European Review for Medical and Pharmacological Sciences 2020; 24: 8232-8238

Climate and COVID-19 pandemic: effect of heat and humidity on the incidence and mortality in world's top ten hottest and top ten coldest countries

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Abstract. – OBJECTIVE: The COVID-19 pandemic has caused a global public health crisis with social, psychological and long-lasting economical damages. Weather-related dynamics have an impact on the pattern of human health and disease. The present study aimed to investigate the impact of heat and humidity on daily basis incidence and mortality due to COVID-19 pandemic in ten of the world's hottest countries compared to ten of the coldest ones.

MATERIALS AND METHODS: Worldwide, we selected 20 countries; 10 hottest countries with the highest temperatures and 10 coldest countries with the lowest temperature. The selection of the countries was based on the daily basis mean temperature from the date of appearance of the initial cases of COVID-19, Dec 29, 2019 to May 12, 2020. In the world's 10 hottest countries, the mean temperature was (26.31±1.51) and humidity (44.67±4.97). However, in the world's 10 coldest countries the mean temperature was (6.19±1.61) and humidity (57.26±2.35). The data on the global outbreak of COVID-19, daily new cases and deaths were recorded from World Health Organization, and daily information on temperature and humidity was obtained from metrological web "Time and Date".

RESULTS: In countries with high temperatures and low humidity, the mean daily cases incidence were (407.12±24.33); cumulative cases (9094.34±708.29); and cumulative deaths (452.84±43.30) were significantly low compared to countries with low temperatures and high humidity: daily cases (1876.72±207.37); cumulative cases (44232.38±5875.11); and cumulative deaths (2008.29±310.13). Moreover, COVID-19 cases and deaths per million population were significantly low in countries with high temperatures (cases 711.23, and deaths 16.27) compared to countries with low temperatures (cases 1685.99; and deaths 86.40). Furthermore, in hottest countries, a 1% increase in humidity reduced number of cases and deaths by (β = -5.40, p<0.001) and (β = -0.187, p=0.004) respectively. A similar trend was seen with a 1°C increase in temperature, reducing the number of deaths by (β = -1.35. p<0.001).

CONCLUSIONS: The results revealed a significant decrease in incidence of daily cases and deaths in countries with high temperatures and low humidity (warmest countries), compared to those countries with low temperatures and high humidity (coldest countries). The findings could be of interest to the policymakers and the health officials on the epidemiological trends of COVID-19 pandemic and weather changes.

Key Words:
COVID 19, Climate, Temperature, Humidity, Incidence, Fatality.

Introduction

The Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) disease, also called COVID-19, has caused a global great damage to human health, lives, and socio-economical conditions[1]. COVID-19 pandemic has been highly predominant and frightening than some earlier pandemics, such as Severe Acute Respiratory Syndrome Coronavirus (SARS-

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CoV-1), and Middle East Respiratory Syndrome Coronavirus (MERS-CoV)[2]. On June 24, 2020, worldwide it involved 216 countries and infected 9071475 people with a fatality rate of 472075 (5.20%)[3].

The COVID-19 has an "animal to animal, animal to human and human to human" transmission[4]. There are some meteorological factors in relation to transmission and severity of spread of viruses[5,6]. The science community is trying to find out various conditions, which may impact on transmission. Previous studies have shown some importance of weather elements in the transmission of infectious diseases. It may be less prevalent in countries closer to the equator, where heat and humidity tend to be higher. Few published reports demonstrated that warm weather and humidity may minimize the COVID-19 global pandemic, which has already infected over nine million people worldwide (World Health Organization, 2020)[3]. It is essential to understand the impact of change in climate on the spread of COVID-19. The present study aims to investigate the impact of heat and humidity on the daily basis incidence of new cases and mortality due to COVID-19 pandemic in world's ten warmest regions and ten coldest ones.

Materials and Methods

We searched the worldwide metrological data of countries with overall high temperatures and humidity and countries with low temperatures and humidity. We recorded the temperature of individual countries from the appearance of the initial cases of COVID-19 in Wuhan, China from Dec 29, 2020 to May 12, 2020. The daily basis mean temperature and humidity were recorded; finally, the study included 20 countries with extremes of temperatures from various corners of the globe; 10 countries with mean high temperature and 10 countries with mean low temperature. The meteorological data were collected from the meteorology web: Times and Date[7]; the hottest and coldest countries with details of their mean values are present in Table I. The population of these countries were obtained from (World Bank, 2020)[8]. In the ten warmest countries, the combined mean population was (192035178±131644730.8) and in the coldest countries, the mean population was (62753407± 36653385.06). In the warmest countries, the mean temperature was (26.31±1.51) and humidity was (44.67±4.97). However, in the coldest countries, the mean temperature was (6.19±1.61) and humidity was (57.26±2.35) (Table I).

The data on the global outbreak of COVID-19, including the daily new cases, daily deaths and cumulative figures were collected from World Health Organization daily situation report of COVID-19 (World Health Organization, 2020)[3]. The population of the selected countries was obtained from the World Bank data (World Bank) and appropriate data were recorded and analyzed.

Simple linear regression analysis was performed to predict the number of cases and deaths with humidity and temperature.

Table I. Comparison of temperature and humidity between world's top ten hottest countries compared to world's top ten coldest countries.

World's Top Ten Hottest Countries			World's Top Ten Coldest Countries		
Country	**Temperature**	**Humidity**	**Country**	**Temperature**	**Humidity**
Iran	16.28	38.76	Finland	-1.56	66.41
Algeria	22.50	68.69	Canada	1.71	61.43
Pakistan	22.60	54.44	Norway	2.12	56.34
India	28.91	47.25	Belarus	3.54	57.96
Mexico	24.63	26.37	Russian Federation	5.76	60.82
Kuwait	28.30	32.32	Estonia	5.80	62.58
United Arab Emirates	28.74	39.96	Sweden	6.76	59.97
Saudi Arabia	29.39	21.39	Kazakhstan	10.55	55.05
Oman	29.42	53.37	United States of America	12.86	52.68
Ghana	32.37	64.18	Austria	14.35	39.33
Mean ± SEM	26.31 ± 1.51	44.67 ± 4.97	Mean ± SEM	6.19 ± 1.61	57.26 ± 2.35

Temperature and humidity were recoded from the date of initial cases appeared from Dec 29 to May 12, 2020. Daily cases and daily deaths were recoded from Dec 29, to May 12, 2020. Data presented in Mean and SEM.

Table II. Comparison of incidence and mortality of daily cases, cumulative cases, daily deaths and cumulative deaths between world's top ten hottest countries compared to world's top ten coldest countries.

Parameters	Countries with high temperature	Countries with low temperature	Significance Level
Daily Cases	407.12 ± 24.33	1876.72 ± 207.37	0.008
Cumulative Cases	9094.34 ± 708.29	44232.38 ± 5875.11	0.02
Daily Deaths	17.80 ± 1.35	100.41 ± 14.88	0.442
Cumulative Deaths	452.84 ± 43.30	2008.29 ± 310.13	0.001

Temperature and humidity were recoded from the date of initial cases appeared from Dec 29 to May 12, 2020. Daily cases and daily deaths were recoded from Dec 29, to May 12, 2020. Data presented in Mean and SEM.

Ethical Statement

For this study the data on the global prevalence and mortality due to COVID-2019 infections and other related information were obtained from the World Health Organization, and metrological data were obtained from world climate web (Time and Date, 2020), from data available publicly, hence ethical approval was not required.

Statistical Analysis

In the present study, 10 countries with high temperatures and 10 countries with low temperatures, and confirmed new cases, new deaths and cumulative data were recorded and analyzed. The Mean and Standard Error of Mean (SEM) were calculated. A descriptive analysis was performed, with numerical variables described using means, SEM and distributions. A correlation coefficient and simple linear regression analysis were performed between meteorological factors, temperature and relative humidity and daily new cases and daily new deaths of COVID-19. *p*-value less than 0.05 was considered significant.

Results

These results are synthesized from the existing data at the time of publication originating from the cited sources. We analyzed the impact of temperature and humidity on the daily new cases and deaths due to the COVID-19 outbreak in ten of the warmest and ten of the coldest countries worldwide. The mean temperature and humidity in these countries is presented in Table I. In the world's hottest countries, the mean temperature was (26.31±1.51) and humidity (44.67±4.97). However, in the world's coldest countries the mean temperature was (6.19±1.61) and humidity (57.26±2.35) (Table I).

The number of daily cases, daily deaths, cumulative cases and cumulative deaths due to COVID-19 are presented in Table II. In countries with high temperatures and low humidity, the mean daily cases were (407.12±24.33); cumulative cases (9094.34±708.29); daily deaths (17.80±1.35); and cumulative deaths (452.84±43.30). These were significantly low in comparison to countries with low temperatures and high humidity where daily cases were (1876.72±207.37); cumulative cases (44232.38±5875.11); daily deaths (100.41±14.88); and cumulative deaths (2008.29±310.13) (Table II, Figure 1).

The COVID-19 cases per one million people in countries with high temperatures were 711.23; and deaths were 16.27 compared to countries with low temperature per one million people were 1685.99; and deaths were 86.40 (Figure 2). The cases and deaths per one million people were significantly low in countries with high temperature compared to countries with low temperature.

The impact of temperature and humidity on the epidemiological trends on number of cases and deaths were presented and correlations coefficient values are given in Table III. The re-

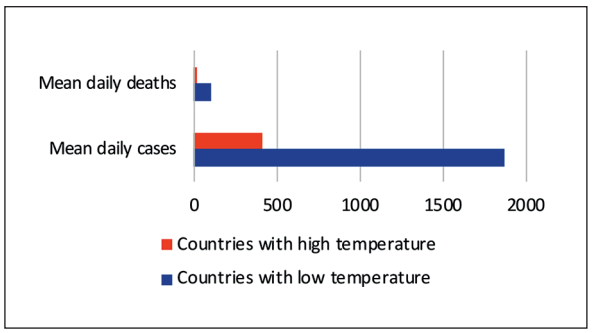

Figure 1. Mean daily cases and daily deaths in world's top ten hottest countries and coldest countries.

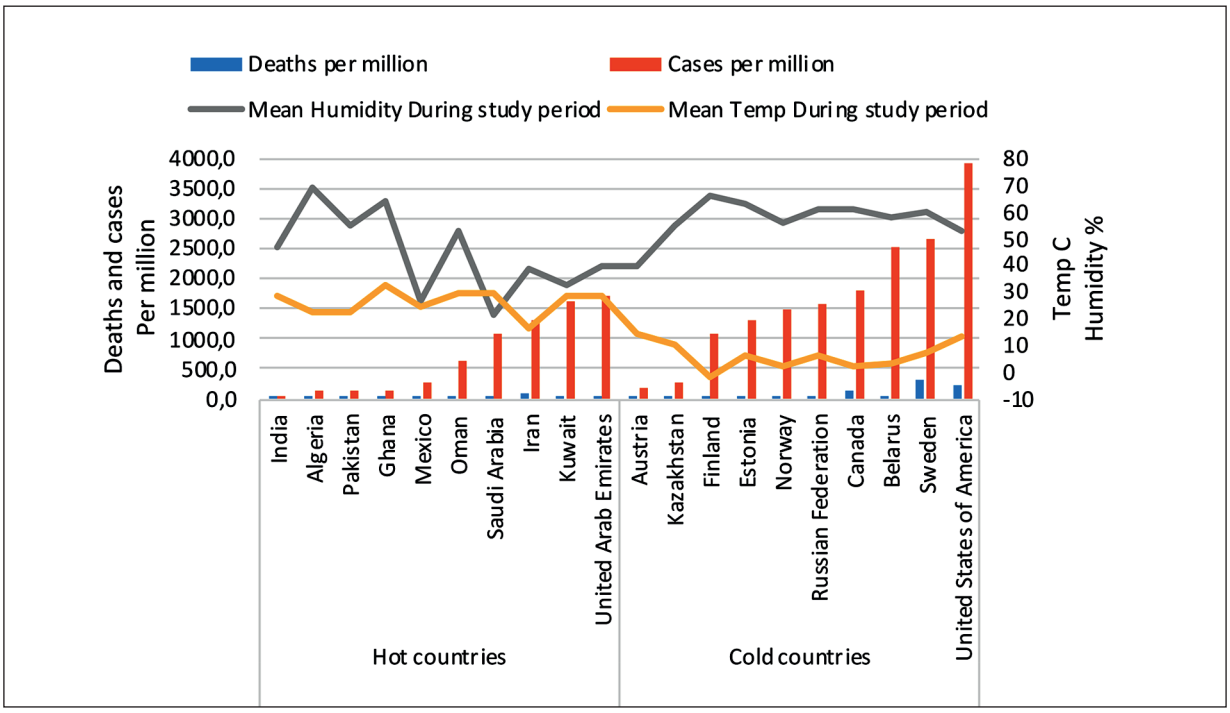

Figure 2. Daily cases and daily deaths per one million population in world's top ten hottest countries and coldest countries.

sults revealed a significant negative correlation between the number of daily new cases and deaths in countries with high temperatures and low humidity (warmest countries), compared to those countries with low temperatures and high humidity (coldest countries) (Table III).

In the hottest countries, the regression analysis results showed that an increase 1% humidity, the number of cases and deaths reduced by (β = -5.40, p<0.001) and (β = -0.187, p=0.004) respectively. A similar trend was seen with a change of 1°C increase in temperature, depicting the deaths reduced by (β = -1.35, p<0.001). The relation between temperature and cases also showed declined pattern but did not achieve the level of significance (β = -2.04, p=0.561).

Discussion

The COVID-19, respiratory pandemic has infected a significant number of people world-

Table III. Correlation coefficient between daily cases, cumulative cases, daily deaths and cumulative deaths between world's top ten hottest countries compared to world's top ten coldest countries.

Comparable parameters	Correlation coefficient in countries with high temperature (n = 10)	Significance Level	Correlation coefficient in countries with low temperature (n = 10)	Significance Level
Temperature and daily cases	-0.016	p = 0.002	0.338	p = 0.001
Temperature-cumulative cases	-0.115	p = 0.001	0.302	p = 0.001
Temperature-daily deaths	-0.248	p = 0.001	0.282	p = 0.001
Temperature-cumulative deaths	-0.241	p = 0.001	0.302	p = 0.001
Humidity-daily cases	-0.166	p = 0.001	-0.082	p = 0.013
Humidity-cumulative cases	-0.145	p = 0.001	-0.089	p = 0.007
Humidity-daily deaths	-0.104	p = 0.003	-0.078	p = 0.019
Humidity-cumulative deaths	-0.103	p = 0.003	-0.078	p = 0.019

Temperature and humidity were recoded from the date of initial cases appeared from Dec 29 to May 12, 2020. Correlation coefficient based on daily cases and daily deaths recoded from Dec 29, to May 12, 2020

wide[2]. The virus does not replicate outside the living cell, but it may persist on contaminated environmental surfaces and the duration of persistence may be change in various weather conditions by heat and humidity[9]. In the earlier six months since its spread starting from Dec 2019, the incidence of COVID-19 over time has been consistently changing. This study investigates the impact of hottest and coldest weather in the incidence of daily cases and daily deaths due to COVID-19 by exploring the relationship between daily average temperatures and humidity with daily cases and deaths due to COVID-19. In the present study, there was a significant impact of high temperature and low humidity on the disease pattern, which resulted in a decreased number of daily cases and deaths from COVID-19.

COVID-19 has been spreading swiftly around the globe, showing variable biological trends despite health officials applying strict precautionary measures to prevent outbreaks[2]. The scientific community and the public in general are expecting climate change, mainly increasing temperature and decreasing humidity, to slow down this pandemic and decrease the incidence and mortality due to COVID-19 pandemic. Chan et al[9] reported that the SARS Coronavirus has better stability at low temperature and low humidity environment hence it may facilitate transmission of the disease. The authors reported that Coronavirus virus viability was rapidly lost at higher temperatures and higher relative humidity. Wu et al[10] assessed the impact of temperature and relative humidity on daily new cases and daily new deaths of COVID-19. The authors identified that temperature and relative humidity have negative association to daily new cases and deaths.

Qi et al[11] found that temperature and humidity showed significant negative relationship with COVID-19. Their study findings suggest that daily temperature and relative humidity influenced the occurrence of COVID-19. However, the association between COVID-19 and temperature and humidity were not consistent throughout Mainland China. The present study results revealed that countries which have an increase in temperature and decrease in humidity were associated with a decrease in the number of daily cases and deaths caused by COVID-19. The results revealed a significant negative correlation between decrease in the number of daily new cases and deaths in countries with high temperature and low humidity (warmest countries), compared to those countries with low temperature and high humidity (coldest countries). The results reflect that high temperature and low humidity work better to minimize daily new cases and deaths.

Xie and Zhu[12] examined the correlation between COVID-19 and temperature in China, and their results showed a positive linear association between the number of COVID-19 cases and the mean temperature. They did not find any evidence supporting the hypothesis that COVID-19 cases could decline when the weather becomes warm. Moreover, Wang et al[13] investigated the association of temperature on the spread of COVID-19 and claimed that temperature significantly affects the transmission of COVID-19. Bannister-Tyrrell et al[14] demonstrated that an average temperature increase was negatively correlated with the number of cases.

Ma et al[15] reported that an increase in diurnal temperature was associated with increase in COVID-19 deaths, whereas an increase in humidity was related to a decrease in the deaths caused by COVID-19. The present study results are inconsistent with the findings reported by Ma et al[15]. In the present study, we identified that an increase in temperature and a decrease in humidity decreased the number of daily cases and daily deaths due to COVID-19. We believe that meteorological parameters are important factors influencing the incidence and mortality trends of COVID-19.

In human body, each cell is vital and plays a significant role in controlling various body functions. The human body needs its normal biological, physiological conditions and environment to perform and maintain various body functions. The metrological conditions including temperature and humidity are essential to maintain normal body functions. The change in environment can change the pattern of health and disease[16].

Extreme temperatures, either very cold or very hot are not physiologically suitable for normal body functions. The respiratory system is highly vulnerable to pollution and microorganisms. In cold weather, the relative risk of respiratory diseases increases and exposure to cold, low temperatures can impair immune mechanisms[17-19]. It is an established fact that respiratory infections are more frequent during cold and low humidity conditions[20]. Earlier studies[21,22] have documented that viruses are more stable in cold and dry conditions, as low temperatures facilitate ideal conditions for virus attachment, replication and transmission.

The exact mechanism of the interaction of the novel coronavirus is still unclear. However, the probable reason might be that a combination of low temperature makes the respiratory mucosa more prone to rupture and creating opportunities for virus invasion[23].

Study Strengths

This is the first article added in the literature, to our knowledge, that has investigated the impact of heat and humidity on the daily new cases and deaths due to COVID-19 in the world's top ten hottest countries compared to the world's top ten coldest ones. Another strength is that the study data were collected using reliable sources including "World Health Organization". Thirdly, the study period is considerably long, starting from Dec 29 until May 12, 2020; hence it can be anticipated that many covariates would differ considerably during such a long period of time. The longer the study period, the more stable the findings. Fourthly, this study was a time, temperature, and humidity analysis, and weather-related data were used to accurately reflect the effect of temperature and humidity on the daily new cases and daily new deaths caused by COVID-19.

Conclusions

The results revealed a significant decrease in the number of daily new cases and deaths in countries with high temperature and low humidity (warmest countries), compared to those countries with low temperature and high humidity (coldest countries). The COVID-19 cases and deaths per million population were significantly low in countries with high temperature compared to countries with low temperature. The findings have outcomes for policymakers, health officials and the public about the impact of temperature and humidity on epidemiological trends of COVID-19. We suggest that required essential measures must be taken to control the source of infection and transmission to prevent the pandemic from spreading even further. More attention should be paid to regions with low temperature, as this environment is more suitable for the viability of the Novel Coronavirus.

Conflict of Interest

The Authors declare that they have no conflict of interests.

Acknowledgements

We thank the "Deanship of Scientific Research, King Saud University, Riyadh, Saudi Arabia, for supporting the work through a research group project (RGP-VPP 181)".

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