoV-2 on surfaces^{20,21}, favoring the condition that higher temperature reduces virus transmission.

Table 1. Characteristics of SARS-CoV, MERS-CoV and SARS-CoV-2.

SARS-CoV	MERS-CoV	SARS-CoV-2	
<i>Year Identified</i>	2002	2012	2019
<i>Country of Origin</i>	China	Saudi Arabia	China
<i>Transmission</i>	Droplet and direct contact	Severe course in patients	Most commonly fever, dry
<i>Clinical Features</i>	Most commonly fever and systemic manifestations like myalgia, chills, or fatigue	with co-morbidities such as renal failure and starts with cough and dyspnea	cough, and fatigue but other symptoms were relatively rare.
<i>Confirmed cases in world</i>	8096	2574 cases (as of March 2021)	200,457,413 (as of August 4, 2021)
<i>Confirmed cases in Pakistan</i>	–	–	1,047,999 (as of August 4, 2021)
<i>Deaths reported worldwide</i>	774	885	4,263,298 (as of August 4, 2021)
<i>Deaths reported from Pakistan</i>	–	–	23,575 (as of August 4, 2021)
<i>Fatality Rate worldwide</i>	9.6%	34.5%	15.4%
<i>Fatality rate in Pakistan</i>	–	–	2.04

The findings of Biryukov et al²² are also in agreement with previous studies^{20,21} suggesting that increasing temperature and relative humidity inactivates SARS-CoV-2 on surfaces. Some authors^{23,24} also suggest that warmer weather or climates do not decrease the transmission of COVID-19. By contrast, few studies suggested that temperature does not affect the incidence of COVID-19^{25,26} but might be affected by relative or absolute humidity²⁶. In addition, Huang et al²⁷ reported that absolute humidity from 3 g/m³ to 103 g/m³ is a favorable condition for COVID-19 spread. Thus, these findings prompt the search for understanding the environmental role in COVID-19 transmission. This paper aims to determine the contribution of temperature and suitable conditions of SARS-CoV-2 transmissibility, thus reducing virus transmission in Pakistan. In considering this, we should keep in mind that numerous additional factors can change with fluctuations in temperature, including the suitability of the virus to different conditions and humans' intrinsic susceptibility to the virus.

Viability of the Virus Under Different Meteorological Conditions

Both SARS-CoV and SARS-CoV-2 first emerged in China during the coldest months (November/December)²⁸. It is likely because viruses generally remain infective longer in cold and dry conditions^{11,28,29}. In addition, 60% of cases of COVID-19 reported from the areas having temperatures 5-15°C²⁷. Influenza, similarly, usually spreads faster in cold and dry weather. The air is generally cold and dry throughout the winter, cre-

ating ideal conditions for influenza transmission³⁰ or viruses causing respiratory illness. However, possibly coronavirus transmission is not affected by the environment²⁵. While the spread of SARS-CoV-2 may be more efficient during the cold seasons³¹, this does not mean it will not spread in late spring. If this is the case, only modest reductions in transmission can be expected in spring¹¹.

Influenza spreads more effectively as temperature and humidity decrease^{30,32}. Some researchers have concluded that like most other viruses, such as influenza, the transmission of coronaviruses also peaks in winter^{14,15}. Huang et al²⁷ observed that low temperature, ranging between 5 to 15°C, facilitates the COVID-19 incidence. Xie et al²³ found a positive correlation between temperature and COVID-19 transmission below 3°C. On the other hand, some suggest that these viruses are not associated with warmth and become inactive when exposed to UV light²⁰. Recently, He et al³² used protein-protein docking and a molecular simulation model to show that the spike proteins in SARS-CoV and SARS-CoV-2 interact with the ACE2 receptor binding protein in human cells. This study suggests that SARS-CoV-2 is more likely to thrive at high temperatures than SARS-CoV. The study also found that SARS-CoV-2 has a greater binding affinity with ACE2 than SARS-CoV and that this affinity decreases as temperature increases³². Therefore, temperature increases may decrease the infectivity of the virus, meaning that the spread will increase in winter. It means that summer and the rainy season will bring reduced transmission of COVID-19¹⁴. SARS-CoV viability can be rapidly lost at higher

temperatures (56°C) and higher relative humidity¹¹. However, it is unclear at what temperatures SARS-CoV-2 can survive. Furthermore, even if transmission increases in summer, the virus may survive, and transmissibility may increase once the weather becomes colder. However, historically, changes in seasons have not stopped the spread of SARS viruses. The primary methods of controlling the spread are public health interventions, such as isolation, social distancing, and quarantine^{33,34}.

Effects of Temperature and Humidity on COVID-19 Incidence in Pakistan

As of September 8th, 2021, Pakistan has reported a total of 1,190,136 cases of COVID-19 (Figure 1A) and 26,413 deaths. The highest number of cases are reported from Sindh (440,164) and Punjab (406,960). The Sindh reported a higher mean temperature of about 32.52°C followed by 28.9°C in Punjab. Sindh had the highest average humidity (65.13%), followed by Kashmir (56.30%), Khyber Pakhtunkhwa (KPK) (39.10%), Punjab (36.45%), and Baluchistan (32.29%)³⁵⁻³⁹. Despite the high temperatures and relative humidity in these provinces, they have seen more cases than cooler regions (KPK and Baluchistan). However, Sindh and Punjab have denser populations than KPK and Baluchistan. The various studies show the positive association between COVID-19 incidence and population density^{40,41}. Thus, the high population density in Karachi and Lahore might offer an opening to COVID-19.

A study on Islamabad conducted from May 1, 2020, to June 15, 2020, determined a significant relationship between temperature (minimum and average) and COVID-19 incidence. But no correlation of humidity and rainfall with COVID-19 was observed³⁶. Another study also based in Islamabad was conducted on COVID-19 cases and weather data from 1 February to 30 July 2020. They found a positive correlation between maximum and average temperature and COVID-19 incidence, whereas a negative correlation with precipitation and COVID-19³⁷. The difference in results of Rehman et al³⁶ and Aslam et al³⁷ might be due to that Rehman et al³⁶ have not included February, March, April, and July. Moreover, during the period of the conducted studies, the temperature was rising, and the virus have not experienced the winter at that time in Pakistan. However, the results of Aslam et al³⁷ were similar to the study carried out in Oslo (Norway) by Menebo et al³⁸ that found that maximum and normal

temperature positively correlates with COVID-19 and that precipitation was negatively correlated. The correlation of rainfall and COVID-19 was also found negative³⁵. Tosepu et al⁴² also reported that average temperature is positively correlated with COVID-19 in Indonesia. Another study from Indonesia also showed a positive correlation of COVID-19 with average temperature, average humidity, and average sunlight⁴³. Moreover, SARS-CoV-2 may also last for a short period in some regions. Wang et al⁴⁴ suggested that the summer season may diminish the COVID-19 transmission. In India, a negative relationship between COVID-19 and maximum temperature was observed⁴⁴. But in Pakistan, the peak in confirmed COVID-19 cases was noticed in June 2020 (the month of summer) when temperatures range between 31-40°C. On 14th June 2020, when the temperature was about 38°C, the highest number of confirmed cases (6,825) were reported. In 2021, the highest one-day confirmed COVID-19 cases (6,127) report on April 17th, 2021, when the temperature was 25°C. However, in months of winter (November-January), the highest number of COVID-19 cases (3,795) report on December 6th, 2021 (Figure 1A). Sindh and Punjab (high-temperature) have a higher number of COVID-19 cases in Pakistan. These findings are consistent with Raza et al³⁵ and Fawad et al⁴⁵ demonstrating that an increase in temperature increases COVID-19 transmission in Pakistan. Fawad et al⁴⁵ also reported that higher temperatures and harsh environment increases COVID-19 death rate, compared to lower average temperature, dew point, and humidity, as in Baluchistan. Similarly, Basray et al⁴⁶ reported that all temperature ranges (minimum, average, maximum) have a positive association with COVID-19 deaths. Although humidity, diurnal temperature range, and rainfall have a negative association. Bu et al⁴⁷ reported that temperature ranges between 13-19°C are optimal for COVID-19. Moreover, Irfan et al⁴⁸ conducted a study on Pakistan provinces from 17 June 2020 to 31 December 2020 to examine the association of temperature and COVID-19. The authors determined that low temperatures are associated with higher COVID-19 incidence. Irfan et al⁴⁸ utilize various computational approaches and incidence models, concluding that in Gilgit Baltistan, Baluchistan, and KPK, when temperature decreases, the COVID-19, daily cases, increase. Though, Punjab and Sindh show the least prominent correlation of COVID-19 transmission with temperature.

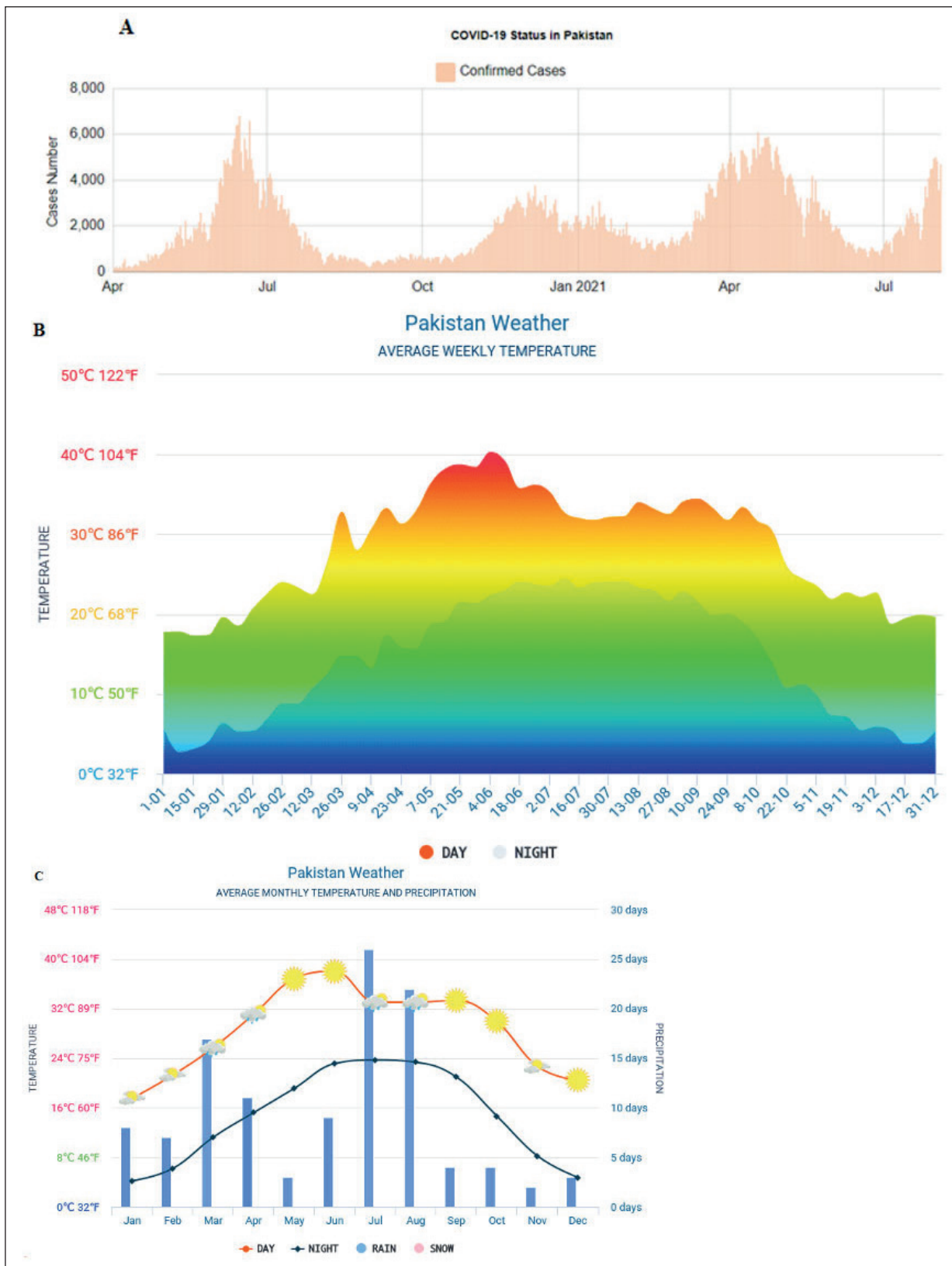


Figure 1. A, The weekly confirmed COVID-19 cases in Pakistan (<https://covid.gov.pk/>). B, Predicted climatological information based on weekly averages in Pakistan. C, Predicted climatological information based on monthly averages in Pakistan (<http://hikersbay.com/climate/pakistan?lang=en>).

Khan⁴⁹ opined that poor air quality facilitates COVID-19 transmissibility in the major cities of Pakistan, i.e., Quetta, Karachi, Lahore, Peshawar, and Islamabad. However, Rehman³⁹ concluded no correlation between environmental factors (temperature, sun exposure, humidity, wind, etc.) and COVID-19 incidence. But the lower temperature was associated with a significantly higher recovery rate in Baluchistan³⁹. A report from India also suggested that temperature and humidity influence COVID-19. However, this association was inconsistent across the nation⁵⁰. In Pakistan, not even high temperatures (Figure 1B-C) have been able to stop the spread of the virus. Similarly, a report from Bangladesh also suggests that the summer season is unlikely to reduce COVID-19 transmission¹⁶. Furthermore, a study found that the incidence of COVID-19 cases and deaths decreases in warmest countries (i.e., with high temperature and low humidity), including Pakistan, compared to coldest countries (low temperature and high humidity)⁵¹. A study from China reported that temperature and humidity have a negative correlation with COVID-19. The authors also revealed that countries with high temperatures and low humidity (warm countries) have a decrease in daily cases and deaths caused by COVID-19⁵². Both Meo et al²² and Qi et al⁵² have the same conclusion that warm countries have a significant decrease in daily incidence and deaths. Lin et al⁵³ study the association of temperature and humidity with COVID-19. They found that high temperature reduces COVID-19 transmission, whereas high humidity and low temperature increase COVID-19 incidence. Also, high humidity with high temperature negatively correlates with SARS-CoV-2⁵³. Shahzad et al⁵⁴ reported that in Spain, the increasing temperature decreases COVID-19 spread. However, another study from China reported a positive association of diurnal temperature range and a negative association of humidity with COVID-19 deaths. They found that an increase in diurnal temperature increases COVID-19 deaths, and an increase in humidity decreases COVID-19 deaths⁵⁵. Similarly, another study on Gulf Corporation Countries in Middle East Region by Meo et al⁵⁶ found that increase in humidity decreases COVID-19 cases and deaths. Another report from Africa by Meo et al⁵⁷ also concluded that increase in humidity and temperature is associated with a decrease in COVID-19 cases and deaths. Results from Africa⁵⁷ were also similar to Ma et al⁵⁵.

We believe that the meteorological parameters are considerably associated with COVID-19 incidence, affecting the number of COVID-19 daily

cases and deaths. Many studies suggest that both conditions (weather and atmosphere) may play a role³⁷, but this is not yet certain. Five studies from Pakistan^{35-37,45,46} determined the positive relation of temperature with COVID-19 transmissibility, two studies^{48,51} found a negative correlation, and one study³⁹ reported no association. There are still many uncertainties about the relationship of the transmission of coronaviruses with temperature change. However, many other factors also influence the spread of the virus (SARS-CoV-2), including population density, population mobility, testing facilities, humans' intrinsic susceptibility to the virus, herd immunity, practices of preventive measures, etc. Furthermore, the review might serve as input for policymakers to make strategies to cope with COVID-19 by observing environmental factors.

Conclusions

Research on the newly emerged virus, SARS-CoV-2, is still in an early phase. Recent studies on SARS-CoV-2 have shown that the infectivity and transmission of these viruses decrease in summer and increase in winter. Analogies to influenza pandemics also suggest that SARS-CoV-2 will spread more effectively in winter. However, some studies also concluded that temperature doesn't affect the spread of COVID-19. This study has observed that in Pakistan temperature and humidity significantly influence the COVID-19 transmission. However, preventive measures such as face masks, social distancing, and eating a healthy diet can control the spread of the virus.

Funding

The authors have not received any funding or benefits from the industry or elsewhere to conduct this study.

Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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