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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

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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 25^{th} 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 Project, 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: : $y= \beta0+\beta1Xi1++\beta2Xi2++\beta3Xi3 +\varepsilon$; 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)

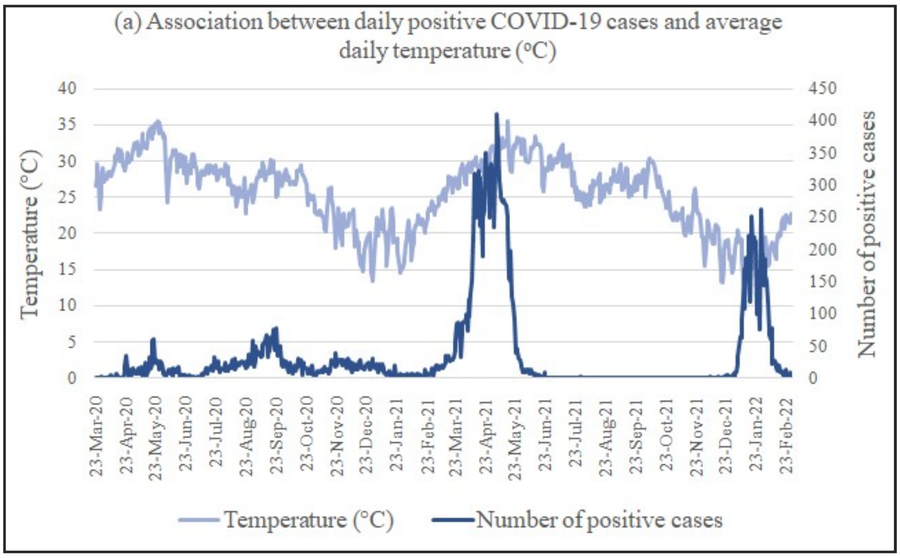

Figure 1 (a)

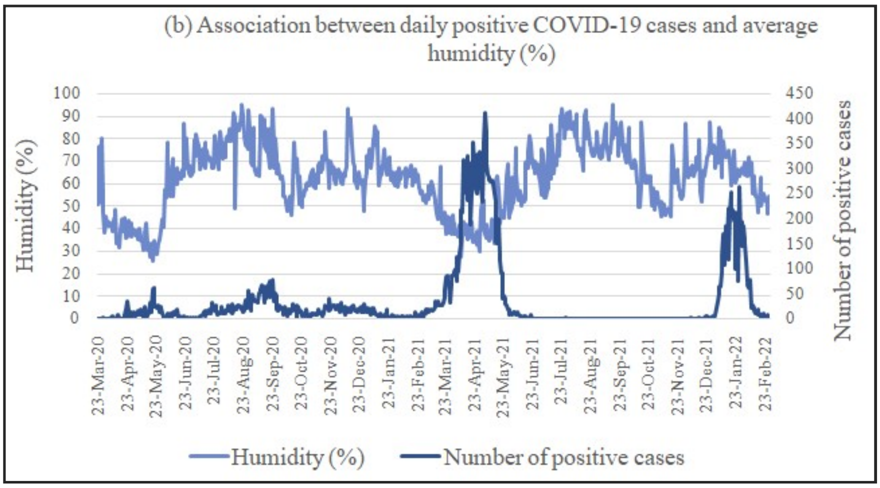

Figure 1(b)

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.

Declaration of competing interest: The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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.

Conflicting Interest: Authors declare no conflict of interest.

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Data Availability

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

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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 Project
p-value	Probability value (used to indicate statistical significance)
%	Percentage

REFERENCES

1. Zhu H, Wei L, Niu P. The novel coronavirus outbreak in Wuhan, China. Glob Health Res Policy [Internet]. 2020 Dec 1 [cited 2022 Apr 25];5(1). Available from: https://pubmed.ncbi.nlm.nih.gov/32226823/
2. Coronavirus Disease (COVID-19) Situation Reports [Internet]. [cited 2022 Apr 21]. Available from: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports
3. WHO Coronavirus (COVID-19) Dashboard | WHO Coronavirus (COVID-19) Dashboard With Vaccination Data [Internet]. [cited 2022 Apr 25]. Available from: https://covid19.who.int/
4. Andrews MA, Areekal B, Rajesh K, Krishnan J, Suryakala R, Krishnan B, et al. First confirmed case of COVID-19 infection in India: A case report. Indian J Med Res [Internet]. 2020 May 1 [cited 2023 Aug 29];151(5):490. Available from: /pmc/articles/PMC7530459/
5. India: WHO Coronavirus Disease (COVID-19) Dashboard With Vaccination Data | WHO Coronavirus (COVID-19) Dashboard With Vaccination Data [Internet]. [cited 2022 Apr 25]. Available from: https://covid19.who.int/region/searo/country/in
6. Tanne JH, Hayasaki E, Zastrow M, Pulla P, Smith P, Rada AG. Covid-19: how doctors and healthcare systems are tackling coronavirus worldwide. BMJ [Internet]. 2020 Mar 18 [cited 2022 Apr 21];368. Available from: https://pubmed.ncbi.nlm.nih.gov/32188598/
7. Lassaunière R, Frische A, Harboe ZB, Nielsen ACY, Fomsgaard A, Krogfelt KA, et al. Evaluation of nine commercial SARS-CoV-2 immunoassays. medRxiv [Internet]. 2020 Apr 10 [cited 2022 Jul 29];2020.04.09.20056325. Available from: https://www.medrxiv.org/content/10.1101/2020.04.09.20056325v1
8. Management of ill travellers at points of entry (international airports, seaports, and ground crossings) in the context of COVID-19, interim guidance, 19 March 2020 [Internet]. [cited 2022 Apr 21]. Available from: https://apps.who.int/iris/handle/10665/331512
9. Nair H, Brooks WA, Katz M, Roca A, Berkley JA, Madhi SA, et al. Global burden of respiratory infections due to seasonal influenza in young children: a systematic review and meta-analysis. The Lancet [Internet]. 2011 Dec 3 [cited 2019 Sep 16];378(9807):1917–30. Available from: http://www.ncbi.nlm.nih.gov/pubmed/22078723
10. Epstein PR. West Nile virus and the climate. J Urban Health [Internet]. 2001 [cited 2022 Dec 27];78(2):367–71. Available from: https://pubmed.ncbi. nlm.nih.gov/11419587/
11. Yuan J, Yun H, Lan W, Wang W, Sullivan SG, Jia S, et al. A climatologic investigation of the SARS-CoV outbreak in Beijing, China. Am J Infect Control [Internet]. 2006 May [cited 2022 Sep 1];34(4):234–6. Available from: https://pubmed.ncbi.nlm.nih.gov/16679182/
12. Bull GM. The weather and deaths from pneumonia. Lancet [Internet]. 1980 Jun 28 [cited 2023 May 12];1(8183):1405–8. Available from: https://pubmed.ncbi. nlm.nih.gov/6104184/
13. Dalziel BD, Kissler S, Gog JR, Viboud C, Bjørnstad ON, Metcalf CJE, et al. Urbanization and humidity shape the intensity of influenza epidemics in U.S. cities. Science [Internet]. 2018 Oct 5 [cited 2023 May 12];362(6410):75–9. Available from: https://pubmed.ncbi. nlm.nih.gov/30287659/
14. Tosepu R, Gunawan J, Effendy DS, Ahmad LOAI, Lestari H, Bahar H, et al. Correlation between weather and Covid-19 pandemic in Jakarta, Indonesia. Sci Total Environ [Internet]. 2020 Jul 10 [cited 2023 May 12];725. Available from: https://pubmed.ncbi.nlm.nih.gov/32298883/
15. Imai C, Brooks WA, Chung Y, Goswami D, Anjali BA, Dewan A, et al. Tropical influenza and weather variability among children in an urban low-income population in Bangladesh. Glob Health Action [Internet]. 2014 [cited 2023 Aug 19];7(1). Available from: https://pubmed.ncbi.nlm.nih.gov/25128806/

16. Chan KH, Peiris JSM, Lam SY, Poon LLM, Yuen KY, Seto WH. The Effects of Temperature and Relative Humidity on the Viability of the SARS Coronavirus. Adv Virol [Internet]. 2011 [cited 2022 Sep 1];2011. Available from: https://pubmed.ncbi.nlm.nih.gov/22312351/
17. Lin K, Fong DYT, Zhu B, Karlberg J. Environmental factors on the SARS epidemic: air temperature, passage of time and multiplicative effect of hospital infection. Epidemiol Infect [Internet]. 2006 Apr [cited 2023 Aug 19];134(2):223–30. Available from: https://pubmed.ncbi.nlm.nih.gov/16490124/
18. Lowen AC, Mubareka S, Steel J, Palese P. Influenza virus transmission is dependent on relative humidity and temperature. PLoS Pathog [Internet]. 2007 Oct [cited 2023 Aug 19];3(10):1470–6. Available from: https://pubmed.ncbi.nlm.nih.gov/17953482/
19. Donaldson GC, Keatinge WR. Early increases in ischaemic heart disease mortality dissociated from and later changes associated with respiratory mortality after cold weather in south east England. J Epidemiol Community Health (1978) [Internet]. 1997 [cited 2023 Aug 19];51(6):643–8. Available from: https://pubmed.ncbi.nlm.nih.gov/9519127/
20. Marshall RJ, Scragg R, Bourke P. An analysis of the seasonal variation of coronary heart disease and respiratory disease mortality in New Zealand. Int J Epidemiol [Internet]. 1988 Jun [cited 2023 Aug 19];17(2):325–31. Available from: https://pubmed.ncbi.nlm.nih.gov/3403127/
21. Tan J, Mu L, Huang J, Yu S, Chen B, Yin J. An initial investigation of the association between the SARS outbreak and weather: with the view of the environmental temperature and its variation. J Epidemiol Community Health (1978) [Internet]. 2005 Mar [cited 2022 Sep 1];59(3):186. Available from: /pmc/articles/PMC1733040/?report=abstract
22. Wang J, Tang K, Feng K, Lv W. High Temperature and High Humidity Reduce the Transmission of COVID-19. SSRN Electronic Journal [Internet]. 2020 Mar 11 [cited 2022 Dec 27]; Available from: https://www.researchgate.net/publication/339851654_High_Temperature_and_High_Humidity_Reduce_the_Transmission_of_COVID-19
23. Yao Y, Pan J, Liu Z, Meng X, Wang W, Kan H, et al. No association of COVID-19 transmission with temperature or UV radiation in Chinese cities. Eur Respir J [Internet]. 2020 May 1 [cited 2022 Nov 12];55(5). Available from: https://pubmed.ncbi.nlm.nih.gov/32269084/
24. Xie J, Zhu Y. Association between ambient temperature and COVID-19 infection in 122 cities from China. Sci Total Environ [Internet]. 2020 Jul 7 [cited 2022 Nov 12];724:138201. Available from: /pmc/articles/PMC7142675/
25. Average monthly humidity in Ujjain (Madhya Pradesh), India [Internet]. [cited 2023 Aug 19]. Available from: https://weather-and-climate.com/average-monthly-Humidity-perc,ujjain-madhya-pradesh-in,India
26. Average temperature in Ujjain (Madhya Pradesh), India (celsius) [Internet]. [cited 2023 Aug 19]. Available from: https://weather-and-climate.com/average-monthly-min-max-Temperature,ujjain-madhya-pradesh-in,India
27. Hall CB, Douglas RG, Geiman JM. Possible transmission by fomites of respiratory syncytial virus. J Infect Dis [Internet]. 1980 [cited 2022 Sep 1];141(1):98–102. Available from: https://pubmed.ncbi.nlm.nih.gov/7365274/
28. Similarities and Differences between Flu and COVID-19 | CDC [Internet]. [cited 2022 Jul 19]. Available from: https://www.cdc.gov/flu/symptoms/flu-vs-covid19.htm
29. Mehta SK, Ananthavel A, Reddy TVR, Ali S, Mehta SB, Kakkanattu SP, et al. Indirect Response of the Temperature, Humidity, and Rainfall on the Spread of COVID-19 over the Indian Monsoon Region. Pure Appl Geophys [Internet]. 2023 Jan 1 [cited 2023 May 12];180(1):383–404. Available from: https://pubmed.ncbi.nlm.nih.gov/36590883/
30. Wu Y, Jing W, Liu J, Ma Q, Yuan J, Wang Y, et al. Effects of temperature and humidity on the daily new cases and new deaths of COVID-19 in 166 countries. Sci Total Environ [Internet]. 2020 Aug 10 [cited 2022 Apr 27];729. Available from: https://pubmed.ncbi.nlm.nih.gov/32361460/
31. Vasquez-Apestegui B V., Parras-Garrido E, Tapia V, Paz-Aparicio VM, Rojas JP, Sanchez-Ccoyllo OR, et al. Association between air pollution in Lima and the high incidence of COVID-19: findings from a post hoc analysis. BMC Public Health [Internet]. 2021 Dec 1 [cited 2023 May 12];21(1). Available from: /pmc/articles/PMC8208068/
32. Lowen AC, Steel J. Roles of Humidity and Temperature in Shaping Influenza Seasonality. J Virol [Internet]. 2014 Jul 15 [cited 2022 Jul 19];88(14):7692. Available from: /pmc/articles/PMC4097773/
33. Kudo E, Song E, Yockey LJ, Rakib T, Wong PW, Homer RJ, et al. Low ambient humidity impairs barrier function and innate resistance against influenza infection. Proc Natl Acad Sci U S A [Internet]. 2019 May 28 [cited 2022 Jul 19];166(22):10905–10. Available from: /pmc/articles/PMC6561219/
34. Mourtzoukou EG, Falagas ME. Exposure to cold and respiratory tract infections. Int J Tuberc Lung Dis [Internet]. 2007 Sep [cited 2022 Nov 19];11(9):938–43. Available from: https://pubmed.ncbi.nlm.nih.gov/17705968/
35. Sangkham S, Thongtip S, Vongruang P. Influence of air pollution and meteorological factors on the spread of COVID-19 in the Bangkok Metropolitan Region and air quality during the outbreak. Environ Res [Internet]. 2021 Jun 1 [cited 2022 Apr 27];197. Available from: https://pubmed.ncbi.nlm.nih.gov/33798521/
36. Pani SK, Lin NH, RavindraBabu S. Association of COVID-19 pandemic with meteorological parameters over Singapore. Sci Total Environ [Internet]. 2020 Oct 20 [cited 2022 Apr 27];740. Available from: https://pubmed.ncbi.nlm.nih.gov/32544735/
37. Kumar G, Kumar RR. A correlation study between meteorological parameters and COVID-19 pandemic in Mumbai, India. Diabetes Metab Syndr [Internet]. 2020 Nov 1 [cited 2022 Apr 27];14(6):1735–42. Available from: https://pubmed.ncbi.nlm.nih.gov/32919321/
38. Sharma P, Singh AK, Agrawal B, Sharma A. Correlation between weather and COVID-19 pandemic in India: An empirical investigation. J Public Aff [Internet]. 2020 Nov 1 [cited 2022 Apr 25];20(4). Available from: /pmc/articles/PMC7404574/
39. To T, Zhang K, Maguire B, Terebessy E, Fong I, Parikh S, et al. Correlation of ambient temperature and COVID-19 incidence in Canada. Sci Total Environ [Internet]. 2021 Jan 1 [cited 2022 Apr 27];750. Available from: https://pubmed.ncbi.nlm.nih.gov/32829260/

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