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Review

Weather Variability and COVID-19 Transmission: A Review of Recent Research

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Abstract: Weather and climate play a significant role in infectious disease transmission, through changes to transmission dynamics, host susceptibility and virus survival in the environment. Exploring the association of weather variables and COVID-19 transmission is vital in understanding the potential for seasonality and future outbreaks and developing early warning systems. Previous research examined the effects of weather on COVID-19, but the findings appeared inconsistent. This review aims to summarize the currently available literature on the association between weather and COVID-19 incidence and provide possible suggestions for developing weather-based early warning system for COVID-19 transmission. Studies eligible for inclusion used ecological methods to evaluate associations between weather (i.e., temperature, humidity, wind speed and rainfall) and COVID-19 transmission. The review showed that temperature was reported as significant in the greatest number of studies, with COVID-19 incidence increasing as temperature decreased and the highest incidence reported in the temperature range of 0–17 °C. Humidity was also significantly associated with COVID-19 incidence, though the reported results were mixed, with studies reporting positive and negative correlation. A significant interaction between humidity and temperature was also reported. Wind speed and rainfall results were not consistent across studies. Weather variables including temperature and humidity can contribute to increased transmission of COVID-19, particularly in winter conditions through increased host susceptibility and viability of the virus. While there is less indication of an association with wind speed and rainfall, these may contribute to behavioral changes that decrease exposure and risk of infection. Understanding the implications of associations with weather variables and seasonal variations for monitoring and control of future outbreaks is essential for early warning systems.

Keywords: COVID-19; weather; temperature; humidity; precipitation; wind speed; seasonality

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1. Introduction

In December 2019, the World Health Organization (WHO) was alerted to cases of atypical pneumonia with unknown etiology in the city of Wuhan, Hubei Province, China. The disease, termed COVID-19 (Coronavirus Disease 2019) spread by human-to-human transmission from China throughout Asia and into Europe, North America, South America and Oceania and declared a pandemic by the WHO on 11 March 2020 [1,2]. As of 16 December 2020, over 74.7 million cases have been confirmed in 214 countries and territories, with over 1.65 million deaths recorded as a result of COVID-19 [3].The three most affected countries account for 45.7% of all cases globally and include the US, with 23% of all cases (n = 17,163,944), India with 13.3% of cases (n = 9,956,557) and Brazil with 9.4% of all cases (n = 7,040,608) and 38.5% of total global deaths from the US (18.7% n = 310,095), Brazil (11.1% n = 183,735) and India (8.7% n = 144,451) (Figure 1).

($r = 0.293$; $p = 0.019$) were significantly positively correlated with COVID-19 cases [51]. Xie and Zhu reported a significant positive correlation with mean temperature in cities in China, where each 1 °C rise was associated with a 4.861% (95%CI: 3.209–6.513) increase in COVID-19 cases when the temperature was below 3 °C [37]. Finally, in Pani et al., for the period from February 4 to May 31, average temperature ($r = 0.4$, $p < 0.01$) and minimum temperature ($r = 0.32$, $p < 0.01$) showed significant positive correlations with new and total COVID-19 cases during this period, while maximum temperature ($r = 0.40$, $p < 0.01$), minimum temperature ($r = 0.39$, $p < 0.01$) and average temperature ($r = 0.47$, $p = 0$) showed strong associations in the early phase of the outbreak from 4 February–30 April [50].

3.3.2. Humidity

Sixteen of the included studies assessed the relationship between humidity and COVID-19, measured as either absolute humidity in g/m^3 (18.8% $n = 3/16$) or relative humidity as a percentage (75% $n = 12/16$), or both absolute humidity and relative humidity (12.5% $n = 2/16$). Twelve studies (75%) reported significant associations with relative humidity, absolute humidity or both, with four studies reporting a positive correlation, six studies reporting a negative correlation and two studies reporting an optimal range of humidity for new cases.

The studies from Africa, New York, USA, Jakarta, Indonesia and one global study of 100 countries ($n = 4/16$) did not find a significant relationship between humidity and COVID-19 [32,33,43,49]. Goswami et al. reported mixed results across the regions of India, with positive associations reported in Madhya Pradesh ($r = 1.211$, $p < 0.05$) and Punjab ($r = 0.584$, $p < 0.05$); while a negative association was reported for Tamil Nadu ($r = -6.79$, $p < 0.05$), the authors also reported a significant interaction between temperature and relative humidity [45]. Qi et al. reported a significant negative association with relative humidity and cases in provinces of China, where for every 1% increase in RH, daily cases decreased in the range of 11–22% when AT was in the range of 5.04 °C to 8.2 °C [38]. The authors also reported an interaction between relative humidity and average temperature. In a multivariate analysis from New South Wales, Australia assessing 9 a.m. and 3 p.m. relative humidity, a significant association with humidity was reported, where a 1% increase in 9 a.m. humidity could increase the number of COVID-19 cases by 6.11% [42]. Wu et al. reported an inverse correlation between relative humidity and global daily new cases, where for every 1% increase in humidity, new daily cases reduced by 0.85% (95% CI: 0.51–1.19%) [31]. Alkhowailed et al. reported a weak positive correlation between average relative humidity and new cases in Saudi Arabia ($r = 0.194$, $p < 0.01$) [44]. Chien and Chen also reported a significant positive association with relative humidity in the US (RR 0.07 95%CI: 0.05–0.09) [35]. In Spain, Paez et al. reported a significant negative association between relative humidity and daily cases, with a 3% reduction in incidence per 1% increase in humidity when adjusting for population density, age and transit controls [47].

All studies assessing absolute humidity reported a significant association with COVID-19. Bukhari reported an optimal absolute humidity range, with the majority of reported cases between 1–9 g/m^3, and Huang et al. reported 73.8% of confirmed cases in regions with absolute humidity in the range of 3–10 g/m^3 [29]. Liu et al. reported a negative correlation between absolute humidity and confirmed case counts across 17 cities in China; when AH increased by 1 g/m^3, cases decreased (when adjusted for onset lag of 7 days and 14 days) RR of 0.72 (95% CI: 0.59–0.89) and 0.33 (95% CI: 0.21–0.51) respectively [36]. Zhu et al. reported varying results for absolute humidity, with significant negative correlation for daily confirmed cases reported for Pichincha ($p < 0.05$) and Rio de Janeiro ($p < 0.01$) and significant positive correlation in Santiago ($p < 0.05$) [40]. In Singapore, Pani et al. reported a weak positive correlation with minimum, maximum and average relative humidity ($r = 0.19$, $r = 0.20$ and $r = 0.21$) and COVID-19 cases ($p < 0.05$), with no significant effect during the early phases of the outbreak from February to March, this effect increased in strength with increases in relative humidity (80 ± 4%) in May. Maximum ($r = 0.27$) and