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# Ambient temperature and COVID-19 outcomes

The coronavirus disease 2019 (COVID-19) pandemic has affected the world in different manners [1–3]. Temperate regions tend to be affected more than tropical regions [1]. We hypothesized that the temperature difference between countries might be one of the reasons for the differences in distribution of COVID-19 as lower temperatures are considered conducive for viral respiratory illness spread in diseases such as influenza [4, 5]. In this study, we evaluated the relationship between the temperature in 15 countries and provinces and their COVID-19 incidence.

Among the countries affected with COVID-19, we obtained data from fifteen countries and provinces (Table 1) which were less than 900 square km in size and had at least 100 cases. We chose this size criterion so that there was a relatively uniform temperature throughout the country, and as to avoid bias secondary to intra-country migration of people. Population data from the 15 countries and provinces, the temperature of the country, the number of COVID-19 cases, and the deaths due to COVID-19 until August 31$^{st}$, 2020 were sorted from online platforms [2, 6, 7]. We studied minimum, maximum, mean, and diurnal temperature variation in these countries from the day of the first case in the country to August 31$^{st}$, 2020. Prior permission was obtained from the World Health Organization (WHO) for using population data available on the WHO website [2]. The data were managed and analyzed using Stata 14.0 statistical software. Quantitative variables were summarized as a median (minimum, maximum). The Pearson correlation coefficient was used to assess the correlation between temperature and COVID-19 incidence.

As of August 31$^{st}$, 2020, from the chosen countries, Singapore had the most reported COVID-19 cases (n = 56717), and Seychelles had the least (n = 131). Countries with higher temperatures were found to have lower fatality rates from COVID-19 (Pearson coefficient –0.66) as depicted in Figure 1. Similarly, the COVID-19 fatality rate had a significant negative correlation with the average minimum temperature (Pearson coefficient –0.63) and average maximum temperature (Pearson coefficient –0.67) (Figure 1). For example, a low-temperature country like San Marino (mean temperature 11.95 degree Celsius) had a higher COVID-19 fatality rate (5.72/100 people infected) compared to a higher mean temperature country such as Singapore (mean temperature 27.75 degree Celsius, 0.04/100 people infected). The higher diurnal temperature variation (temperature gradient) was also associated with an increased COVID-19 fatality rate, although with a weak correlation (Pearson coefficient 0.25). However, the COVID-19 incidence did not correlate with environmental temperature.

Our analysis demonstrated that higher temperatures might confer protection with respect to COVID-19 mortality. It has been previously shown that the incidence of influenza infection might be affected by temperature. Lower temperatures and higher diurnal variations of temperature might be associated with an increased incidence of influenza infection [5]. However, our analysis suggests no relation between incidence of COVID-19 and temperature.

This analysis has several limitations as countries are in different stages of the pandemic, and the effect of ecological differences on disease

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**Table 1. Data from several countries comparing their mean daily temperature range, mean, minimum, and maximum temperature, and respective COVID-19 incidence and case fatality.**

| Country/ province | Size [km$^2$] | Mean temperature | Mean of minimum temperature [degree Celsius] | Mean of maximum temperature [degree Celsius] | Temperature gradient (mean maximum temperature — mean minimum temperature) | Incidence/ /lac population | Incidence/ /lac/sq km | Incidence/ /lakh/sq km/day | Case fatality rate (per 100) |
|---|---|---|---|---|---|---|---|---|---|
| Cayman Islands | 240 | 27.16667 | 23.48333 | 31 | 7.516667 | 311.9199051 | 1.299666271 | 0.009152579 | 0.487805 |
| Bermuda | 50 | 23.41667 | 21.3 | 26.01667 | 4.716667 | 269.7581811 | 5.395163621 | 0.039670321 | 5.357143 |
| Gibraltar | 10 | 19.5 | 16.16667 | 22.33333 | 6.166667 | 813.2735745 | 81.32735745 | 0.542182383 | 0 |
| Barbados | 430 | 26.76667 | 22.86667 | 30.18333 | 7.316667 | 57.76424532 | 0.134335454 | 0.000980551 | 4.216867 |
| Aruba | 180 | 28.13333 | 25.91667 | 30.73333 | 4.816667 | 1730.88811 | 9.616045058 | 0.068198901 | 0.4329 |
| Sint Maarten | 34 | 26.76667 | 24.25 | 29.26667 | 5.016667 | 1035.54436 | 30.45718707 | 0.222315234 | 3.828829 |
| Isle of Man | 570 | 11.58333 | 8.65 | 14.63333 | 5.983333 | 395.1407101 | 0.693229316 | 0.005135032 | 7.142857 |
| Bahrain | 760 | 27.14286 | 25.61429 | 31.24286 | 5.628571 | 3020.201872 | 3.973949831 | 0.029656342 | 0.367769 |
| Malta | 320 | 20.83333 | 16.38333 | 24.81667 | 8.433333 | 418.5807235 | 1.308064761 | 0.0088984 | 0.541419 |
| Singapore | 700 | 27.75 | 24.625 | 30.5 | 5.875 | 971.3629721 | 1.387661389 | 0.007265243 | 0.047605 |
| Andorra | 470 | 6.216667 | 1.1 | 11.1 | 10 | 1455.317606 | 3.096420439 | 0.020371187 | 4.715302 |
| San Marino | 60 | 11.95714 | 8.357143 | 15.24286 | 6.885714 | 2161.413027 | 36.02355046 | 0.230920195 | 5.729877 |
| Turks and Caicos | 430 | 26.83333 | 24.83333 | 29.16667 | 4.333333 | 1265.593925 | 2.943241686 | 0.022640321 | 0.612245 |
| Seychelles | 460 | 27.18333 | 25.15 | 28.8 | 3.65 | 133.2018262 | 0.289569187 | 0.002083232 | 0 |
| Maldives | 300 | 28.01667 | 25.56667 | 30.73333 | 5.166667 | 1401.921028 | 4.673070092 | 0.031789592 | 0.369491 |

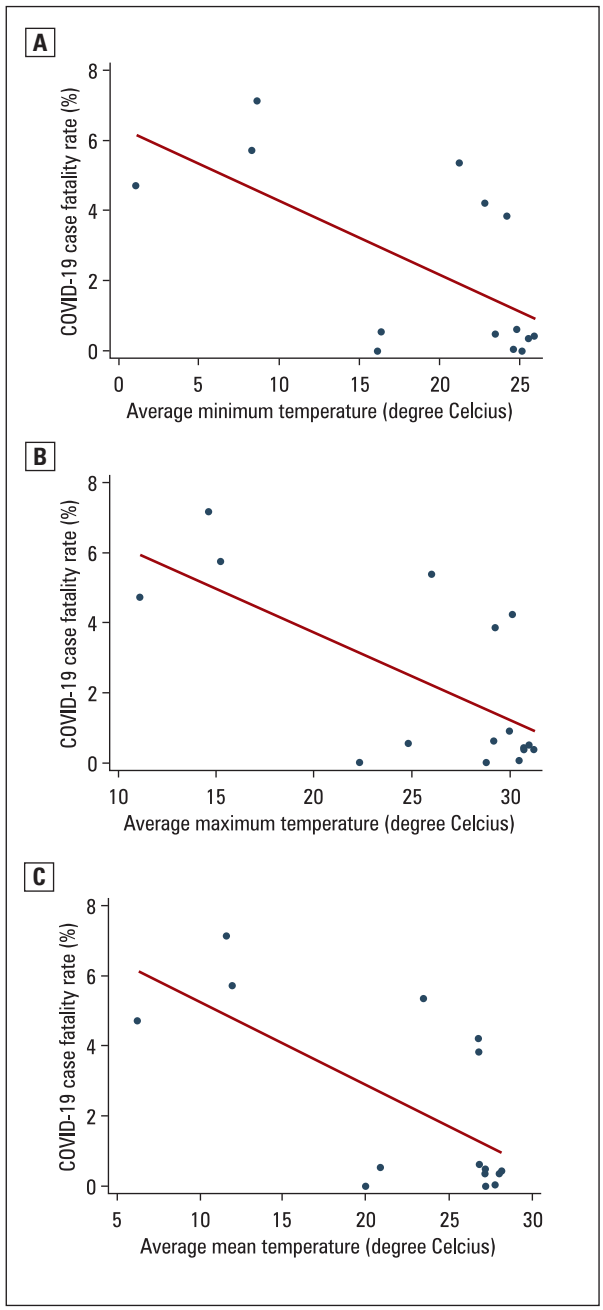


**Figure 1.** The relationship between the COVID-19 fatality rate and average minimum temperature (**A**), average maximum temperature (**B**), and average mean temperature (**C**)

transmission has not been determined. Secondly, the administrative strategies (such as testing, contact tracing, lockdown, and quarantine) for disease control differ between countries. This may affect the exact incidence of disease thus affecting our study outcomes. Some other potential factors affecting COVID-19 incidence include traveling patterns, vaccination coverage, and tuberculosis incidence, which might affect outcomes in our analysis [8]. We conclude that there might be a significant correlation between mean lower temperatures and an increased COVID-19 fatality rate. This knowledge may help to plan appropriate preventive strategies as well as incite future research into temperature correlation.

## Conflict of interest

None declared.

## References:

1. Sajadi MM, Habibzadeh P, Vintzileos A, Shokouhi S, Miralles-Wilhelm F, Amoroso A. Temperature, Humidity, and Latitude Analysis to Estimate Potential Spread and Seasonality of Coronavirus Disease 2019 (COVID-19). JAMA Netw Open. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7290414/ (16.12.2020).
2. Who.int. 2020. Coronavirus. https://www.who.int/emergencies/diseases/novel-coronavirus-2019 (5.09.2020).
3. Hussain A, Yadav S, Hadda V, et al. Covid-19: a comprehensive review of a formidable foe and the road ahead. Expert Rev Respir Med. 2020; 14(9): 869–879, doi: 10.1080/17476348.2020.1782198, indexed in Pubmed: 32529866.
4. Pahuja S, Madan M, Mittal S, et al. Weather Parameters and COVID-19: A Correlational Analysis. J Occup Environ Med. 2021; 63(1): 69–73, doi: 10.1097/JOM.0000000000002082, indexed in Pubmed: 33177471.
5. Park JE, Son WS, Ryu Y, et al. Effects of temperature, humidity, and diurnal temperature range on influenza incidence in a temperate region. Influenza Other Respir Viruses. 2020; 14(1): 11–18, doi: 10.1111/irv.12682, indexed in Pubmed: 31631558.
6. Worldometers.info. 2020. Coronavirus Update (Live): Worldometer. https://www.worldometers.info/coronavirus/ (5.09.2020).
7. Weather Online - current weather and weather forecast worldwide. Weatheronline.in. 2020. https://www.weatheronline.in/ (1.10.2020).
8. Madan M, Pahuja S, Mohan A, et al. TB infection and BCG vaccination: are we protected from COVID-19? Public Health. 2020; 185: 91–92, doi: 10.1016/j.puhe.2020.05.042, indexed in Pubmed: 32590235.