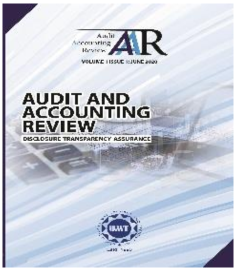

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Article: **Association of Temperature and Humidity with COVID-19 Transmission in Punjab, Pakistan**

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Association of Temperature and Humidity with COVID-19 Transmission in Punjab, Pakistan

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Abstract

Due to the spread of multiple variants of COVID-19, the influence of humidity and temperature on their transmission and spread is a matter of scientific investigation. This research investigates the connection of relative humidity and daily high temperature with the quantity of daily definite COVID-19 cases in Punjab, Pakistan from March 11, 2020 to June 30, 2020. Generalized Additive Model (GAM) was applied to measure the said association. In this study, the interaction of relative humidity and temperature were discussed and the results indicated that the growth in humidity and temperature leads to a decline in the daily occurrence of cases. On the basis of the findings, the development and implementation of a proficient and effective health care information system is recommended so that the frequency and transmission of COVID-19 can be curtailed.

Keywords: COVID-19, Generalized Additive Model, humidity, temperature

JelCode: C140, I120, I180, Q24

Introduction

In the earlier days of December 2019, acute respiratory coronavirus 2 (SARS-CoV-2) cases were documented in Wuhan, China. SARS-CoV-2 triggered a new coronavirus disease (COVID-19) (Wu et al. 2020), and now it is a world pandemic (WHO, 2020). The clinical indications of covid-19 contain dry cough, severe fever, pneumonia, and myalgia, causing respiratory failure because of alveolar injury and bereavement (Huang et al., 2020). Pakistan faced its first case on March 11, 2020. 221,896 patients were registered in Pakistan (GOP) and 4551 deaths reported in Pakistan.

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Breathing drops and physical contact with an infected person are the main ways of spread of Covid-19 (WHO, 2020). Other aspects that might cause the spread of Coronavirus include relative humidity and temperature (Casanova et al., 2010). By influencing the endurance of the virus in its spread routes, there is an affirmation for intense respiratory Covid (SARS-CoV) (Cai et al. 2007; Tan et al., 2005) and disorder Covid (MERS-CoV) (Altamimi & Ahmed, 2020; Gardner et al., 2019).

The novel virus has elevated worldwide issue and come to be the wickedest health issues. The epidemic and later pandemic spread dynamics will heavily be influenced by the stages and the period of resistance, on the consequence of weather to contagious, and common cold coronaviruses (Kissler et al., 2020). The coronavirus are linked with infection and track a seasonal form triggering winter outbreaks (Killerby et al., 2018).

How and whether the environmental influence the transmission of coronavirus has not been examined so far. By taking the data of cases from the Punjab province of Pakistan, we observed the relationship among environmental causes such as relative humidity and temperature with day by day affirmed cases of COVID-19. This study aims to offer scientific proof related to future evolution under Climatic factors' variability.

This paper's remainder is organized as follows: we briefly highlight the previous literature in the next section. Section 3 describes the material and method utilized in this paper. Section 4 describes the results, and Section 5 details the discussion and presents the corresponding analysis. Whereas section 6 offers the conclusion of the study.

Literature Review

Chen et al. (2020) led a study and discovered a destructive relationship of temperatures with COVID-19. The outcomes are in accordance with the prior studies such as (Ghalhari et al., 2016) reported that as temperature expands, the quantity of cases decreases. Thus the spread of Corona is strongly associated with temperature. Numerous other studies also find the same results (Dadbakhsh et al., 2017; Gómez-Acebo et al., 2013; Macfarlane, 1977). Another study by (Li et al. 2019) exposed that both hot and cold weather conditions adversatively affect respiratory infections. Kim et al. (2016) concluded a study in East Asian cities and stressed that increased temperature is linked with the decreased risk of cardiovascular diseases. In the season of winter, the collective risk of cardiovascular and respirational diseases is enhanced with a high rate in Tabriz (Sharafkhani et al., 2019). Using time-series data, a research has shown the impact of daily high temperature on the chronic obstructive pulmonary disease (COPD) in Shanghai, which shows that a 1°C rise in daily temperature decreased the threat of disease by 1.25% (Song et al., 2008). Similarly, Shephard and Shek (1998) stress that a low degree of temperature may suppress the immune system. Inhaling cold air can shrink the bronchial, helping the vulnerability to lung infection (Martens, 1998).

Moreover, SARS-CoV is delicate to hot temperatures, and increased high temperature makes it tougher to sustain (Bunker et al., 2016). Correspondingly, it is discovered by Donaldson et al. (1999) that low temperature is related to lessening the lung system and enhancing the exacerbations for patients with COPD. The daily temperature is considered a full scale to calculate temperature variability to analyze this indicator's impact on health status (Easterling et al., 1997). Sharafkhani et al. (2019) examined the rapid temperature changes and found that a respiratory and low-temperature burden may cause an increase in environmental stress. It is also found that the doctors advised the patients to keep open the windows of patients' rooms and avoid air conditioners.

Earlier studies also tried to determine the impact of weather variability in the existence and spread of different viruses such as MERS-CoV and SARS-CoV (Bi et al., 2007; Chan et al., 2011; Casanova et al., 2010; van Doremalen et al., 2013; Tan et al., 2005). Tan et al. (2005) a study conducted in Beijing, Guangzhou and Hong Kong, identified the optimal fever related to SARS was 18°C to 30°C. Likewise, Bi et al. (2007) have documented the negative connection between temperature and SARS spread in Beijing. Casanova et al. (2010) experimented in the laboratory to conclude the effect of climate on coronavirus sustainability and reported that the virus becomes deactivated at 24°C than at 10°C. Similar laboratory research stated that coronavirus on plane surfaces was steady for more than six days at the temperature of 22°C, and the virus's capability suddenly gets lost at the 38°C temperature (Chan et al., 2011). Van Doremalen et al. (2013) also detected that MERS-CoV viruses were less harmful in hot weather. Conclusively, it has been inferred by many studies that the high temperature is detrimental to the existence of coronavirus.

Davis et al. (2016) analyzed that hypothesis and confirmed that low temperature and humidity are sources to increase diseases. Barreca and Shimshack (2012) carried the same study in the USA, and the results also specify that the mortality risk from disease increases as the decrease in humidity. Inhaling cold and dry air can damage epithelial, promoting the infection. Furthermore, the spread of flu disease is effectual in cold and dry weather (Steel et al., 2011). Such viruses also get enlarged with the reduced humidity (Shaman et al., 2009), which is very much like the novel coronavirus. Hence, the mortality from COVID-19 can be associated with the lesser humidity in cold weather.

The high temperature was a powerful cause in the transmission of breathing diseases in China (Wang et al., 2020). Sajadi et al. (2020) analyzed the respiratory virus's fever, which was significant. Chen et al. stress in their study that meteorological factors can forecast the outbreak. In Wuhan, disease and weather are correlated, and these variables can reduce the infection when the weather gets warm (Guo et al., 2020). An additional study by Chan et al. (2020) stated that wind and humidity factors could impact the environment's permanency.

Along with these variables, temperature was also found a key element in the situation of the covid-19 pandemic. Ma et al. (2020) also found that humidity and temperature variability significantly influence covid-19 mortality. There is a substantial and robust association between the transmission of Coronavirus on environment and temperature (Poole, 2020).

After registering a novel coronavirus's initial cases, it was recognized that body to body spread was taking place (Lai et al., 2020; Chen et al., 2020). The higher temperature was also documented to reduce infection (Lamarre & Talbot, 1989/). The previous understanding of SARS had confirmed that the virus vanished in hot weather in July (Wallis & Nerlich, 2005). Specialists have also observed the same results in Covid-19 because of its link with the same virus. (Wilder et al., 2020). Tropical areas, lower temperatures, and high humidity were more suitable for transmitting the

SARS epidemic in 2003 (Chan et al., 2011). New research finds a link between air pollution and the Chinese city Wuhan's mortality rate due to a novel coronavirus pandemic using the Generalized Additive Model (Ma et al., 2020). The fever was also linked to the covid-19 spread in Jakarta (Tosepu et al., 2020). Wang et al. (2020) advocate that low fever is viable for coronavirus spread.

Methods and Materials

Data and Study Area

The quantity of every day affirmed corona cases in the Punjab were officially composed from the website of Pakistan Command and Control Center of Coronavirus (NCOC) from March 11, 2020, to June 20, 2020. Climatic data such as daily relative humidity (RH) and Daily Maximum Temperature (DMT) of the Punjab capital (Lahore) were collected from the Meteorological Department of Pakistan (MET). The dispersal of corona positive cases was expected to be a adverse binomial due to the mean of regular cases being less than their variance.

Statistical Analysis

To measure the connection among environmental aspects and daily COVID-19 positive cases, a "generalized additive model" (GAM) was utilized. The GAM is a further addition of the generalized linear model (GLM) and semi-parametric, which is beneficial to discover the non-linear affiliation among weather aspects and fitness consequences (Lin et al., 2018; Liu et al., 2020; Peng et al., 2006; Talmoudi et al., 2017; Wu et al., 2018). Considering the growth time of corona, the influence of RH and DT, covariates were displayed utilizing the 14-day Exponential Moving Average (EMA). To justify their possible lag impact, interaction of DT and RH was also included if found significant. The short-term pattern is additionally featured by utilizing splines of time with two degrees of freedom. This model's degree of freedom is identified using the Generalized Cross-Validation score (GCV). The GCV reduces the equation:

$$v_g = \frac{n \sum_{i=1}^{n} (y_{i-\hat{f_i}})^2}{[tr\,(I - A)]^2}$$

Where "A" is the predicted matrix, it is clear that whenever the value of lambda is near one, then the spline will be extra smoothed. On the other hand, if the lambda value is near zero, then our spline will not be castigated so that the model will act just like an OLS model.

The model is stated as:

$$E(c_t) = \mu_t$$

$$\log \mu_t = \beta_0 + \beta_1 DMT_t + \beta_2 RH_t + \beta_3 DMT_t \times RH_t + \beta_4 ns_1 + \beta_5 ns_2$$

where c_t are the confirmed daily cases in a day t; μ_t is the predictive values of regular cases at day t; β_1 shows the impact of daily maximum temperature whereas β_2 represents the influence of relative humidity; and β_3 is the multiplicative term of DMT and RH; and the rest of the coefficients are the natural splines coefficients of the period with two degrees of freedom. The transient worldly pattern was demonstrated utilizing regular splines of time. Earlier research has also recognized non-linear relations such as "U, J or V" shaped daily cases (Braga et al., 2002; Carson et al., 2006; Muggeo, 2008; Kim et al., 2006; Curriero et al., 2002; Ren et al., 2008; Hoffmann et al., 2008; Anderson & Bell, 2009), which are primarily embodied by piecewise linear terms (Carson et al., 2006; Muggeo, 2008; Kim et al., 2006) or other such a natural cubical spline (Curriero et al. 2002; Ren et al., 2008; Hoffmann et al., 2008; Anderson & Bell, 2009). It is usually assumed that the temperature impacts only the cases of the same day or one day of lag (Carson et al., 2006; Kim et al., 2006; Curriero et al., 2002; Ren et al., 2008). A substitute for this single-day model is a distributed lag model (Schwartz, 2000). In this model, a spline of time is utilized to describe the enduring trend, and perplexing impacts such as air pollution are also controlled meticulously by splines. Furthermore, Stata version 12 was used to perform statistical analysis.

Results

Daily confirmed cases of the province of the Punjab is summarized in Figure 2. The cases varied from 10 persons to 40,601 persons, and 53.42% of confirmed cases occurred in Lahore, whereas Rawalpindi had almost 8.01% of all confirmed cases. The everyday most extreme temperature went from 25.5 °C to 46.5 °C (Figure 1a). Figure 1b displays the daily confirmed cases in the Punjab enhanced quickly right after May 20, 2020, and also the normal relative humidity fluctuated from 27.3% to 76.1% (Figure 1c). The per day temperature varied from 4.5 °C to 9.79 °C, varying frequently about 5°C. The everyday average relative humidity also changed from 30% to 86.82%, lasting more significantly than 40% on most days.

Figure 1a

The Daily Maximum Temperature Time Series in the Punjab Province from March 11, 2020, to June 30, 2020

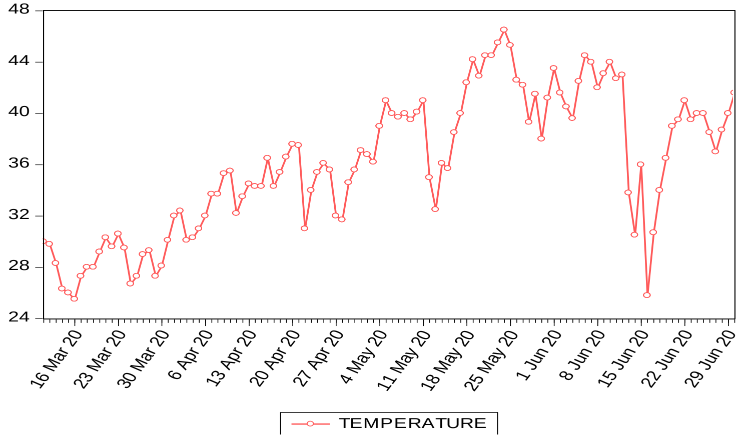

Figure 1b

The Time Series of the Daily Counts in the Punjab Province from March 11, 2020, to June 30, 2020

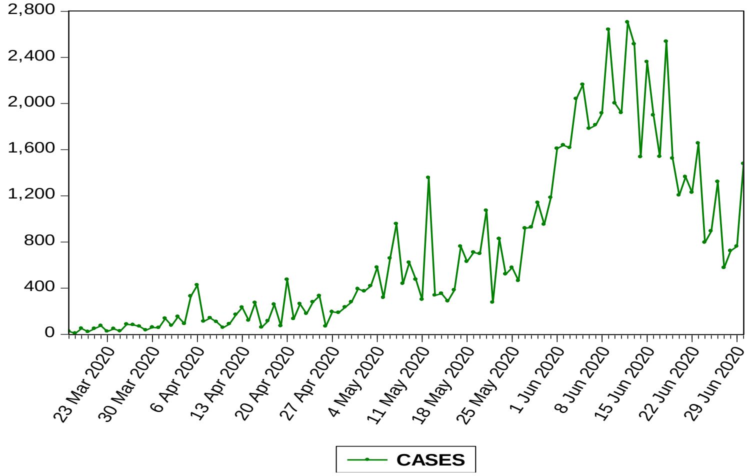

Figure 1c

The Monthly Average Relative Humidity in the Punjab Province from March 11, 2020, to June 30, 2020

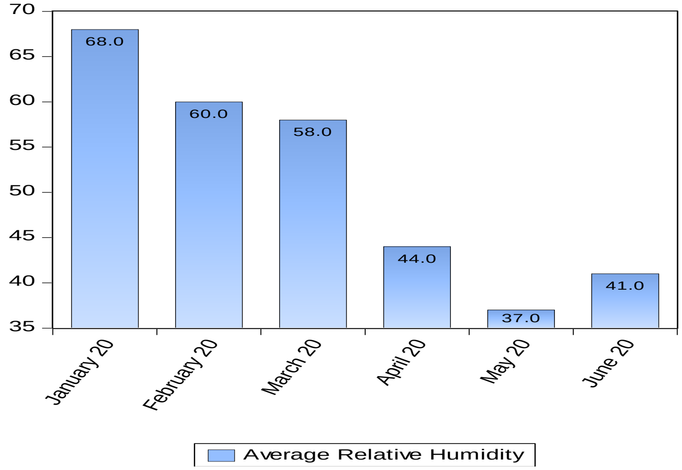

Table 1

Estimates of Regression Coefficients of the GAM for Punjab Province

Parameter	Coefficient	95% Confidence Interval	Z-value	P-value
Intercept	31.11	14.11 – 60.21	3.17	0.002
Daily Maximum Temperature	-4.51	-5.32 to -0.65	-2.56	0.013
Daily Average Relative Humidity	-0.47	-0.93 to -0.22	-3.11	0.002
DT × RH	0.07	0.009 – 0.11	2.21	0.029
ns_1	3.84	-0.1 – 8.42	1.58	0.120
ns_2	4.63	2.67 – 8.14	4.63	0.001
R-squared	0.863	Adjusted R-squared		0.811

The results of the regression of the GAM for the province of Punjab are shown in Table 1. The result indicates a positive significant correlation among DMT and RH, the coefficient value is 0.07, and the confidence interval ranged from 0.009 – 0.11. The connection among everyday cases and environmental factors is also given in table 1. DMT shows a negative association with daily patients, which specifies that an increase in DMT by 1°C leads to decreased daily counts of COVID-19. Each 1% increment in day-by-day the normal relative humidity prompted a decline in the cases by 47%.

Discussion

This study shows that relative humidity and daily maximum fever and inclined the spread of COVID-19 in Pakistan's Punjab province. Approximately of the confirmed cases had occurred before the Punjab Government imposed the lockdown period. Therefore, most of the cases appeared at the time of the lockdown. As the regular maximum fever increased, the quantity of daily cases started dropping compared to the lower temperature. Empirical evidence from the preceding research and laboratory examinations has recognized the negative relationship between DMT and ARH and other corona related viruses (Chan et al., 2011; Gardner et al., 2019; Zhang et al., 2004). Another study has stated that the threat of an enlarged daily confirmed cases of SARS was 19 times higher at less temperature in the period of the outbreak than on hotter days (Lin et al., 2006). SARS-CoV and MERS-Cov are likely to be steadier in cold weather; lower fever and lower humidity prompted an increment of suspended substance in the air, which facilitates the perfect atmosphere for virus transmission (Cai et al., 2003; Gardner et al., 2019; van Doremalen et al., 2013).

The finding of the research is the associations between DMT and RH and the spread of corona cases. In the Punjab province, the interaction amongst DMT and RH was found to impact transmission significantly. One possible argument is that a mixture of less DMT and low RH makes the nasal mucosa inclined to little breaks, producing more chances for virus attack (Zhou & Jiang, 2004). Some earlier studies have detected a combination of humidity and temperature (Firestone et al., 2012; Liu et al., 2019). Though earlier studies have rarely investigated the impact of the combination of climatological factors, concentrating on the solo aspect, either temperature or humidity, on the occurrence of COVID-19 (Luo et al., 2020; Wang et al., 2020). Hence, when analyzing the effect of climatic factors on the spread of corona, the combination of climatic influences must be examined.

Conclusion

The research identified the connection of temperature and humidity with the figure of COVID-19 daily cases reported in Punjab, Pakistan by applying the Generalized Additive Model (GAM). The results indicated a harmful relationship of the daily temperature with the regular instances of COVID-19. Additionally, this research also examined the daily humidity level and reported that it also significantly affects the virus spread. In this conclusion, meteorological factors affect the COVID-19 spread, possibly having a multiplicative impact on daily maximum fever and average relative humidity on COVID-19 frequency. The cyclical nature of a pandemic caused by a virus is a general phenomenon and is portent with peaks.

The results are valuable in developing and implementing an effective and efficient health care information system to prevent the rising frequency of cases and to curtail the transmission of COVID-19, globally.

This study has certain limitations. First, some other possible influences that can impact the occurrence of COVID-19, such as economic and social status, were not examined in this study. Furthermore, the data about regular fever and relative humidity were taken only from Lahore, the capital city of Punjab province. Future studies may incorporate the data of all cities of Punjab, Pakistan for a broader analysis.

References

Altamimi, A., & Ahmed, A. E. (2020). Climate factors and incidence of Middle East respiratory syndrome coronavirus. *Journal of Infection and Public Health*, *13*(5), 704-708. https://doi.org/10.1016/j.jiph.2019.11.011

Anderson, B. G., & Bell, M. L. (2009). Weather-related mortality: how heat, cold, and heat waves affect mortality in the United States. *Epidemiology (Cambridge, Mass.)*, *20*(2), 205-213. https://doi.org/10.1097/EDE.0b013e318190ee08

Barreca, A. I., & Shimshack, J. P. (2012). Absolute humidity, temperature, and influenza mortality: 30 years of county-level evidence from the

United States. *American Journal of Epidemiology*, *176* (suppl_7), S114-S122. https://doi.org/10.1093/aje/kws259

Bi, P., Wang, J., & Hiller, J. E. (2007). Weather: driving force behind the transmission of severe acute respiratory syndrome in China?. *Internal Medicine Journal*, *37*(8), 550-554. https://doi.org/10.1111/j.1445-5994.2007.01358.x

Braga, A. L., Zanobetti, A., & Schwartz, J. (2002). The effect of weather on respiratory and cardiovascular deaths in 12 US cities. *Environmental Health Perspectives*, *110*(9), 859-863.

Bunker, A., Wildenhain, J., Vandenbergh, A., Henschke, N., Rocklöv, J., Hajat, S., Sauerborn, R. (2016). Effects of air temperature on climate-sensitive mortality and morbidity outcomes in the elderly; a systematic review and meta-analysis of epidemiological evidence. *Ebiomedicine* 6, 258–268

Cai, Q. C., Jiang, Q. W., Zhao, G. M., Guo, Q., Cao, G. W., & Chen, T. (2003). Putative caveolin-binding sites in SARS-CoV proteins. *Acta Pharmacologica Sinica*, *24*(10), 1051-1059.

Cai, Q.-C., Lu, J., Xu, Q.-F., Guo, Q., Xu, D.-Z., Sun, Q.-W., Yang, H., Zhao, G.-M., & Jiang, Q.-W. (2007). Influence of meteorological factors and air pollution on the outbreak of severe acute respiratory syndrome. *Public Health*, *121*(4), 258-265. https://doi.org/10.1016/j.puhe.2006.09.023

Carson, C., Hajat, S., Armstrong, B., & Wilkinson, P. (2006). Declining vulnerability to temperature-related mortality in London over the 20th century. *American Journal of Epidemiology*, *164*(1), 77-84.

Casanova, L. M., Jeon, S., Rutala, W. A., Weber, D. J., & Sobsey, M. D. (2010). Effects of air temperature and relative humidity on coronavirus survival on surfaces. *Applied and Environmental Microbiology*, *76*(9), 2712-2717.

Chan, K. H., Peiris, J. M., Lam, S. Y., Poon, L. L. M., Yuen, K. Y., & Seto, W. H. (2011). The effects of temperature and relative humidity on the viability of the SARS coronavirus. *Advances in Virology*, *2011*, 1-7.

Chen, H., Guo, J., Wang, C., Luo, F., Yu, X., Zhang, W., Li, J., Zhao, D., Xu, D., Gong, Q., Liao, J., Yang, H., Hou, W., & Zhang, Y. (2020). Clinical characteristics and intrauterine vertical transmission potential of COVID-19 infection in nine pregnant women: a retrospective review of medical records. *The Lancet*, *395*(10226), 809-815. https://doi.org/https://doi.org/10.1016/S0140-6736(20)30360-3

Curriero, F. C., Heiner, K. S., Samet, J. M., Zeger, S. L., Strug, L., & Patz, J. A. (2002). Temperature and mortality in 11 cities of the eastern United States. *American journal of Epidemiology*, *155*(1), 80-87.

Dadbakhsh, M., Khanjani, N., Bahrampour, A., & Haghighi, P. S. (2017). Death from respiratory diseases and temperature in Shiraz, Iran (2006–2011). *International Journal of Biometeorology*, *61*(2), 239-246. https://doi.org/10.1007/s00484-016-1206-z

Davis, R. E., Hondula, D. M., & Patel, A. P. (2016). Temperature observation time and type influence estimates of heat-related mortality in seven US cities. *Environmental Health Perspectives*, 124(6), 795-804.

Donaldson, G. C., Seemungal, T., Jeffries, D. J., & Wedzicha, J. A. (1999). Effect of temperature on lung function and symptoms in chronic obstructive pulmonary disease. *European Respiratory Journal*, *13*(4), 844-849.

Du, Z., Xu, L., Zhang, W., Zhang, D., Yu, S., & Hao, Y. (2017). Predicting the hand, foot, and mouth disease incidence using search engine query data and climate variables: an ecological study in Guangdong, China. *BMJ Open*, *7*(10), e016263. http://dx.doi.org/10.1136/bmjopen-2017-016263

Easterling, D. R., Horton, B., Jones, P. D., Peterson, T. C., Karl, T. R., Parker, D. E., Salinger, M. J., Razuvayev, V., Plummer, N., & Jamason, P. (1997). Maximum and minimum temperature trends for the globe. *Science*, *277*(5324), 364-367.

Firestone, S. M., Cogger, N., Ward, M. P., Toribio, J. A. L., Moloney, B. J., & Dhand, N. K. (2012). The influence of meteorology on the spread of influenza: survival analysis of an equine influenza (A/H3N8) outbreak. *PLoS One*, *7*(4), e35284. https://doi.org/10.1371/ journal.pone.0035284

Gardner, E. G., Kelton, D., Poljak, Z., Van Kerkhove, M., Von Dobschuetz, S., & Greer, A. L. (2019). A case-crossover analysis of the impact of weather on primary cases of Middle East respiratory syndrome. *BMC Infectious Diseases*, *19*(1), 1-10. https://doi.org/10.1186/s12879-019-3729-5

Ghalhari, G. F., & Mayvaneh, F. (2016). Effect of air temperature and universal thermal climate index on respiratory diseases mortality in Mashhad, Iran. *Archives of Iranian Medicine*, *19*(9), 0-0.

Gomez-Acebo, I., Llorca, J., & Dierssen, T. (2013). Cold-related mortality due to cardiovascular diseases, respiratory diseases and cancer: a case-crossover study. *Public Health*, *127*(3), 252-258. https://doi.org/10.1016/j.puhe.2012.12.014

Guionie, O., Courtillon, C., Allee, C., Maurel, S., Queguiner, M., & Eterradossi, N. (2013). An experimental study of the survival of turkey coronavirus at room temperature and+ 4 C. *Avian Pathology*, *42*(3), 248-252. https://doi.org/10.1080/03079457.2013.779364

Guo X-J, Zhang H, Zeng Y-P. (2020). *Transmissibility of COVID-19 and its Association with Temperature and Humidity*. https://doi.org/10.21203/rs.3.rs-17715/v1

Hoffmann, B., Hertel, S., Boes, T., Weiland, D., & Jöckel, K. H. (2008). Increased cause-specific mortality associated with 2003 heat wave in Essen, Germany. *Journal of Toxicology and Environmental Health, Part A*, *71*(11-12), 759-765.

Huang, C., Wang, Y., Li, X., Ren, L., Zhao, J., Hu, Y., Zhang, L., Fan, G., Xu, J., & Gu, X. (2020). Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *The Lancet*, *395*(10223), 497-506.

Killerby, M. E., Biggs, H. M., Haynes, A., Dahl, R. M., Mustaquim, D., Gerber, S. I., & Watson, J. T. (2018). Human coronavirus circulation in the United States 2014–2017. *Journal of Clinical Virology*, *101*, 52-56.

Kim, H., Ha, J. S., & Park, J. (2006). High temperature, heat index, and mortality in 6 major cities in South Korea. *Archives of Environmental & Occupational Health*, *61*(6), 265-270.

Kim, J., Shin, J., Lim, Y.-H., Honda, Y., Hashizume, M., Guo, Y. L., Kan, H., Yi, S., & Kim, H. (2016). Comprehensive approach to understand the association between diurnal temperature range and mortality in East Asia. *Science of the Total Environment*, *539*, 313-321.

Kissler, S. M., Tedijanto, C., Goldstein, E., Grad, Y. H., & Lipsitch, M. (2020). Projecting the transmission dynamics of SARS-CoV-2 through the postpandemic period. *Science*, *368*(6493), 860-868.

Lai, J., Ma, S., Wang, Y., Cai, Z., Hu, J., Wei, N., Wu, J., Du, H., Chen, T., & Li, R. (2020). Factors associated with mental health outcomes among health care workers exposed to coronavirus disease 2019. *JAMA Network Open*, *3*(3), e203976-e203976.

Lamarre, A., & Talbot, P. J. (1989). Effect of pH and temperature on the infectivity of human coronavirus 229E. *Canadian Journal of Microbiology*, *35*(10), 972-974.

Li, M., Zhou, M., Yang, J., Yin, P., Wang, B., & Liu, Q. (2019). Temperature, temperature extremes, and cause-specific respiratory mortality in China: a multi-city time series analysis. *Air Quality, Atmosphere & Health*, *12*(5), 539-548. https://doi.org/10.1007/s11869-019-00670-3

Li, Q., Guan, X., Wu, P., Wang, X., Zhou, L., Tong, Y., ... & Feng, Z. (2020). Early transmission dynamics in Wuhan, China, of novel coronavirus–infected pneumonia. *New England Journal of Medicine*, 382, 1199–1207.

Lin, H., Tao, J., Kan, H., Qian, Z., Chen, A., Du, Y., ... & Ma, W. (2018). Ambient particulate matter air pollution associated with acute respiratory distress syndrome in Guangzhou, China. *Journal of Exposure Science & Environmental Epidemiology*, *28*(4), 392-399. https://doi.org/ 10.1038/s41370-018-0034-0

Lin, K. U. N., Fong, D. Y. T., Zhu, B., & Karlberg, J. (2006). Environmental factors on the SARS epidemic: air temperature, passage of time and multiplicative effect of hospital infection. *Epidemiology & Infection*, *134*(2), 223-230.

Liu, K., Hou, X., Ren, Z., Lowe, R., Wang, Y., Li, R., Liu, X., Sun, J., Lu, L., Song, X. (2020). Climate factors and the East Asian summer monsoon may drive large outbreaks of dengue in China. *Environmet Research*, *183*. 109190. https://doi.org/10.1016/j.envres.2020.109190

Liu, Z., Zhang, J., Zhang, Y., Lao, J., Liu, Y., Wang, H., & Jiang, B. (2019). Effects and interaction of meteorological factors on influenza: based on the surveillance data in Shaoyang, China. *Environmental Research*, *172*, 326-332. https://doi.org/10.1016/j.envres.2019.01.053

Lowen, A., & Palese, P. (2009). Transmission of influenza virus in temperate zones is predominantly by aerosol, in the tropics by contact: A hypothesis. *PLoS currents*, *1*, RRN1002.

Lu, F., Zhou, L., Xu, Y., Zheng, T., Guo, Y., Wellenius, G. A., Bassig, B. A., Chen, X., Wang, H., & Zheng, X. (2015). Short-term effects of air pollution on daily mortality and years of life lost in Nanjing, China. *Science of the Total Environment*, *536*, 123-129.

Luo, W., Majumder, M., Liu, D., Poirier, C., Mandl, K., Lipsitch, M., & Santillana, M. (2020). *The role of absolute humidity on transmission rates of the COVID-19 outbreak*. https://dash.harvard.edu/handle/1/42639515

Ma, Y., Zhao, Y., Liu, J., He, X., Wang, B., Fu, S., Yan, J., Niu, J., Zhou, J., & Luo, B. (2020). Effects of temperature variation and humidity on the death of COVID-19 in Wuhan, China. *Science of the Total Environment*, *724*, 138226. https://doi.org/10.1016/j.scitotenv.2020.138226

Macfarlane, A. (1977). Daily mortality and environment in English conurbations. Air pollution, low temperature, and influenza in Greater London. *Journal of Epidemiology & Community Health*, *31*(1), 54-61. http://dx.doi.org/10.1136/jech.31.1.54

Martens, W. J. (1998). Climate change, thermal stress and mortality changes. *Social Science & Medicine*, *46*(3), 331-344. https://doi.org/10.1016/S0277-9536(97)00162-7

Muggeo, V. M. (2008). Modeling temperature effects on mortality: multiple segmented relationships with common break points. *Biostatistics*, *9*(4), 613-620.

National Command and Operation Center (http://covid.gov.pk/stats/punjab)

Pakistan Metreological Department. http://www.pmd.gov.pk/cdpc/Pak%20Mean%20Temp

Peng, R. D., Dominici, F., & Louis, T. A. (2006). Model choice in time series studies of air pollution and mortality. *Journal of the Royal Statistical Society: Series a (Statistics in Society)*, *169*(2), 179-203. https://doi.org/10.1111/j.1467-985X.2006.00410.x

Poole, L. (2020). Seasonal influences on the spread of SARS-CoV-2 (COVID19), causality, and forecastabililty (3-15-2020). *Causality, and Forecastabililty (3-15-2020) (March 15, 2020)*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3554746

Ren, C., Williams, G. M., Morawska, L., Mengersen, K., & Tong, S. (2008). Ozone modifies associations between temperature and cardiovascular mortality: Analysis of the NMMAPS data. *Occupational and Environmental Medicine*, *65*(4), 255-260.

Sajadi, M. M., Habibzadeh, P., Vintzileos, A., Shokouhi, S., Miralles-Wilhelm, F., & Amoroso, A. (2020). Temperature, humidity, and latitude analysis to estimate potential spread and seasonality of coronavirus disease 2019 (COVID-19). *JAMA Network Open*, *3*(6), e2011834-e2011834.

Schwartz, J. (2000). The distributed lag between air pollution and daily deaths. *Epidemiology*, *11*(3), 320-326.

Shaman, J., & Kohn, M. (2009). Absolute humidity modulates influenza survival, transmission, and seasonality. Proceedings of the *National Academy of Sciences*, *106*(9), 3243-3248. https://doi.org/10.1073/pnas.0806852106

Sharafkhani, R., Khanjani, N., Bakhtiari, B., Jahani, Y., Tabrizi, J. S., & Tabrizi, F. M. (2019). Diurnal temperature range and mortality in Tabriz (the northwest of Iran). *Urban Climate*, *27*, 204-211.

Shephard, R. J., & Shek, P. N. (1998). Cold exposure and immune function. *Canadian Journal of Physiology and Pharmacology*, *76*(9), 828-836.

Song, G., Chen, G., Jiang, L., Zhang, Y., Zhao, N., Chen, B., & Kan, H. (2008). Diurnal temperature range as a novel risk factor for COPD death. *Respirology*, *13*(7), 1066-1069. https://doi.org/10.1111/j.1440-1843.2008.01401.x

Steel, J., Palese, P., & Lowen, A. C. (2011). Transmission of a 2009 pandemic influenza virus shows a sensitivity to temperature and humidity similar to that of an H3N2 seasonal strain. *Journal of Virology*, *85*(3), 1400-1402.

Talmoudi, K., Bellali, H., Ben-Alaya, N., Saez, M., Malouche, D., & Chahed, M. K. (2017). Modeling zoonotic cutaneous leishmaniasis incidence in central Tunisia from 2009-2015: Forecasting models using climate variables as predictors. *PLoS Neglected Tropical Diseases*, *11*(8), e0005844. https://doi.org/10.1371/journal.pntd.0005844

Tan, J., Mu, L., Huang, J., Yu, S., Chen, B., & Yin, J. (2005). An initial investigation of the association between the SARS outbreak and weather: With the view of the environmental temperature and its variation. *Journal of Epidemiology & Community Health*, *59*(3), 186-192. http://dx.doi.org/10.1136/jech.2004.020180

Tosepu, R., Gunawan, J., Effendy, D. S., Lestari, H., Bahar, H., & Asfian, P. (2020). Correlation between weather and Covid-19 pandemic in Jakarta, Indonesia. *Science of the total environment*, *725*, 138436.

Van Doremalen, N., Bushmaker, T., & Munster, V. J. (2013). Stability of Middle East respiratory syndrome coronavirus (MERS-CoV) under different environmental conditions. *Eurosurveillance*, *18*(38), 20590.

Wallis, P., & Nerlich, B. (2005). Disease metaphors in new epidemics: the UK media framing of the 2003 SARS epidemic. *Social Science & Medicine*, *60*(11), 2629-2639. https://doi.org/10.1016/j.socscimed.2004.11.031

Wang, M., Jiang, A., Gong, L., Luo, L., Guo, W., Li, C., Zheng, J., Li, C., Yang, B., & Zeng, J. (2020). Temperature significant change COVID-

19 Transmission in 429 cities. *Medrxiv*. https://doi.org/10.1101/2020.02.22.20025791

WHO. (2020). *WHO characterizes COVID-19 as a pandemic*. https://www.who.int/

Wilder-Smith, A., Chiew, C. J., & Lee, V. J. (2020). Can we contain the COVID-19 outbreak with the same measures as for SARS?. *The Lancet Infectious Diseases*, *20*(5), e102-e107.

Wu, J. T., Leung, K., & Leung, G. M. (2020). Nowcasting and forecasting the potential domestic and international spread of the 2019-nCoV outbreak originating in Wuhan, China: A modelling study. *The Lancet*, *395*(10225), 689-697. https://doi.org/10.1016/S0140-6736(20)30260-9

Wu, X., Lang, L., Ma, W., Song, T., Kang, M., He, J., ... & Ling, L. (2018). Non-linear effects of mean temperature and relative humidity on dengue incidence in Guangzhou, China. *Science of the Total Environment*, *628*, 766-771. https://doi.org/10.1016/j.scitotenv.2018.02.136

Yanping, Z. (2020). The epidemiological characteristics of an outbreak of 2019 novel coronavirus diseases (COVID-19) in China. *Zhonghua liuxingbingxue zazhi*, *41*(2), 145.

Zhang Qiang, Y.X.-W., Ye, Dian-xiu, Xiao, Feng-jin, Cheng, Zheng-hong. (2004). Meteorological characteristics and their impacts during the SARS epidemic period. *Journal Nanjing Institute Meteorol*, *19*, 849–855.

Zhou, Z. X., & Jiang, C. Q. (2004). Effect of environment and occupational hygiene factors of hospital infection on SARS outbreak. *Zhonghua lao dong wei sheng zhi ye bing za zhi= Zhonghua laodong weisheng zhiyebing zazhi= Chinese Journal of Industrial Hygiene and Occupational Diseases*, *22*(4), 261-263.