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Nexus between temperature and COVID-19 pandemic: A meta-analysis

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Abstract: Background: After the outbreak of the novel coronavirus (COVID-19) pandemic, the impact of temperature became a debatable issue among researchers and policymakers. Extant research has examined the relationship between COVID-19 pandemic and temperature; however, existing research remains inconclusive so far. Hence, current research aims to synthesize these mixed findings to confirm the relationship between temperature and the COVID-19 outbreak and determine the possible causes of inconclusive findings in prior research. Methods: For this meta-analysis, we retrieved the empirical studies from Scopus and Web of Science using the keywords "temperature," "SARS-COV-2," and "COVID19". Following PRISMA guidelines, we have selected 63 studies that have reported the correlation coefficient values between temperature and COVID-19 pandemic. Results: Our study fails to find a significant association between COVID-19 pandemic and temperature. We find that healthcare resources, COVID-19 response strategies, and climate zones play a moderating role in the relationship between COVID-19 and temperature. Conclusion and Implications: Our findings help the health practitioners and policy makers in combating the COVID-19 pandemic. Current research fails to establish the direct association between temperature and COVID-19; hence our findings suggest that instead of relying on meteorological indicators, policymakers need to utilize health care resources better and effectively execute Covid-19 strategies.

Keywords: COVID-19; temperature; meta-analysis

1. Introduction

A number of recent literature have researched the impact of temperature in the spread of COVID-19 in different contexts. Both laboratory and epidemiological studies report that the effect of temperature over COVID-19 outbreak cannot be ignored and their conclusion remains controversial [1-5]. On the one hand, temperature is credited with the spread of COVID-19 [6-8]; whereas a significant number of studies indicated that COVID-19 outbreak will be inversely impacted by the summer temperature on the other hand [9-11]. Prata, *et al.* [12] explored the COVID-19 outbreak in 27 states of Brazil to indicate a negative linear association with temperature and number of confirmed cases. On the contrary, a number of research studies also implied the contradictory findings to conclude that COVID-19 transmission is not affected with temperature fluctuations as number of travelers, age and population density are most dominant indicators [13,14]. Another study by Yao et al., 2020 stated no association between covid-19 outbreak with UV radiation or temperature in 224 Chinese cities. Likewise, Jahangiri, *et al.* [15] reported that COVID-19 transmission had low sensitivity to temperature in Iran. Thus, the contemporary research on relationship between COVID-19 pandemic and temperature is inconclusive and our study aims to meta-analysis these inconclusive studies.

The investigations of viral outbreaks such as COVID-19 is impacted by a number of moderating variables. Current investigations broaden this discussion by investigating the moderating impact of climate zones, healthcare resources and coronavirus resilience. First, climate conditions impact the way humans live and can have direct/indirect impact. The second moderating variable included by current research is the availability of health care resources to combat the surge of COVID-19 outbreak. Our third moderating indicator of coronavirus resilience explored the association between COVID-19 and, lockdown severity, community mobility, impact on economic growth, universal healthcare coverage and human development index. Our study fails to find a significant association between COVID-19 pandemic and temperature. We find that healthcare resources, COVID-19 response strategies, and climate zones play a moderating role in the relationship between COVID-19 and temperature.

Rest of the study as follows, section 2 presents the methods, section 3 provides the results of the study, and section 4 provides the discussion and concludes the study.

2. Methods

In order to address possible variations, different combinations of keywords are used here to find studies that investigate the relationship between COVID-19 and temperature. These keyword phrases are "COVID-19" OR Coronavirus OR "Corona virus" OR Coronaviruses OR "2019-nCoV" "COVID-19 pandemic" and temperature. Several databases and editorial sources such as the ScienceDirect, ISI Web of Science, Blackwell, Emerald, EJS, ABI Inform, and EBSCO. Furthermore, in order to find out more studies in this field, the references of related and recent studies are accessed. Following inclusion criteria will use to finalize the studies for this meta-analysis.

Empirical studies that explore the relationship between COVID-19 and temperature.

Studies that report the correlation value (r).

Until now through the extensive literature search, we find a total of 41 studies that meet the inclusion criteria.

Our study employs the meta-analysis method of Hunter and Schmidt [16], we have calculated the mean correlation value and Z statistics for testing the hypothesis of our study. Our study has also examined the moderating role of the climate zones, healthcare resources, and COVID-19 response strategies of the Governments on the relationship of COVID-19 and temperature. We have classified the climate zones into tropical, sub-tropical, and temperature zones among our selected studies. For healthcare resources, we have calculated an index of country's number of doctors, nurses, and beds per 1000 population form World Development indicators. We have constructed the index by mean values of three factors average score in last ten years. We have classified the countries into high and low healthcare resources based on the median value of the country's healthcare index score. The countries in our selected studies that have healthcare index score above median value are treated as *high healthcare resources* countries, whereas countries with healthcare index score below median value are treated as *low healthcare resources* countries. Finally, for COVID-19 response strategies, we classified the countries into effective and ineffective responses based on the median value of the country's Bloomberg COVID-19 resilience score. The countries in our selected studies that have Bloomberg COVID-19 resilience score's above median value are treated as *effective COVID-19 response countries*, whereas countries with Bloomberg COVID-19 resilience score's below median value are treated as in*effective COVID-19 response countries.*

In additional analysis we have classified our findings based on specific context and cross-country context. Further we have classified the countries based on proxies of COVID-19 (cases and deaths) and temperature (average, maximum, and minimum). Table 1 provides main results of the study. We failed to identify significant relationship between temperature and COVID-19 pandemic in all country scenario. However, the relationship between temperature and COVID pandemic cases in single country scenario is significantly positive whereas the relationship is significantly negative in cross country setting.

The relationship between temperature and COVID pandemic is insignificant in total COVID-19 cases, COVID-19 new cases and aggregate COVID-19 cases. Temperature and COVID pandemic relationship is also insignificant in case of daily new deaths, total deaths and aggregate deaths.

Table 1. Main results.

Results	Sample (N)	Mean Correlation	Observed variance	Estimate error variance	Standard deviation	Z statistics
Overall	282	0.026	0.165	0.583	0.024	1.087
Single country	163	0.099	0.173	0.315	0.033	3.057
Cross country	119	-0.109	0.123	0.205	0.032	-3.37
Total COVID-19 cases (a)	110	0.086	0.24	0.372	0.047	1.838
COVID-19 new cases (b)	101	-0.037	0.106	0.135	0.032	-1.14
Aggregate COVID-19 cases (a+b)	211	0.020	0.171	0.477	0.029	0.693
Daily new deaths (c)	18	-0.024	0.123	0.021	0.083	-0.29
Total deaths (d)	53	0.082	0.154	0.09	0.054	1.521
Aggregate Deaths (c+d)	71	0.046	0.146	0.105	0.045	1.008

Table 2 provides the moderation analysis results. We find that there is significant positive relationship between temperature and COVID pandemic in tropical climate zone countries. Whereas the relationship is insignificant in subtropical and temperature climate zone countries. Countries having high health care resources have shown insignificant relationship between temperature and COID pandemic. More interestingly this relationship is significantly positive in low health care resources countries. Countries who have effectively implement response strategies for COVID-19 pandemic have shown significant positive relationship between temperature and COVID pandemic. Whereas the relationship is insignificant in the countries where enforcement of response strategies is ineffective.

Table 2. Moderation Analysis.

Results		Sample (N)	Mean Correlation	Observed variance	Estimate error variance	Standard deviation	Z statistics
Climate Zone	Tropical	62	0.203	0.138	0.107	0.047	4.298*
	Subtropical	77	0.061	0.162	0.155	0.046	1.332
	Temperature	24	-0.051	0.226	0.05	0.097	-0.53
Healthcare resources	High	88	0.053	0.162	0.137	0.043	1.233
	Low	163	0.099	0.173	0.315	0.033	3.057*
COVID response strategies	Effective	54	0.229	0.117	0.111	0.046	4.925*
	Ineffective	117	0.072	0.187	0.225	0.04	1.798

5. Conclusions

The current study conducts the meta-analysis of mixed findings regarding the association between the COVID-19 pandemic and temperature. Our study fails to document a clear and significant relationship between COVID-19 pandemic and temperature. Our study finds that context of the study, climate zones, healthcare resources, and COVID-19 response strategies significantly influence above relationship. Our study provides the implications for the policymakers and regulators to make decision regarding the role of temperature while looking at the spread of COVID-19. We also encourage the upcoming studies to use big data analytics and artificial intelligence to examine the nexus between COVID-19 and temperature.

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