RESEARCH ARTICLE

ASSOCIATION BETWEEN TEMPERATURE AND HUMIDITY WITH COVID-19 DAILY POSITIVE CASES IN UJJAIN, INDIA

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ABSTRACT

Background: The COVID-19 pandemic has prompted extensive research into the factors influencing its transmission, with climatic variables such as temperature and humidity being of particular interest. **Aims:** This study aims to explore the relationship between mean temperature, humidity, and daily COVID-19 positive cases in central India. **Methods and Material:** A total of 24,355 confirmed cases were analyzed from March 23, 2020, to February 28, 2022. Spearman's rank correlation test and multiple linear regression were used to examine the relationship between daily COVID-19 positive, recovered, and death cases with average daily temperature (°C) and average daily humidity (%). **Results:** The study revealed that for every unit increase in mean humidity, there was a 1.63-unit decrease in daily positive COVID-19 cases, holding all other variables constant (p<0.001). A similar pattern was observed with daily recovered cases, where a unit increase in mean humidity resulted in a 1.42-unit decrease in recovered cases (p<0.001). There was no correlation between mean temperature and daily positive cases. However, a unit increase in average temperature was associated with a 0.02-unit increase in daily death cases (p<0.001). Additionally, each unit increase in average humidity was linked to a 0.01-unit decrease in daily death cases (p<0.001). **Conclusions:** The study shows that increased mean humidity is linked to decreases in positive COVID-19 cases and death rates, suggesting its role in reducing viral transmission. While mean temperature showed no correlation with positive cases, it was unexpectedly associated with a slight increase in daily death cases. These findings emphasize the need to consider climatic factors in public health strategies for managing COVID-19

INTRODUCTION

Coronavirus disease 2019 (COVID-19) has become a serious public health issue globally. The COVID-19 pandemic began in Asia in Wuhan, China and has spread widely through the continent (1). From early January to March 2020, SARS-CoV-2 quickly spread around the world, causing a global pandemic (2). Globally Covid-19 cases reported 505 million (505,817,953) cases and 6 million (6,213,876) death are reported (3). The COVID-19 pandemic in India is a part of the worldwide pandemic of coronavirus disease 2019 (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).

As per the latest WHO data India reports the highest number of cumulative positive COVID-19 cases in south east Asia is present in India which is second highest in the world followed by United States of America (USA) and the third-highest number of COVID-19 deaths (after the USA and Brazil) at 523,622 deaths (3). The first case of COVID-19 was reported in India on January 30, 2020 with origin from China (4). It spreads to the maximum districts of the country. On March 24 2020, the Government of India ordered a nationwide lockdown for 21 days, limiting movement of the entire 1.3 billion population of India as a preventive measure against the 2020 coronavirus pandemic in India. It was ordered after a 14 hours voluntary public curfew on March 2022, followed by enforcement of a series of regulations in the country's

COVID-19-affected regions. The lockdown was placed when the number of confirmed positive coronavirus cases in India was approximately 500. This lockdown enforces restrictions and self-quarantine measures. Lockdown was extended nationwide till May 3, with a conditional relaxation promised after April 2020 for the regions where the spread has been contained by then. As of 25th April 2022, in India 43 million (43,052,425) cases and 0.5 million (522,116 deaths) deaths are reported (5). Global data certainly play an important role in elucidating the epidemiology of COVID-19. and this data is confounded by several factors which includes country-specific responses to the pandemic, varying degrees of compliance (2,6), variations in testing availability and policies (7), varying mobility and travel by the population (8), seasonal climate in the two hemispheres (9), etc. The effect of weather conditions on the spread of the virus was always an interesting point of discussion among researchers. In the case of West Nile Virus in the United States and Europe (10), A study in China done by Yuan et al. studied the relationship between climate conditions and SARS-CoV, and suggested that climate variable can also be the cause of biological interactions between SARS-CoV and humans (11). It already suggested that weather is very significantly correlated with change in mortality rates due to pneumonia (12). Factors like clouding, temperature, humidity, and population density were also found to be associated with transmission of the viruses(13). A study form Jakarta, Indonesia showed the significant correlation between weather condition and COVID-19 (14).. The present study will certainly work as input in this direction and useful for further research to reach on specific conclusion as very limited research is on this subject under the Indian context, specially, effect of climate changes on COVID-19 pandemic.

There has been a lot of debate as to whether warming temperatures with the beginning of spring and summer would lead to reduced transmission in tropical countries like India, as is observed for many viral respiratory infections in tropical regions where the vast majority of LMICs are located, this will also have consequences for the risk of spread (15). Higher temperatures have been demonstrated to be safe against the broadcast of the severe acute respiratory syndrome (SARS) in 2002–2003, possibly due to the decreased survival of the SARS-CoV on surfaces at higher temperatures (16,17). Reduced aerosol spread at higher temperatures is another possible mechanism, as observed for human influenza viruses (16,18). Also, there is good experimental and epidemiological evidence that patients may have a decline in respiratory function during certain meteorological events (19,20). There is also some evidence that COVID-19 cases have particularly clustered around cooler, drier regions(21,22). However, there is still a lack of evidence, because some studies found no association of COVID-19 transmission with temperature(23,24).This motivated us to start a meteorological investigation to determine the influence of weather on COVID-19 outbreak. This study has investigated the relationship between meteorological factors, especially the average temperature and humidity and the daily number of probable COVID-19 patients in Ujjain, India.

MATERIAL AND METHODS

Study area: Ujjain is in the west-central part of India and is north of the upper limit of the Vindhya Mountain ranges on the Malwa plateau in Madhya Pradesh, India. In Ujjain, the average annual temperature and average annual humidity are is 25.2 °C (19 ° C - 33° C) and 50 % respectively with August having the highest relative humidity, with a percentage of 85.75 and April, with an extremely low level of relative humidity at only 21.15 percent (25,26). The first confirmed case of COVID-19 was identified on 23 March 2020 in Ujjain. The cases till February 28, 2022 were considered for analysis in this study.

Data sources: The data of daily COVID-19-related variables like daily sample tested, COVID-19 positive cases, recovered cases, deaths, and active cases were abstracted from the daily health bulletin published by Integrated Disease Surveillance Program, Department of Health and Family Welfare Government of Madhya Pradesh, India. The data on the daily average temperature (^{0}C) and average humidity (%) of Ujjain city were obtained during the study period using the database timeanddate.com (weblink: https://www.timeanddate.com). Permission for using the data was approved by the District and State Government of India.

Statistical analysis: Descriptive statistics included means, standard deviations (±SD) for daily confirmed cases, reported number of tests, and meteorological variables were provided. To assess, if an association exists between average temperature and humidity with daily confirmed cases of COVID-19, a multiple linear regression model was fitted in the following form: : y= $\beta_0 + \beta_1 X_{i1} + + \beta_2 X_{i2} + + \beta_3 X_{i3} + \varepsilon$; i = 1.2…..708; in which y is the number of daily confirmed COVID-19, and X1, X2, and X3 are average daily temperature, humidity, and reported number of tests on a daily basis. STATA Version 15.0 (Stata Corp, College Station, TX) was used for all analyses. Spearman's rank correlation test was used to examine the relationship between Daily COVID-19 positive, recovered cases, death cases with Average daily temperature (°C) and Average daily Humidity (%).

Ethical consideration: Ethics committee approval was obtained from R D Gardi Medical College, Ujjain. (Reference number IEC/07/2022.)

RESULTS

This study included 24,355 confirmed COVID-19 cases during the observation period (March 23, 2020 to February 28, 2022). The average number of daily confirmed cases and the number of tests were 34.39(±70.34) and 907.80(±645.74) respectively with mean positivity of 3.94(±7.46). Table 1 summarizes the descriptive statistics for the COVID-19 related variables and meteorological variables which included like daily tested samples, daily positive covid-19 cases, daily recovered cases, daily death cases, daily active cases, average daily temperature (°C), average daily humidity (%), respectively. The meteorological data showed the lowest average temperature of 11.5°C and the highest average temperature of 33.55^{0}C, and the lowest humidity of 25.5% with the highest humidity of 95%. The observed patterns were further illustrated through Figure 1, showcasing the associations between COVID-19 cases, average temperature, and humidity levels.The number of COVID-19 cases during peak of second wave ware four folds higher than the first wave. The period when virus was prevalent during the second wave the maximum per day COVID-19 positive cases were reported on days when humidity was below 40%.

Table 1. Descriptive statistics of daily COVID-19 related and climate related variables form March 23, 2020 to February 28, 2022

Variables	Mean (±SD)	Range	
		Lowest	Highest
COVID-19 related variables			
Daily tested samples	907.80(±645.74)	0	2763
Daily positive COVID-19 cases	34.39(±70.34)	0	410
Daily recovered cases	34.08(±72.93)	0	454
Daily death cases	0.24(±0.68)	0	6
Daily active cases	353.35(±687.30)	0	3262
Daily positivity	3.97(±7.46)	0	100
Climate related variables			
Average daily temperature (^{0}C)	25.51(±5.04)	11.5	33.55
Average daily Humidity (%)	62.30(±15.11)	25.5	95

Table 2: Multiple linear regression model of the association between average temperature and humidity with daily positive COVID-19 cases from March 23, 2020 to February 28, 2022

| Outcome variable	Climate related variables	Coefficient of regression	SE	t-value	*P*-value	*Spearman's rank correlation coefficient (P-value)*
Daily positive COVID-19 cases	Average daily temperature (^{0}C)	-0.522	.052	-1.00	0.317	0.0646 (0.086)
	Average daily Humidity (%)	-1.63	0.17	-9.36	<0.001	-0.2411 (<0.001)
Daily recovered cases	Average daily temperature (^{0}C)	0.35	0.54	0.64	0.522	0.0516 (0.1701)
	Average daily Humidity (%)	-1.42	0.18	-7.76	<0.001	-0.2217 (<0.001)
Daily death cases	Average daily temperature (^{0}C)	0.02	0.004	5.03	<0.001	0.2896 (<0.001)
	Average daily Humidity (%)	-0.01	0.001	2.20	<0.001	-0.2926 (<0.001)
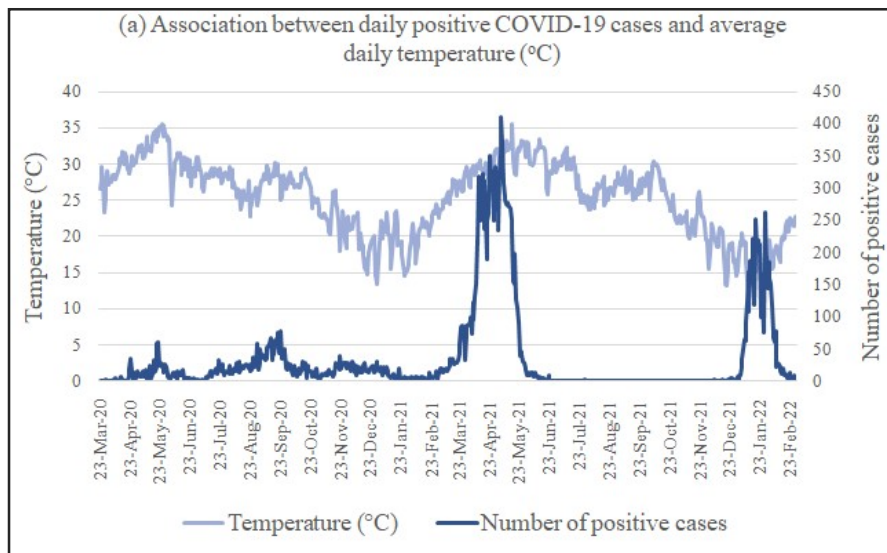
Figure 1 (a)

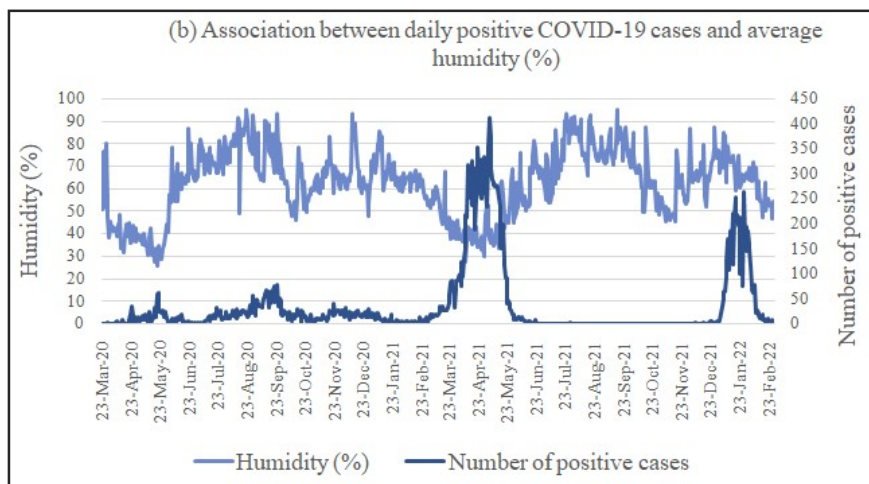**Figure 1(b)**

Figure 1. (a) Association between daily positive COVID-19 casesand average daily temperature (^{0}C), (b) Association between daily positive COVID-19 cases and average humidity (%)

Table 2 shows the multiple linear regression model of the association along with Spearman's Rank Coefficient between average temperature and humidity with daily positive COVID-19 cases, daily recovered cases, and daily death cases. Significantly ($p<0.001$), for every unit increase in average humidity, a -1.63 unit decrease in daily positive COVID-19 cases is predicted, holding all other variables constant. There was no corelation seen between temperature and daily positive COVID-19 cases. Similarly, there was statistically significant association seen between average humidity and daily recovered cases were with every unit increase in average humidity, a -1.42unit decrease in daily recovered cases was seen ($p<0.001$). There was a positive association seen between temperature and daily death cases where with every unit increase in average temperature there is unit 0.02 increase in daily death cases was reported ($p<0.001$). Similarly, with every unit increase in average humidity, a -0.01 unit decrease in daily death cases was seen ($p<0.001$).

DISCUSSION

Viruses do not replicate outside living cell but infectious virus may persist on contaminated environmental surfaces and the duration of persistence of viable virus is affected markedly by temperature and humidity. Contaminated surfaces are known to be significant vectors in the transmission of infections in the hospital setting as well as the community. The role of fomites in the transmission of RSV has been clearly demonstrated (27). In this paper, we have identified an association between mean temperature and mean humidity with corona virus-associated infection, recovery, and death. Our findings show a negative association between average humidity and the number of positive COVID-19 cases. Similarly, daily recovery from COVID-19 was having a negative association with average humidity and a positive association with average temperature. Increasing average humidity was also having a positive association with death cases in the district. In addition, with climate factors, India being a country of young population may be another reason for the spread of COVID-19 in India as young people interact daily with other people more frequently and hence population density may be another reason for the spread of COVID-19 in India.

Comparison with previous studies: Both COVID-19 and flu can spread from person to person between people who are in close contact with one another (within about 6 feet). Both are spread mainly by large and small particles containing viruses that are expelled when people with the illness (COVID-19 or flu) cough, sneeze, or talk(28). Our finding of association shows a negative association between average humidity and number of positive COVID-19 cases and are consistent with similar recent studies which shows that lower humidity can increase the transmission of Influenza and COVID-19 (22,29,30). There are some studies which reported that there is no association between COVID-19 transmission and meteorological factors (23,31). However, our finding was not inline these studies.

Possible mechanism: It is already known that Influenza and COVID-19 have many similarities in terms of mode of spread (28). The main reasons are documented elsewhere are that the Influenza virus is more stable in cold temperatures, and respiratory droplets containing viruses, remain suspended longer in dry air (32). Another reason identified was that hosts' immunity also gets compromised due to inhaled cold air,

cooling of the body surface and cold stress induced by lowering the core body temperature which cause pathophysiological responses such as vasoconstriction in the respiratory tract mucosa leading them more susceptible to the virus (33).Another review article also suggests that exposure to cold, either during induced hypothermia or due to exposure to low environmental temperatures, increases the risk of developing upper and lower respiratory tract infections and associated mortality (34).

Association of positivity recovery and deaths with average temperature: Most studies in Thailand, Singapore, India, and China, found a positive relationship between temperature and the daily number of COVID-19 cases (35–38). Several research, however, found a negative association between temperature and COVID-19 cases. Wu et al. (30)and To et al. (39), for example, discovered that rising temperatures were associated with a decrease in daily new cases of COVID-19 in Brazil and Canada. In our study the association of COVID-19 positivity and recovery with average temperature was not significant. However, COVID-19 associated deaths was having a significant positive association with average temperature in our study and the findings were in line with multicentric study done in 166 countries (30).

Limitations: This study reports significant finding between weather and COVID-19 but the study has few limitations. First, many factors like population, population density, education, availability, and accessibility of medical facility were not studies in this study. Secondly self-limiting factors like co-morbidities, personal hygiene practices, immunity of a person, use of mask and sanitizers may be the other factors, which can influence the spread of COVID-19 in India but are not covered in the study. The impact of COVID-19 policies was not assessed in our study.

CONCLUSION

The analysis revealed that higher mean humidity was associated with significant reductions in daily positive COVID-19 cases and recovered cases, while no significant correlation was observed between mean temperature and positive cases. Intriguingly, a positive correlation was found between average temperature and daily death cases. Additionally, an inverse relationship between humidity and death cases was identified. The multiple linear regression models reaffirmed these associations, underscoring the impact of humidity on positive and death cases, and the influence of temperature on death cases. Overall, this study contributes insights into the intricate interplay between meteorological factors and COVID-19 dynamics, shedding light on potential variables affecting the spread and severity of the disease.Considering the existing body of scientific research, it appears that warmer and more humid climates might contribute to a reduction in the transmission of COVID-19. However, it's important to note that these climatic factors alone do not account for the majority of the variability observed in the spread of the disease.Factors such as public health interventions, herd immunity, migration patterns, population density, and cultural influences play a significant role in shaping the transmission of the virus. Despite the evidence being of relatively low certainty, the consistency of results across included studies underscores the importance of understanding the interplay between weather conditions and public health policies for the greater well-being of humanity during this critical period.

Author's Contribution

AM conceived the idea and is the guarantor of the study. RU and ASG collected the data. AM and SS supervised the collection of the data. AM and RU carried out data management. AM and PM analysed the data. AM and PM drafted the manuscript. AM, SS, PM, RU and ASG read the drafts and provided feedback. All authors read and approved the final manuscript.

Data Availability

All relevant data are within the manuscript and its Supporting Information files can be obtained for Institutional Ethics Committee after application.

Abbreviations

Abbreviation	Full Form
COVID-19	Coronavirus Disease 2019
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
WHO	World Health Organization
USA	United States of America
LMIC	Low and Middle-Income Countries
°C	Degrees Celsius
SD	Standard Deviation
RSV	Respiratory Syncytial Virus
STATA	Statistical Analysis Software (used for regression analysis)
IEC	Institutional Ethics Committee
RD Gardi Medical College	Ruxmaniben Deepchand Gardi Medical College
IDSP	Integrated Disease Surveillance Program
p-value	Probability value (used to indicate statistical significance)
%	Percentage

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