JCHR

Journal of Community Health Research 2021; 10(3): 270-280.

Effect of Ambient Temperature on the Spread of COVID-19: A Systematic Review

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ARTICLE INFO

Review Article

Received: 20 April 2020
Accepted: 28 August 2021

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ABSTRACT

Introduction: So far, the so many people has been infected by novel coronavirus (SARS-CoV-2) in the worldwide and almost all the countries have reported infected and death cases. Some studies have shown that coronaviruses are sensitive to air temperature and in warm temperature the rate of spread decreases. This study aimed to review the literature whether or not the temperature can affect the spread rate of COVID-19.

Methods: In this study, three main scientific electronic databases, including Scopus, PubMed, Web of Science and also Scholar Google were searched on April 14, 2020 to find relevant studies on COVID-19 and its spread in different ambient temperature.

Results: Totally 588 articles were found for screening and 27 articles were selected for data extraction. The result of some of these studies showed that weather variations can affect transmission of coronavirus. Low temperature and low humidity may be essential factors for survival of coronaviruses. A temperature of 4°C is ideal for the life of this virus and it may be sensitive to 70°C temperature. The increase in temperature of stainless steel, wood, fabrics, and metal can eliminate and remove coronaviruses according to the findings of some of these reviewed articles.

Conclusion: This review study failed to precisely report the effect of temperature or humidity to stop the virus from spreading and transmitting. It is required to conduct more studies in this regard to introduce the exact pattern of transmission by examining the conditions of virus transmission in different climatic conditions.

Keywords: Systematic Review; Coronavirus; Temperature, Environmental Factors

How to cite this paper:
Heydari A, FallahAliabadi S, Habibi P. Effect of Ambient Temperature on the Spread of COVID-19: A Systematic Review. J Community Health Research 2021; 10(3): 270-280.

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[DOI: 10.18502/jchr.v10i3.7284]

Introduction

Since December 2019, the first outbreak of COVID-19 reported in Wuhan city(1). According to the World Health Organization (WHO) reports, on 24th march 2020, the total globally confirmed cases were 372757 and the total confirmed deaths were 16,231 and 195 countries were infected, causing global negative effects (2). Given that this coronavirus is highly contagious and its diagnosis, prevention, and control is a great challenge . The death number because of COVID-19 was reported to be unbalanced in different countries (3, 4). The pattern of outbreak of many viral infectious diseases has been affected by change in environmental patterns (5). Some studies on environmental subjects, such as climatic and weather condition, have found that climatical factors can affect the space and time correlations of viral diseases (6). The humidity and air temperature are important indicators in spread of influenza outbreaks in tropical countries (7). Environmental factors are often defined based on air temperature. Moreover, relative humidity, radiation, pressure at ground level, wind speed, snowfall and rain amount are the basic environmental and climatical variables that can affect the outbreak of COVID-19 in different places (8, 9). Finfing the correlation of metrological factors and the spread of COVID-19 is a key issue to predict the outbreak and the end time of epidemic (10). Some previous researches have been studied to find the relationship between environmental conditions and coronavirus epidemics. For instance, a study confirmed that the severe acute respiratory syndrome (SARS) outbreaks had a significant inverse association with temperature and its variations (11, 12). According to the similarity of SARS (13) and COVID-19, it has pointed out that high temperature will weaken the activity of SARS-COV-2 (14). Although many researches have been done on investigating the role of environmental indicators on outbreak of coronaviruses, limited studies have been done to investigate the effect of temperature and humidity on COVID-19. Therefore, the aim of this study is to identify and quantify the relationship between environmental factors and 2019-nCOV spread through a systematic review.

Methods

Bibliography search strategy

This systematic review study was performed based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (15) (16).

Three main databases including PubMed, Scopus, Web of Science, were searched for articles published from 2019 to April 14, 2020. Also Google Scholar has been searched by hand-searching. All the search terms related to the ‘COVID-19’ were found by the PubMed Mesh system, as well as an expert’s opinion on synonyms of key-words in combination with "temperature". The search strategy was developed by keywords and their synonyms and were searched in title, abstract, or keyword fields in scientific databases. Also, to find more relevant documents the reference lists of the included documents were investigated by hand-searching. The following search strategy were used to find the relevant documents in databases:

PubMed: (coronavirus[tiab] OR covid*[tiab] OR 2019-nCoV[tiab] OR COVID-19[tiab]) AND (weather*[tiab] OR temperature*[tiab] OR heat*[tiab] OR hot[tiab] OR warm*[tiab] OR cold[tiab] OR heat*[tiab])

Eligibility criteria

The “PICO” strategy for systematic exploratory review was: P (individuals), I (temperature), C (COVID-19), and O (COVID-19 outbreak).

The inclusion criteria of the articles included if they (a) were peer review articles; (b) were conducted on environmental factors; (c) were about the COVID-19; (d) were about the impacts of temperature on COVID-19; (e) consisted of comparison of outbreak among countries or regions.

The exclusion criteria of the articles included if (a) they were about mortality and morbidity because of SARS, Middle East Respiratory Syndrome (MERS), and influenza; (b) they were

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[DOI: 10.18502/jchr.v10i3.7284]

concluded based on SARS, MERS, and influenza findings; (c) they were published before December, 2019; (e) full-text articles or conference papers were not available.

Study selection

All of the founded documents were exported to EndNote sprograme, then the duplicated documents were identified and removed. One of researchers (PH) screened the documents according to their title and abstract, and study selection and data extraction were conducted by two investigators (AH and PH) from the eligible studies independently by reviewing the full-text. The disagreement between the two investigators on inclusion and exclusion of studies was resolved by the research team consensus.

Data extraction and quality assessment

After conducting screening, two checklists were applied for the data extraction. The first checklist consisted of the included articles information, including the first author name, publication year, document type, the methodology, objective, and quality score. The second checklist was used in order to gather the findings. The methodological quality assessment of the included studies was prepared using a researchers-made checklist. The quality assessment of the included studies was done by two independent reviewers (SF and AH) using a 16-items, quality appraisal checklist (QATSDD). This checklist shows a good reliability and validity in the quality assessment of studies diversity (17). Any disagreement between reviewers was resolved by the research group consensus.

Results

Search Results

The process of screening and selection of identified researches presented in Figure 1. 589 documents were found through electronic search resulted.

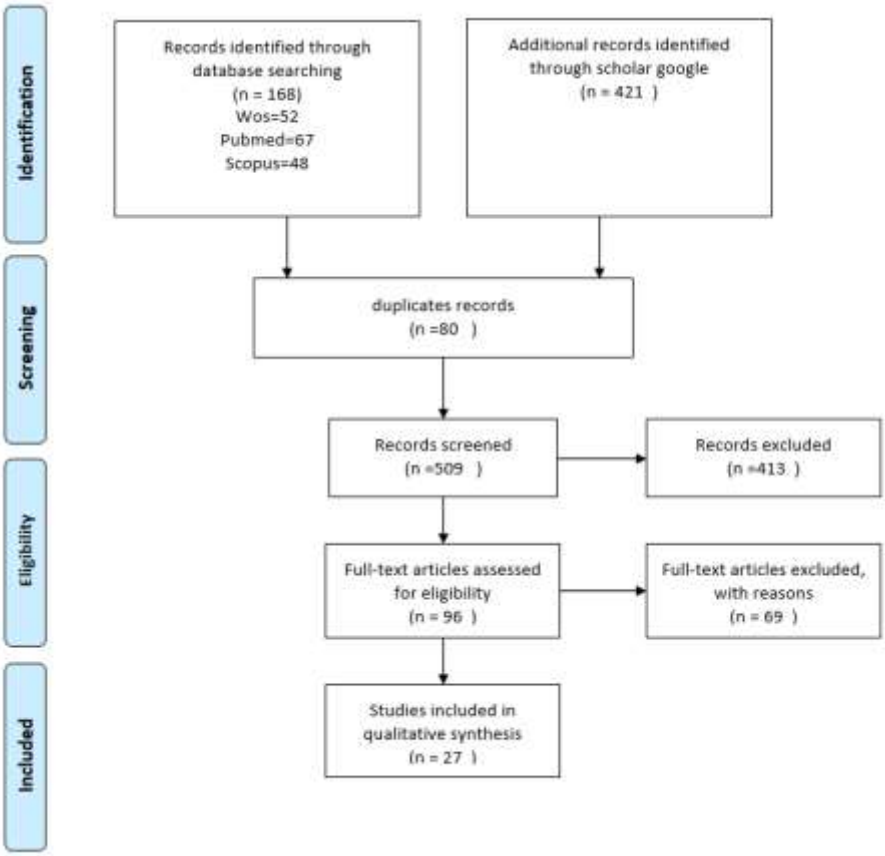

Figure 1. Flow diagram of the search and selection and screening of studies

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[DOI: 10.18502/jchr.v10i3.7284]

Table 1. Characteristics of studies included in the systematic review

	Author and year	Country	Methodology	Meteorological factor(s)	Study objective	Quality score
1	Cai et al. (2020)(١٨)	China	Case Study	Air temperature	To study whether the Ambient Temperature can affect the survival of COVID-19 cases	34
2	Wang et al, (2020)(19)	China	Case Study	Humidity and temperature	The relationsheep between Temperature and Humidity in Reducing the Transmission of COVID-19	30
3	He et al (2020) (20)	China	Simulations	Temperature	Investigating the Molecular mechanism of evolution and human infection of 2019-nCoV	35
4	Alrousan et al (2020)(9)	China	Case Study	Temperature, humidity, win speed, radiation	Investigating the effect of the variation of environmental variables and geographical nature on the spreading of the novel 2019-nCoV coronavirus epidemic	35
5	Lou et al (2020) (21)	China	Case Study	Humidity and temperature	To investigate the effect of humidity on transmission of COVID-19	33
6	Poirier et al (2020)(22)	China	Case Study	Humidity and temperature	To investigate the effect of environmental factors on transmission of COVID-19	32
7	Oliveiros et al (2020) (23)	China	Cross-Sectional	Temperature and humidity	To evaluate the meteorological impact on COVID-19 duplication time.	33
8	Mao et al (2020) (24)	China	Simulation	Temperature and humidity	To examine the effect of different temperature on the man-man transmission of COVID-19	35
9	Pang et al (2020)(7)	China	Ecological study	Humidity and temperature	To examine the effect of temperature and absolute humidity on the coronavirus disease	35
10	Nazari Harmooshi et al (2020)(25)	Iran	Review	Humidity and temperature	To survey the role of environment on transmitting and survival of COVID-19	30
11	Xie et al (2020)(26)	China	Case Study	Temperature	To examine the effect oftemperature on infection of novel coronavirus	35
12	Tosepu et al (2020)(27)	Indonesia	Case Study	Temperature and humidity amount of rainfall	To survey the relationsheep of weather and covid-19	32
13	Moghadami, et al (2020)(28)	Iran	Simulation	Environmental conditions	To predict future values of regular time series from weighted averages of past daily values of the series	30

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14	Ma et al (2020)(29)	Iran	Case Study	Temperature, humidity, and diurnal temperature	To survey the temperature, humidity, and diurnal temperature range on the daily death counts of COVID-19	37
15	Jamil et al (2020(30)	Saudi Arabia	Case Study	Temperature	To survey the association of apparent exponential rate of SARS39 CoV-2 spread and the Basic Reproductive number of infection and the average daily temperature	29
16	Bannister et al (2020) (31)	Australia	Case Study	Temperature	Gathierin preliminary data on seasonal variation in COVID-19 outbreak	36
17	Harbert et al (2020)(32)	United States	Simulation	Temperature precipitation, solar radiation, wind speed, and water vapor pressure	To Model the SARS-CoV-2 spread association with climatic variables	33
18	Chin et al (2020) (33)	China	Letter to editor	Temperature	tTo investigate the stability of SARS-CoV-2 in various environmental conditions	34
19	Baker et al (2020)(34)	China	Simulation	Humidity and temperature	To examine the climatical factors onbeta coronavirus transmission	31
20	Alvarez-Ramirez et al (2020)(35)	China	Case Study	Temperature and humidity	To determine the association of environmental factors (and COVID-19	32
21	Notari (2020)(36)	Spain	Case Study	Temperature	To understand effect of growth rate of the confirmed cases on the population decrease by increasing temperature	32
22	Sajadi et al (2020) (37)	Iran	Case Study	Humidity and temperature	To know if SARS-CoV-2 a seasonal respiratory virus and can its spread be predicted	35
23	Islam et al (2020) (38)	United Kingdom	Case Study	Humidity, temperature and wind	To investigate the effect of meteorological factors on the COVID-19 outbreak	34
24	Anis (2020)(39)	Australia And Egypt	Simulation	Temperature	To predict the future of the virus spread during the upcoming seasons	30
25	Bukhari et al (2020) (40)	United States	Case Study	Humidity and temperature	To explore the role (if any) of weather in the transmission of coronavirus	36
26	Araujo et al (2020)(41)	Portugal	Simulation	Temperature and precipitation conditions	To minimize uncertainties related with spread of SARS CoV-2, providing critical information for anticipating the adequate social, economic and political responses	35
27	FICETOLA ET AL (2020)(42)	Italy	Case Study	Humidity and temperature	To assess the role of temperature and humidity on the global patterns of COVID-19	28

Note; AT= air temperature

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[DOI: 10.18502/jchr.v10i3.7284]

Descriptive statistics

Finally, 27 eligible and relevant studies out of 588 studies were identified for data extraction, which presented weather variations, including air temperature, relative humidity, precipitation, wind speed, and infrared radiation, as well as type of transmissibility of the coronavirus. The results of these studies showed that weather variations affected coronavirus. From the data abstraction undertaken based on the adopted keywords; 27 selected studies were grouped into major theme parameters. They include environmental factors and the effect of these variables on the spread and transmission of COVID-19 among population and the ways to prevent it. Climatic conditions refer to a set of conditions distinguishing a large area from another. In each climate, there are specific geographical conditions in that area, including the distance above sea level and longitude and latitude, which can cause particular climatic conditions. The humid area is the area that wet bulb temperature higher than 28 ℃ is a minimum temperature that can cool the air at constant pressure by evaporating water. There are different climatic conditions throughout the world, including warm-dry, warm-semi humid, hot-humid, mild-dry, and mild-humid.

Relationship between the spread of COVID-19 and environmental factors

Surveying the extracted articles through the current systematic review, different approaches were found to examine the relationship between the number of patients infected with the coronavirus and environmental conditions. In these studies, it was mentioned that COVID-19 is likely to increase through human exposure and also, sometimes cold weather due to the effect of this virus on the respiratory system (32). Exposure to cold environment can induce hormonal changes, which might directly or indirectly alter the immune system (18). As shown in some of the extracted articles, there was a significant relationship between the confirmed cases of COVID-19 and ambient temperature (18, 21, 26, 29, 31, 36, 38, 41, 42). Oliveiros et al. and Ficetola et al. stated that with the onset of warm seasons, such as spring and summer, the progression rate of COVID-19 is expected to be slower. Warm seasons results in higher temperature and more hot days; therefore, it is expected to see the mortality of the confirmed and severe cases would averagely decrease (23, 42). Also, the results showed that continuous warm-dry weather, such as the temperature range from 13°C to 19°C and relative humidity from 50% to 80% are suitable for the survival and transmission of this new coronavirus, and this climatic condition is conducive to the survival of the 2019-nCoV (23). However, Anis confirmed that the appropriate average temperature for virus activity and transmission ranges between 13°C to 24 °C (39).

Mao et al. showed that the virus is highly sensitive to high temperature; since it prevents the virus spreading and strongly affects the transmission of the disease. In general, the transmission and survival of coronaviruses has been affected in low temperature and low humidity . It has been indicated that the recent temperature drop in China might pose important effect on possible reversal of the epidemic. Every 1℃ increase in the minimum temperature decreased the number of cases, and there was a significant correlation between temperature and the transmission of COVID-19 ($p<0.0001$)(24). Zhu and Xie stated that the relationship between mean temperature and COVID-19 in the confirmed cases was approximately linear in the range of lower than 3 °C and became flat above 3 °C. When mean temperature was below 3 °C, each 1 °C rise was associated with a 4.861% increase in the daily number of the COVID-19 confirmed cases (26).

In some studies, the effect of humidity has been investigated on virus growth or transmission (19, 21-23, 29, 37, 38, 41). In the study conducted by Wang et al. the results showed that, relative humidity can significantly affect the spread of COVID-19. In warm and humid environments (28 °C and 85% RH), humidity and heat caused a reduction in the coronavirus transmission among the population with different hot-humid climatic conditions. Death and infection of the patients in human or human-to-human transmission have been

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[DOI: 10.18502/jchr.v10i3.7284]

attributed to low radiant and air temperatures, as well as relative humidity (19). However, in a study, Tosepu et al. mentioned no evidence for the relationship between humidity and rainfall amount with COVID-19 pandemic (27).

Chin et al. reported that the virus is highly stable at 4°C; however, it is sensitive to heat and when the temperature increases to 70°C, the time for the virus inactivation reduces to 5 minutes (33). The increase in air temperature can eliminate and remove these coronaviruses survived for a shorter time on different surfaces, such as stainless steel, wood, fabrics, and metal (23).

The results of the study conducted by Al-Rousan et al. showed that the short wave radiation and temperature were the most effective variables, and the confirmed cases were mostly affected by weather variables. The level of radiation and its wavelength or the spectral content received by the virus affects the radiation intensityIn addition to this effective factor, there are other 8 environmental variables considered in this study, including air temperature, relative humidity, pressure at ground level, wind speed, wind direction, rainfall rate, snowfall rate, and snow depth (9).

In some studies the relationship between environmental conditions and the epidemic has been declined or questioned (25, 30, 40). A study concluded that there is no significant relationship between absolute humidity and COVID-19; however, lower and higher temperatures may decrease the COVID-19 spread (7). Therefore, in countries and regions around the world where the COVID-19 can spread , the government and organizations should adopt the strictest control measures to prevent future reversal (24, 34). The lack of data about the virus behavior is a reason that makes it difficult to predict the relationship between seasonal patterns and climatic conditions (14). Also, conducting more research studies in future may solve the problem and determine the hidden aspects of the subject (32)

Discussion

Since late 2019, the new coronavirus has been identified in China, and gradually has spread to most countries around the world, killing many people. The virus transmits by contacting with an infected person or touching infected surfaces. In the present study, scientific articles that stated the effect of climatic variables on the growth and spread of coronavirus were introduced and the relationship between these variables and this type of virus were investigated. As mentioned in result section, a number of articles have examined the relationship between environmental factors and the rate of infection and mortality. Investigating the articles showed that environmental variables, such as temperature, relative humidity, and wind affect the behavior of the virus. However, the effect of a particular temperature or humidity has not been proven compared to other factors, such as methods of prevention and treatment (25, 29, 35, 43). Therefore, it is necessary to examine different data from different countries with various climatic conditions or study accurate laboratory analysis of the virus behavior. These analyses may be published in future research articles, and it is necessary to conduct another systematic review with new studies. The research studies that definitively explain the effect of air temperature or humidity on virus behavior will be useful and can be a good guide for preventive measures and give communities hope that at certain temperatures the reproduction or transferring of the virus will decrease. The studies conducted before the onset of COVID-19 pandemic, were performed on behavior of coronaviruses in different climatic conditions (11, 12, 44-50). For example, a study on MERS using case-crossover showed that cold and dry weather conditions affect the behavior of the virus (44). However, the results of previous studies on viruses and diseases, such as MERS or influenza cannot be generalized to the new coronavirus. The results of a study showed that the new coronavirus would better respond to the rising temperature rather than SARS and would be easier to control (29). Bu et al. stated that temperatures between 13 and 19 degrees Celsius and humidity between 50% and 80% provide favorable conditions for virus transmission. Although, this conclusion is based on

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[DOI: 10.18502/jchr.v10i3.7284]

the conditions of SARS, it has also been extended to the new coronavirus (8). Simmering at al. also reported that in some diseases, such as Community-acquired Pneumonia, higher humidity causes the virus to spread further (49). Limited studies have definitively linked the relationship between temperature and humidity with the virus condition (21, 30, 32, 34). Luo et al. found that temperature and humidity particularly do not affect the virus behavior, and also other factors affecting the growth and spread of the virus. The paper notes that the disease occurred in provinces with different climatic conditions in China, indicating that the virus does not spread at specific climatic conditions (21). However, Poirier, Cai, Bannister, and Zhu indicated that there is no significant relationship between temperature and the number of patients (22, 26, 31, 43). Oliveiros et al. also stated that the portion of temperature and humidity affect only 18% in reducing virus transmission and believed that public health policies, population density, transportation status, and cultural conditions have the main role in reducing virus transmission (23). Wang et al. pointed to the role of temperature in reducing or increasing the spread of coronavirus and believed that lower temperature provides a favorable environment for the virus to grow and spread (24). Wang et al. also reported that one-degree increase in temperature and one percent increase in humidity are effective in reducing the virus transmission. Moreover, the arrival of summer and raining has been considered to be an effective factor in reducing the transmission of the virus (19). However, Zhu and Xie indicated that each 1 °C rise in temperature, accompanies with a 4.861% increase in the daily number of the COVID-19 confirmed cases (26). Bannister-Tyrrell also stated that there is a negative correlation between the predicted number of cases with temperature from 1°C and above (31).

AL Rousan et al. and Moghadami et al. predicted the status of the virus in the future through modeling (9, 28). Some other studies highlighted the unknown nature of the virus, and emphasized the importance of applying preventive measures by local and international governments and communities (34-37). In another study, the effect of temperature on the human immune system was examined; however, this factor should have been considered along with other effective variables, such as age, sex, chronic disease, and etc. (51).

Limitations

Lack of studies to use their different models to estimate the expected number of infected cases and mortalities by using different policies. In the current study, reputable databases were searched; however, eventually some of the articles found in the three main databases were removed from the study, and the included studies selected were more from Google Scholar. Furthermore, given that a short time has passed since the outbreak of coronavirus, it is required to conduct a systematic review with more studies in future.

Conclusion

The present study sought to determine the relationship between climatic variables with the survival and spread of the new coronavirus. Therefore, the published and related articles were systematically reviewed, and after reviewing the articles resulting from searching the scientific databases, a few articles were obtained. These articles aimed to find a precise link between the virus and climatic variables, but failed to report a specific temperature or humidity to stop the virus from spreading and transmitting the virus. Given the short time that has passed since the outbreak of the coronavirus worldwide, it is required to conduct more studies in this regard to introduce the exact pattern of transmission by examining the conditions of virus transmission in different climatic conditions.

Conflict of interest

None declared.

Authors' contribution

SF and AH conceptualized and designed the study, AH and PH carried out screening and extracting the data and prepared the manuscript. SF carried out quality assessment as third reviewer. AH, SF and PH supervised the study and provided

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[DOI: 10.18502/jchr.v10i3.7284]

critical comments. All authors read and approved the final manuscript.

Ethical approval

Ethical approval with ethical code IR.SSU.SPH.REC. 1400.038 was provided by the Iran Research Ethics Committee of Shahid Sadoughi University of Medical Sciences and Health Services, Yazd, Iran.

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