High temperature slows coronavirus disease 2019 transmission rate: A within and among country analysis

Ourania S Kotsiou (✉ raniakotsiou@gmail.com)

University of Thessaly Faculty of Medicine <https://orcid.org/0000-0001-5219-6971>

Vaios S Kotsios

National Technical University of Athens

Ioannis Lampropoulos

University of Patras

Thomas Zidros

Alexander Technological Educational Institute of Thessaloniki

Sotirios G Zarogiannis

University of Thessaly Faculty of Medicine

Konstantinos I Gourgoulialis

University of Thessaly Faculty of Medicine

Research

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Abstract

Background: The pandemic of coronavirus disease 2019 (COVID-19) is a global issue. The relationships between temperature and incidence, transmission, or survival of many enveloped coronaviruses such as severe acute respiratory syndrome (SARS), and Middle East respiratory syndrome (MERS) have been previously widely investigated. However, there has been a lively debate in the literature over whether higher temperatures modulate coronaviruses' infectivity and spreading, which sets a fertile ground for research on a global scale. In this study, we aimed to investigate the relationship between day-to-day temperature variability and daily COVID-19 incidence rate, as well as the *time is taken* to reach the total *number of* 200 confirmed COVID-19 *cases within* the worst-hit countries by the pandemic.

Methods: A *within* and *among countries* analysis of the relationship between daily fluctuations in the number of new confirmed COVID-19 cases and temperature for the period starting from 31st December 2019 to 29th March 2020, was conducted. The 46 worst-hit countries by the pandemic were included in the analysis.

Results: What emerges from our results is that daily new COVID-19 cases were negatively correlated with daily temperature variation. Moreover, higher temperatures were positively correlated with a longer time to reach a standard *number of* confirmed COVID-19 *cases within* countries. Notably, countries with daily average temperatures below 20°C had a faster transmission rate than countries with higher daily average temperatures.

Conclusions: Our study provides further insights into the hypothesis that there is an association between temperature and rate of COVID-19 spread within a country.

Background

The present outbreak of a coronavirus-associated acute respiratory disease called coronavirus disease 19 (COVID-19) caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is the third documented spillover of an animal coronavirus to humans in only two decades [1, 2]. On March 12th, 2020, the World Health Organization declared coronavirus a “pandemic” as worldwide deaths reached 4.616 in 126.122 reported confirmed cases.

A high genetic similarity has been documented between the SARS-CoV-2 identified in Wuhan, Hubei, China in December 2019, and the SARS-CoV originated in the city of Foshan, China, in November 2002. Both outbreaks started during the winter [3, 4]. In China, November to January are the coldest months of the year with an average temperature lower than 0°C that is getting lower from south to north of China, caused by the winter monsoon. Moreover, a severe drought occurred in both locations at the times of the outbreaks [4–6]. The annual rainfall in Foshan in December 2002 nearly reached 0 mm [4–6]. Coincidentally, Wuhan also suffered its worst drought in almost 40 years [4–6].

The relationship between temperature and incidence, transmission, or survival of many enveloped coronaviruses such as severe acute respiratory syndrome (SARS), and Middle East respiratory syndrome (MERS) has been previously widely investigated [7]. However, there has been a lively debate in the literature over whether higher temperatures modulate coronavirus infectivity and spreading. Recent evidence suggests that temperatures had a negative linear relationship with the number of confirmed COVID-19 cases [8–10]. Conversely, other studies do not support the hypothesis that high temperatures can reduce the transmission of COVID-19 [11]. World Health Organization supports that the COVID-19 virus can be transmitted in hot and humid climates [12]. There is still a lack of evidence on the role that weather conditions could have on the transmission rate of COVID-19 on a global scale, which could yield useful implications for policymakers and the interested public.

In this study, we aimed to investigate the relationship between day-to-day temperature variability and daily COVID-19 incidence rate, and time is taken to reach the total number of 200 confirmed COVID-19 cases within the worst-hit countries by the pandemic.

Methods

This was a within and among countries analysis investigating the association of daily fluctuations in new confirmed COVID-19 cases and temperature, for the period starting from 31st December 2019 to 29th March 2020. 46 countries with the largest number of COVID-19 cases (more than 1000 confirmed cases) were included in the analysis [13]. Data were classified into three categories according to the time elapsed from the first confirmed case.

Daily 24 hourly temperature measurements from all available monitoring stations were recorded to account for differences in the temperature within countries with a large geographic distribution, e.g., USA [14, 15]. The daily average values for temperature were found by summing the 24 hourly measurements and dividing by the number of measurements [16]. The average temperature was measured by the formula: Average temperature = sum of daily measured temperatures ÷ number of measurements, where the sum of measured temperatures was found by adding up all of the daily measurements. The average temperatures for all standard measuring stations were subsequently calculated.

Unpaired t-test was used to identify differences between two independent groups. Bivariate analyses of correlations of numerical data between groups were tested by Pearson's Correlation R. A result was considered statistically significant when the *P*-value was < 0.05. Data were analyzed and visualized using Statistical (SPSS Statistics 23) and Business Intelligence (Tableau Software LLC, Seattle, WA, USA) tools, respectively.

Results

The analysis of the day-to-day temperature variability applied to the daily fluctuations in the number of new COVID-19 cases for the most affected countries (with more than 1000 COVID-19 cases), is presented in Fig. 1 as well as in the interactive dashboard found on <https://public.tableau.com/profile/social.analytics.gr#!/vizhome/NovelCoronavirusDisease2019PandemicCasesvsTemperature/Countries1000cases>. Data were classified in three categories according to the time elapsed from the first confirmed case.

Notes. Comparison analysis between the number of daily new COVID-19 cases and day-to-day temperature variability from 31 December 2019 to 29th March 2020, for the 46 countries with the highest numbers of confirmed COVID-19 cases (> 1000 cases), by country and date of first confirmed case. The line width represents the daily average of new COVID-19 cases.

The Figure/Dashboard illustrates an impact of temperature on the rate of disease spread as countries with lower temperatures and particularly with average temperatures below 20 °C had a faster transmission rate as indicated by the number of daily new confirmed COVID-19 cases compared to countries with higher average temperatures. The effect of temperature appears to be independent of the time of the first outbreak. Spearman correlation coefficients showed that the number of daily new COVID-19 cases was negatively correlated with daily average temperature ($r = -0.4$, $p < 0.001$).

Furthermore, higher temperatures were positively correlated with a longer time to reach the targeted number of 200 confirmed COVID-19 cases within countries ($r = 0.339$, $p = 0.031$) (Fig. 2).

Notes. The correlation between the time elapsed from the first confirmed case to reach a peak of a total of 200 confirmed COVID-19 cases and average temperature occurred during that individual subperiod in each country. 46 worst-hit countries by the pandemic included in the analysis.

Overall, the countries with daily average temperatures of lower than 20 °C, had shorter time to reach the targeted number of 200 confirmed COVID-19 cases (25.31 ± 13.6 vs. 40.6 ± 24.4 , $p = 0.021$) (Fig. 3).

Notes. The time elapsed from the first confirmed case to reach a peak of a total of 200 confirmed COVID-19 cases, according to average temperature ($< 20^\circ\text{C}$ or $\geq 20^\circ\text{C}$) occurred during that individual subperiod, for each country. 46 worst-hit countries by the pandemic included in the analysis.

Discussion

This study examined the association between daily temperature variation and daily fluctuations in the number of new COVID-19 cases and on transmission rate on a global scale. What emerges from the results is a negative correlation between day-to-day temperature variability and COVID-19 incidence. Moreover, we found that warmer temperatures slowed the transmission rate, as higher temperatures were positively correlated with a longer time to reach a standard number of confirmed COVID-19 cases. Especially, countries with daily average temperatures of 0 °C – 20 °C, had a faster transmission rate compared to countries with higher daily average temperatures.

These data accord with earlier studies in this area demonstrated that ambient temperature dips increase the incidence of viral acute respiratory tract infections [3, 4 9, 10, 17]. Our findings also broadly support current observations, which showed that temperatures had a negative linear relationship with the number of confirmed cases [8, 9].

Evidence from several experimental studies has established a relationship between temperature and viral epidemics supporting that cold temperature usually provides a conducive environmental condition for virus survival. Existing research recognized a rapid decrease in MERS-CoV and SARS-CoV viability at higher temperatures [18, 19], further supported that direct contact transmission via aerosols, and not fomite transmission, would be the most likely route of zoonotic and human-to-human transmission of the viruses in outdoor settings [18, 19].

In accordance with the present results, a recent study has documented that temperature decreases spread parameters of the new COVID-19 case dynamics [20]. Chan et al. previously supported that virus viability was rapidly lost at higher temperatures (e.g., 38 °C) [21]. Furthermore, another study documented a relatively short survival of another type of coronavirus, Turkey coronavirus (TCoV), at room temperature as compared to a lower temperature (4°C), claiming the limited virus survival during summer months [22]. More recently, it has been reported that first MERS human cases in Saudi Arabia were more likely to occur when conditions were relatively cold and dry, which is similar to seasonal patterns described for other respiratory diseases such as influenza in temperate climates [23]. A different study on this topic has shown that during the epidemic, the risk of increased daily incidence of SARS was 18.18-fold higher in days with a lower air temperature than in days with a higher temperature, in Hong Kong [24] and other regions [25].

Shaw Stewart proposed four mechanisms that could be the main drivers of the seasonality of viral epidemics [26]. He suggested that winter temperatures are associated with increased crowding that might enhance viral transmission. Furthermore, he suggested that low temperatures can increase the stability of virions outside the body, the host susceptibility, and may activate dormant virions [26].

Winter conditions suppress humans' innate immune response leading to reduced blood supply and decreased availability of immune cells to the nasal mucosa. Additionally, low humidity can impair mucociliary clearance as nasal mucus becomes dry, the innate immune defense, and airway

cells' ability to repair damage; thus, the nasal cavity is vulnerable to virus invasion [27]. Therefore, relative to temperature, low humidity seems to be a critical environmental factor influencing the outbreak of human coronavirus disease.

The origin(s) of coronaviruses are still unknown; however, some general epidemic patterns are noticeable [5]. If bats were the natural hosts of SARS-CoV and SARS-CoV-2, cold temperature, and low humidity in these times might provide environmental conditions favorable for prolonged viral survival in these regions concentrated with bats [5]. The widespread existence of these bat-carried or -released viruses might have an easier time breaking through human defenses when harsh winter makes human bodies more vulnerable [5].

Nevertheless, over the years, contradictory claims have debated the impact of temperature in coronavirus infectivity. Some studies argued that high temperature and low relative humidity contributed to increased MERS-CoV spread [28]. The seasonal variation of MERS-CoV was inversely associated with temperature and relative humidity among children during MERS-endemic to the Riyadh Region [5]. In experimental conditions, the survival ability of SARS coronavirus in human specimens and environments was found to be relatively strong in various temperatures (4°C, 20°C, and 37°C) for at least 2 hours without a remarkable change in the infectious ability in cells. Only heating and ultraviolet irradiation could efficiently eliminate viral infectivity [29].

Our study provides further insights into the hypothesis that there is an association between temperature and COVID-19 spreading. A limitation of the study was that the number of confirmed coronavirus cases reported by provinces could be profoundly affected by underreporting, low number of people who got tested, and different measures of detection and prevention of SARS-CoV-2 as sampling strategies differ vastly between countries. Our design is fit for hypothesis generation to be later tested in more detail in each country's setting, taking into account other environmental parameters.

Conclusions

A debate has long prevailed as to whether lower temperatures modulate coronaviruses' infectivity and spreading. What emerges from our results is that day-to-day temperature variability correlates with the daily COVID-19 incidence rate. The countries with lower temperatures and particularly those with daily average temperatures of 0 °C – 20 °C, were found to have a faster transmission rate. Moreover, higher temperatures were positively correlated with a longer time to reach a standard number of confirmed COVID-19 cases within countries. This knowledge provides unique perspectives on health policy making. However, our data warrant further investigation of the relationship between viral susceptibility and environmental parameters. Since then, precautionary measures must be adopted to block community transmission and prevent further spread of COVID-19.

Abbreviations

COVID-19, coronavirus disease 19; MERS, Middle East respiratory syndrome; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; TCoV, Turkey coronavirus

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' Contributions

KIG, IL and OSK conceived of the presented idea. OSK edited the manuscript. IL, TZ and VSK assisted in data collection. VSK and OSK analyzed the data and produced the draft figures. KIG and SGZ critically evaluated the final draft. All authors approved the final version of the manuscript.

References

1. Spiteri G, Fielding J, Diercke M, Campese C, Enouf V, Gaymard A, et al. First cases of coronavirus disease 2019 (COVID-19) in the WHO European Region, 24 January to 21 February 2020. *Euro Surveill.* 2020;25:pii:2000178, doi: 10.2807/1560-7917.ES.2020.25.9.2000178.
2. Coronaviridae Study Group of the International Committee on Taxonomy of Viruses. The species Severe acute respiratory syndrome-related coronavirus: classifying 2019-nCoV and naming it SARS-CoV-2. *Nat Microbiol.* 2020;5:536-44, doi: 10.1038/s41564-020-0695-z.
3. Lu H; Stratton CW; Tang YW. Outbreak of Pneumonia of Unknown Etiology in Wuhan China: The Mystery and the Miracle. *J Med Virol.* 2020;92:401–2, doi: 10.1002/jmv.25678.
4. Sun Z, Thilakavathy K, Kumar SS, He G, Liu SV. Potential Factors Influencing Repeated SARS Outbreaks in China. *Int J Environ Res Public Health.* 2020;17:pii:E1633, doi: 10.3390/ijerph17051633.
5. China Weather Network, 6 May 2010. Drought stress in 2002. <http://www.weather.com.cn/drought/ghsj/2002/05/443027.shtml>. Accessed 25 May 2020.
6. Wuhan Weather News. The average rainfall in Wuhan in December was 26 millimeters, and there were only scattered light rain on the 3rd. 2020. <https://weather.mipang.com/wuhan/news1549253.html#>. Accessed on 29 May 2020.
7. Prussin AJ^{2nd}, Schwake DO, Lin K, Gallagher DL, Buttling L, Marr LC. Survival of the Enveloped Virus Phi6 in Droplets as a Function of Relative Humidity, Absolute Humidity, and Temperature. *Appl Environ Microbiol.* 2018;84:pii: e00551-18, doi: 10.1128/AEM.00551-18.
8. Prata DN, Rodrigues W, Bermejo P. Temperature significantly changes COVID-19 transmission in (sub)tropical cities of Brazil. *Sci Total Environ.* 2020;729:138862, doi: 10.1016/j.scitotenv.2020.138862.
9. Xie J, Zhu J. Association between ambient temperature and COVID-19 infection in 122 cities from China. *Sci Total Environ.* 2020;72:138201, <https://doi.org/10.1016/j.scitotenv.2020.138201>.
10. Tosepu R, Gunawan J, Effendy DS, Ahmad OAI, Lestari H, Bahar H, et al. Correlation between weather and Covid-19 pandemic in Jakarta, Indonesia. *Sci Total Environ.* 2020;725:138436, doi: 10.1016/j.scitotenv.2020.138436.
11. 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.* 2020;55:2000517, doi:10.1183/13993003.00517-2020.
12. World Health Organization. Coronavirus disease (COVID-19) advice for the public: Myth busters. 2020. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public/myth-busters?gclid=CjwKCAjwztL2BRATEiwAvnALcvmxAfoepSwugW0ouqECya09KXlcsA6hYipi-VUnJBZ7m-Z3TtJ0dhoCFogQAvD_BwE#climate_ Accessed 25 April 2020.
13. Johns Hopkins Coronavirus Resource Center. 2020. Johns Hopkins University & Medicine. 2020. <https://coronavirus.jhu.edu/map.html>. Accessed 29 May 2020.
14. National Oceanic and Atmospheric Administration. 2020. <https://www.ncei.noaa.gov/access/search/data-search/global-summary-of-the-day>. Accessed 29 May 2020.
15. AccuWeather: Local, National, & Global Daily Weather Forecast. 2020. <https://www.accuweather.com/>. Accessed 29 May 2020.
16. S. Department of Commerce Weather Bureau. 1949. The Climatic Handbook for Washington, DC, Weather Bureau Technical Paper, No. 8, p. 4.
17. Shi P, Dong Y, Yan H, Li X, Zhaom C, Liu W, et al. The impact of temperature and absolute humidity on the coronavirus disease 2019 (COVID-19) outbreak evidence from China. *MedRxiv.* 2020, doi: <https://doi.org/10.1101/2020.03.22.20038919>
18. Leclercq I, Batéjat C, Burguière AM, Manuguerra JC. Heat inactivation of the Middle East respiratory syndrome coronavirus. *Influenza Other Respir Viruses.* 2014;8:585-6, doi: 10.1111/irv.12261.
19. van Doremalen N, Bushmaker T, Munster VJ. Stability of Middle East respiratory syndrome coronavirus (MERS-CoV) under different environmental conditions. *Euro. Surveill.* 18, pii: 20590. Erratum in: *Euro. Surveill.* 2013;18:pii/20599.
20. Demongeot J, Flet-Berliac Y, Seligmann H. Temperature Decreases Spread Parameters of the New Covid-19 Case Dynamics. *Biology (Basel).* 2020;9:pii: E94, doi: 10.3390/biology9050094.
21. Chan KH, Peiris JS, Lam SY, Poon LL, Yuen KY, Seto WH. The Effects of Temperature and Relative Humidity on the Viability of the SARS Coronavirus. *Adv Virol.* 2011;734690, doi: 10.1155/2011/734690.
22. Guionie O, Courtillon C, Allee C, Maurel S, Queguiner M, Etteradossi N. An experimental study of the survival of turkey coronavirus at room temperature and +4°C. *Avian Pathol.* 2013;42:248-52, doi: 10.1080/03079457.2013.779364.
23. Gardner EG, Kelton D, Poljak Z, Van Kerkhove M, von Dobschuetz S, Greer AL. A case-crossover analysis of the impact of weather on primary cases of Middle East respiratory syndrome. *BMC Infect Dis.* 2019;19:113, doi: 10.1186/s12879-019-3729-5.
24. Lin K, Fong DYK, Zhu B, Karlberg J. Environmental factors on the SARS epidemic: air temperature, passage of time and multiplicative effect of hospital infection. *Epidemiol Infect.* 2006;134:223–30, doi: 10.1017/S0950268805005054.
25. 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.* 2006;34:234–6, doi: 10.1016/j.ajic.2005.12.006.

26. Shaw Stewart PD. Seasonality and selective trends in viral acute respiratory tract infections. *Med Hypotheses*. 2016;86:104-19, doi: 10.1016/j.mehy.2015.11.005.

27. 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 USA*. 2019;116:10905–10, doi: 10.1073/pnas.1902840116.

28. Altamimi A, Ahmed AE. Climate factors and incidence of Middle East respiratory syndrome coronavirus. *J Infect Public Health*. 2019;pii: S1876-0341(19)30351-X, doi: 10.1016/j.jiph.2019.11.011.

29. Duan SM, Zhao XS, Wen RF, Huang JJ, Pi GH, Zhang SX, et al. SARS Research Team. Stability of SARS coronavirus in human specimens and environment and its sensitivity to heating and UV irradiation. *Biomed. Environ Sci*. 2003;16:246-55.

Figures

Figure 1

Comparison analysis between the number of daily new COVID-19 cases and day-to-day temperature variability Notes. Comparison analysis between the number of daily new COVID-19 cases and day-to-day temperature variability from 31 December 2019 to 29th March 2020, for the 46 countries with the highest numbers of confirmed COVID-19 cases (>1000 cases), by country and date of first confirmed case. The line width represents the daily average of new COVID-19 cases.

Figure 2

Correlation between the time to reach a peak of COVID-19 cases and temperature Notes. The correlation between the time elapsed from the first confirmed case to reach a peak of a total of 200 confirmed COVID-19 cases and average temperature occurred during that individual subperiod in each country. 46 worst-hit countries by the pandemic included in the analysis.

Figure 3

The time to reach the total number of 200 confirmed COVID-19 cases according to average temperature occurred during that period, in the 46 worst-hit countries by the pandemic. Notes. The time elapsed from the first confirmed case to reach a peak of a total of 200 confirmed COVID-19 cases, according to average temperature (<20°C or ≥20°C) occurred during that individual subperiod, for each country. 46 worst-hit countries by the pandemic included in the analysis.