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Review

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

Hannah McClymont * and Wenbiao Hu

School of Public Health and Social Work, Institute of Health and Biomedical Innovation, Queensland University of Technology, Brisbane, QLD 4059, Australia; w2.hu@qut.edu.au
* Correspondence: n7006039@qut.edu.au

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).

correlations with COVID-19 incidence. The differences in temperature ranges could be as a result of short data sets leading to a decreased range of temperature data points over a shorter period of time, particularly during the seasonal transition from winter to spring or summer to autumn. In some regions, low case numbers and limited local transmission were reported at the beginning of the pandemic, particularly in the southern hemisphere and equatorial countries, such as Indonesia, where low case numbers were reported initially, most likely due to low testing capacity, and cases have since increased significantly [54]. Moreover, some research did not control potential confounders (Table 1) and model fit needs to be further improved.

A significant association with humidity was also reported in 66.7% of the included studies, the associations reported varied between positive and negative associations. One study reporting for every 1% increase in relative humidity, new daily cases reduced by 0.85% (95% CI: 0.51–1.19%), while another reported for every 1% decrease in absolute humidity cases decreased by 0.33 (95% CI: 0.21–0.51)—0.72 (95% CI: 0.59–0.89) [31,36].

Temperature and humidity are significant factors in virus transmission and seasonality for several reasons; firstly, these factors determine virus survivability and persistence in the air and on surfaces or fomites [55]. Generally, increased persistence of SARS-CoV-2 and similar viruses is associated with low temperatures and low relative humidity, Chan et al. reported viability of SARS-CoV of over 5 days at temperatures of 22–25 °C and relative humidity of 40–50% on smooth surfaces [56]. A recent study suggested that SARS-CoV-2 may remain viable on glass, stainless steel and banknotes for up to 28 days in optimal temperature conditions of 20 °C, with viability decreasing to 24 h at 40 °C [57]. Outside these optimal ranges, virus survivability is limited, but is sufficient for transmission, as the adaptive immune response is lacking for a previously unknown coronavirus. This leads to a second consideration for the role of weather in transmission, and that is the effect on host susceptibility, where cold dry air inhibits the innate immune response through damage to mucous membranes and slowing of mucociliary clearing [58]. The innate immune response is vital in preventing initial infection, inhibiting viral replication and in mediating the severity of the immune response and inflammation [59].

Following the initial outbreak in Wuhan, COVID-19 spread globally, with the majority of cases recorded in temperate regions in the northern hemisphere experiencing decreased temperatures and humidity [60]. This correlates with an optimal temperature range for transmission proposed by Huang et al. and Bukhari et al., where recorded cases of COVID-19 were significantly associated with temperature in the ranges of 5–15 °C or 0 °C–17 °C and absolute humidity ranges of 1–9 g/m^3 and 3–10 g/m^3 respectively in the period up to May 2020 or the early stages of spring in the northern hemisphere [29,30]. Since May, as autumn and winter began in the southern hemisphere, cases have increased significantly, particularly in India and South America. The studies included reported significant association with temperature and humidity in these regions [40,41,45,46].

The seasonal patterns of COVID-19 may be similar to influenza, where temperate northern hemisphere regions exhibit a well-defined seasonal outbreak pattern in winter, while tropical and subtropical regions may exhibit a less-defined outbreak over a longer period of time or across multiple seasons—autumn through to spring, as observed in annual influenza patterns [61]. It is vital to understand the effect of weather on COVID-19 transmission for mitigating and preventing future outbreaks, as without significant herd immunity achieved either through a vaccine or exposure or shifting to a less-virulent strain, COVID-19 is likely to continue circulating globally, exerting a significant toll on wellbeing, lives and the economy.

The initial onset or phase one of the outbreak may be delayed in warmer and wetter regions, due to the less optimal conditions for transmission but due to the infectivity of COVID-19 and the lack of existing immunity in the population; these regions will still experience significant outbreaks and mortality rates similar to temperate climates. As the pandemic has progressed, outbreaks have spread to hotter climates and throughout the southern hemisphere—this suggests that hotter countries could experience a lag in the