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Climate factors and incidence of Middle East respiratory syndrome coronavirus

Asmaa Altamimi^a, Anwar E. Ahmed^{b,*}

^a Tropical Diseases Center, National Health Laboratory, Saudi Center for Disease Prevention and Control (Saudi CDC), Riyadh, Saudi Arabia

^b Uniformed Services University of the Health Sciences, F. Edward Hébert School of Medicine, Department of Preventive Medicine & Biostatistics/Henry M Jackson Foundation for the Advancement of Military Medicine, Bethesda, MD, USA

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ABSTRACT

Background: Our understanding of climate factors and their links to the Middle East Respiratory Syndrome Coronavirus (MERS-CoV) outbreaks is incomplete. This study aimed to estimate the monthly incidence of MERS-CoV cases and to investigate their correlation to climate factors.

Methods: The study used aggregated monthly MERS-CoV cases that reported to the Saudi Center for Disease Prevention and Control from the Riyadh Region between November 1, 2012 and December 31, 2018. Data on the meteorological situation throughout the study period was calculated based on Google reports on the Riyadh Region (24.7136°N, 46.6753°E). The Poisson regression was used to estimate the incidence rate ratio (IRR) and its 95% confidence intervals (CI) for each climate factor.

Results: A total of 712 MERS-CoV cases were included in the analysis (mean age 54.2 ± 9.9 years), and more than half (404) (56.1%) MERS-CoV cases were diagnosed during a five-month period from April to August. The highest peak timing positioned in August 2015, followed by April 2014, June 2017, March 2015, and June 2016. High temperatures (IRR = 1.054, 95% CI: 1.043–1.065) and a high ultraviolet index (IRR = 1.401, 95% CI: 1.331–1.475) were correlated with a higher incidence of MERS-CoV cases. However, low relative humidity (IRR = 0.956, 95% CI: 0.948–0.964) and low wind speed (IRR = 0.945, 95% CI: 0.912–0.979) were correlated with a lower incidence of MERS-CoV cases.

Conclusion: The novel coronavirus, MERS-CoV, is influenced by climate conditions with increasing incidence between April and August. High temperature, high ultraviolet index, low wind speed, and low relative humidity are contributors to increased MERS-CoV cases. The climate factors must be evaluated in hospitals and community settings and integrated into guidelines to serve as source of control measures to prevent and eliminate the risk of infection.

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Introduction

The most recent human coronavirus (CoV), Middle East Respiratory Syndrome (MERS) or MERS-CoV [1], continues circulating and impacting healthcare systems in Saudi Arabia [2]. Despite the virus having been linked to high mortality [3,4], its transmission mechanisms remain inadequately understood [5]. As of June 30, 2019, there have been a number of recurrent outbreaks reported, in which there were 2449 laboratory-confirmed MERS-CoV cases, including 845 deaths [1,3].

The incidence rate of MERS-CoV in Saudi Arabia is the highest compared to any other infected country [6]. Another study reported

that seasonal variation of respiratory viruses was inversely associated with temperature and relative humidity among children during MERS-endemic to the Riyadh Region [7].

To date, limited studies investigate climate parameters as factors that could promote the MERS virus activity and transmission. Although MERS-CoV cases were reported throughout the year in Saudi Arabia, a seasonality pattern appears to be higher during certain months of the year [8]. Similar seasonality may exist in the Riyadh Region as well.

Gardner et al. have recently reported an association between climate factors and the appearance of virus in primary MERS-CoV cases [9]. The findings of this study may represent primary MERS-CoV cases. In addition, Gardner categorized climate variables into groups: tertiles and halves. However, our study tends to report the correlation between climate variables (as quantitative) and the occurrence of all laboratory-confirmed MERS-CoV cases. The study also assesses the effects of five climate factors: temperature, rela-

* Corresponding author at: Uniformed Services University of the Health Sciences, 4301 Jones Bridge Rd, Bethesda, MD 20814, USA.
E-mail address: anwar.ahmed.ctr@usuhs.edu (A.E. Ahmed).

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Table 1
Monthly climate factors and MERS-CoV cases in Riyadh Region, November 1, 2012–December 31, 2018.

	Monthly MERS-CoV frequency	Temperature °C	Humidity %	Ultraviolet index	Cloud	Winds
Mean	11.30	26.46	22.70	6.76	8.65	13.117
Std. Deviation	20.305	7.666	10.776	1.563	5.984	2.0756
Minimum	1	14	9	4	0	7.6
Maximum	128	38	48	9	27	17.1
Median	4.00	27.00	22.00	7.00	7.00	13.200
25 th Percentiles	3.00	20.00	13.00	5.00	4.00	11.700
75 th Percentiles	9.00	34.00	30.00	8.00	12.00	14.800

tive humidity, ultraviolet index, cloud, and wind speed, which have been reported to be mostly associated with viral activity in primary cases [9].

The monthly variations in MERS-CoV frequencies [10] should be further investigated by exploring the role of climate factors on the incidence of MERS-CoV infection. This may provide better understanding and the ability to prepare and implement an efficient health information system to reduce the incidence of MERS-CoV infection in Saudi Arabia. Therefore, we aimed to estimate the monthly incidence and to investigate the effects of climate factors on the monthly frequency of MERS-CoV infections reported from Riyadh, Saudi Arabia. It was hypothesized that the monthly average of temperature, ultraviolet index, relative humidity, cloud, and wind speed are important factors of the MERS-CoV occurrence in Riyadh, Saudi Arabia.

Methods

The study utilized a retrospective design to study a cohort of MERS patients reported in Riyadh, Saudi Arabia. The study site is Riyadh, which is the capital city of Saudi Arabia, located in the center, and with a population of over 5 million. We chose to study cases reported from the Riyadh Region because this region has a more substantial number of cases than any other regions in the country. Also investigating one location may provide a more precise estimate of the climate factors where the cases are reported.

The Ethics Committee at the Saudi Ministry of Health has granted approval to conduct the study, IRB log number:18-138E. The study has been exempted from patient and publication consent due its design. Data were obtained from Saudi Center for Disease Prevention and Control, Riyadh, Saudi Arabia. All hospitals in Riyadh and other regions are required to report laboratory-confirmed MERS-CoV cases to the Saudi Ministry of Health through this center.

The study included all laboratory-confirmed MERS-CoV cases reported from the Riyadh Region between November 1, 2012 and December 31, 2018. The study aggregated daily and weekly incidence of MERS-CoV cases and patients' data into monthly reports. Data on the climate situation throughout the study period, based on Google reports, were calculated using the monthly average of temperature °C, relative humidity (%), ultraviolet index, cloud, and wind speed in Riyadh (24.7136°N, 46.6753°E).

Statistical analysis

The statistical analysis in this study was performed using STATA V 15 (STATA Corp., Texas, USA). The monthly incidence of MERS-CoV cases was treated as a discrete random variable, where MERS-CoV cases were counted over each month from November 2012 to December 2018. Climate factors and the number of MERS-CoV cases were summarized by descriptive statistics (Table 1). The Poisson model is commonly used to model discrete random variables, and the Poisson regression was used to estimate the monthly incidence

Table 2
The effects of months and years on frequency of MERS-CoV cases, November 1, 2012–December 31, 2018.

Month	B	SE	z	P	IRR	95% CI for IRR	
						LCL	UCL
2	0.271	0.224	1.210	0.227	1.311	0.845	2.035
3	0.307	0.230	1.340	0.181	1.360	0.866	2.135
4	0.352	0.221	1.590	0.111	1.422	0.922	2.194
5	1.110	0.211	5.270	0.001 ^a	3.033	2.008	4.583
6	0.887	0.211	4.210	0.001 ^a	2.427	1.606	3.666
7	-0.862	0.293	-2.940	0.003 ^a	0.422	0.238	0.750
8	1.821	0.201	9.050	0.001 ^a	6.178	4.164	9.166
9	0.427	0.219	1.950	0.051	1.533	0.999	2.354
10	-0.093	0.240	-0.390	0.698	0.911	0.569	1.459
11	-0.560	0.258	-2.170	0.030 ^a	0.571	0.344	0.948
12	-0.292	0.263	-1.110	0.266	0.747	0.446	1.250
Year							
2013	0.616	0.594	1.040	0.300	1.852	0.578	5.937
2014	1.648	0.582	2.830	0.005 ^a	5.194	1.660	16.252
2015	2.156	0.580	3.710	0.001 ^a	8.636	2.769	26.937
2016	0.726	0.591	1.230	0.219	2.067	0.649	6.584
2017	1.006	0.588	1.710	0.087	2.733	0.864	8.651
2018	0.360	0.597	0.600	0.547	1.433	0.445	4.620

^a Significant at $\alpha = 0.05$.

Table 3
The effects of climate factors on the frequency of MERS-CoV, November 1, 2012–December 31, 2018.

	B	SE	z	P	IRR	95% CI for IRR	
						LCL	UCL
Temperature °C	0.052	0.005	9.790	0.001 ^a	1.054	1.043	1.065
Humidity %	-0.045	0.004	-10.850	0.001 ^a	0.956	0.948	0.964
Ultraviolet index	0.337	0.026	12.890	0.001 ^a	1.401	1.331	1.475
Cloud	-0.012	0.006	-1.880	0.06	0.988	0.975	1.000
Wind speed	-0.057	0.018	-3.130	0.002 ^a	0.945	0.912	0.979

^a Significant at $\alpha = 0.05$. Incidence rate ratio (IRR).

rate ratio (IRR) of MERS-CoV and its 95% confidence intervals (CI) by months and years (Table 2) and by climate factors (Table 3). In this analysis, we tested a number of hypotheses in which the monthly incidence rate is influenced by climatic conditions. A two-sided $P \leq 0.05$ was considered significant. Line plots were used to illustrate the correlation between each of the climate factors and the monthly number of MERS-CoV cases (Figs. 2–6).

Results

A total of 712 MERS-CoV cases were included in the analysis (mean age 54.2 ± 9.9 years), and 404 (56.1%) MERS-CoV cases were diagnosed during a five-month period from April to August over the study period. Table 1 summarizes the climate factors and distribution of MERS-CoV cases. The median number of MERS-CoV cases was 4 (IQR ranges from 3 to 9) per month. The median values of monthly average temperature, relative humidity, ultraviolet index, cloud, and wind speed were 27 °C, 22%, 7, 7, and 13.2, respectively.

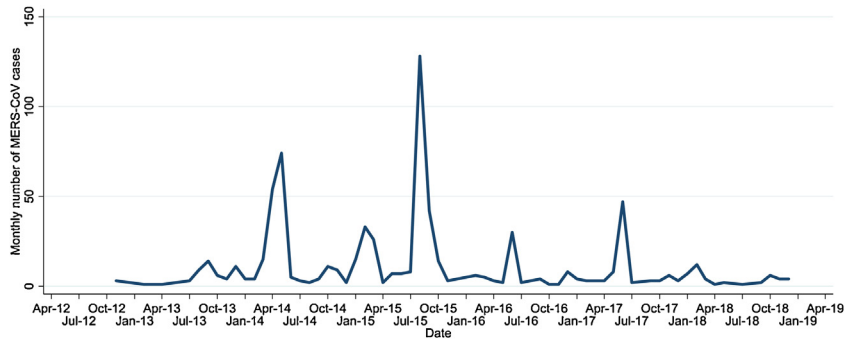


Fig. 1. Monthly MERS-CoV cases in Riyadh Region, November 1, 2012–December 31, 2018.

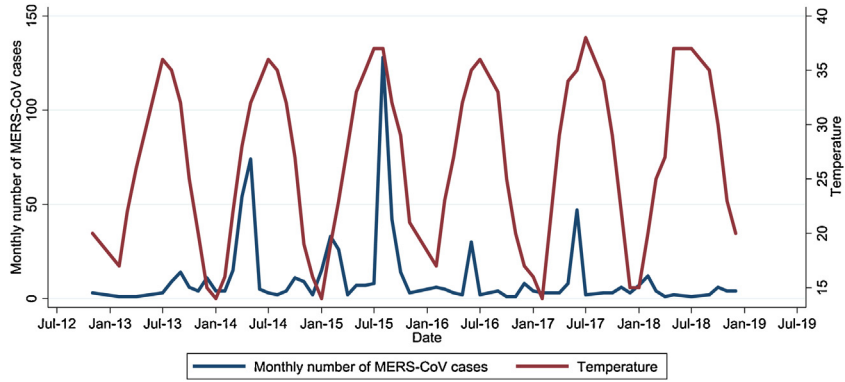


Fig. 2. Monthly MERS-CoV cases and temperature in Riyadh Region, November 1, 2012–December 31, 2018.

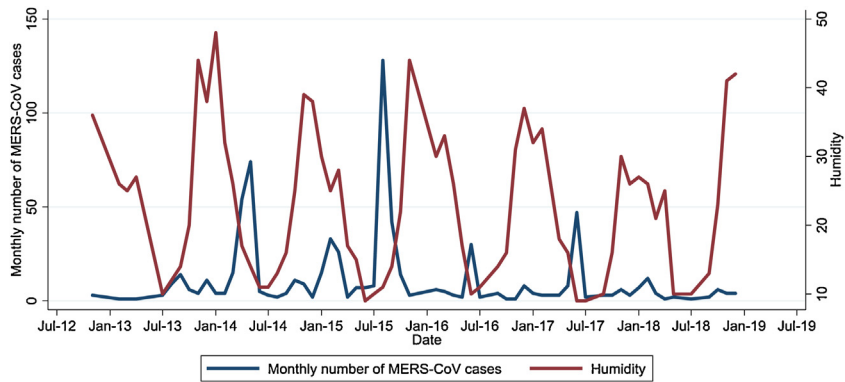


Fig. 3. Monthly MERS-CoV cases and humidity in Riyadh Region, November 1, 2012–December 31, 2018.

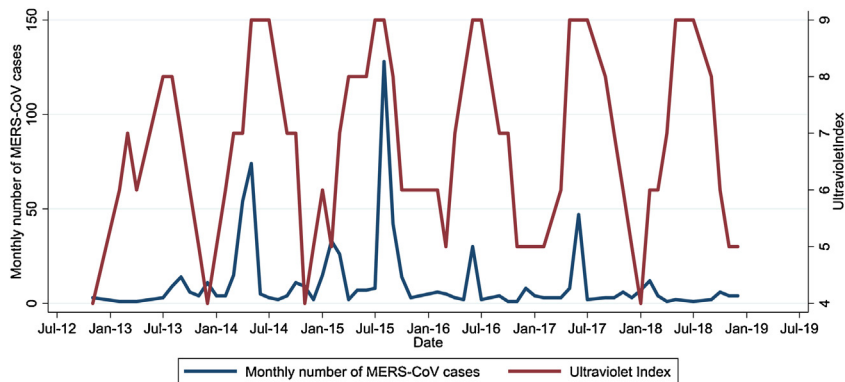


Fig. 4. Monthly MERS-CoV cases and Ultraviolet index in Riyadh Region, November 1, 2012–December 31, 2018.

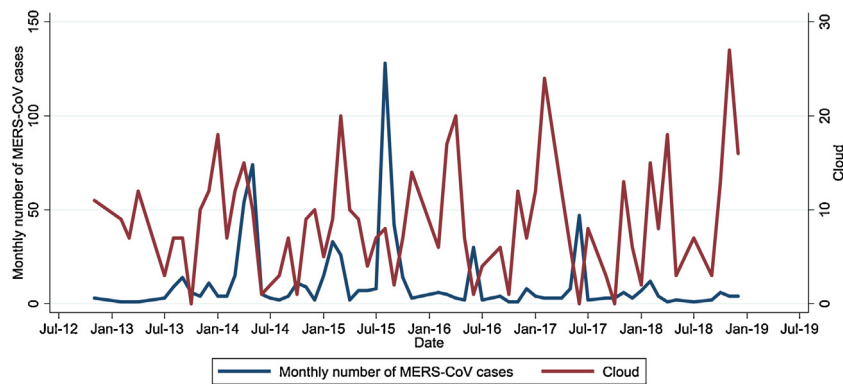


Fig. 5. Monthly MERS-CoV cases and cloud index in Riyadh Region, November 1, 2012–December 31, 2018.

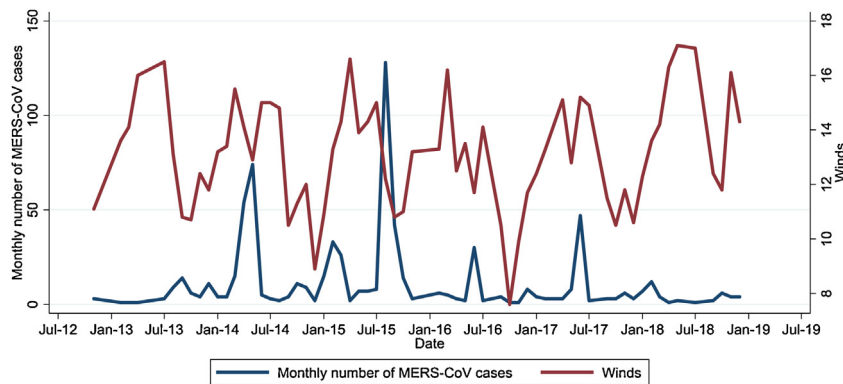


Fig. 6. Monthly MERS-CoV cases and wind index in Riyadh Region, November 1, 2012–December 31, 2018.

The incidence of the MERS-CoV cases by time in the Riyadh Region is presented in Fig. 1. The highest peak timing was positioned on August 2015, followed by April 2014, June 2017, March 2015, and June 2016. Findings of these figures were confirmed with the estimated IRRs in Table 2. The highest IRRs were noted in August (IRR = 6.178, 95% confidence interval (CI): 4.164–9.166) and followed by May (IRR = 3.033, 95% CI: 2.008–4.583) and June (IRR = 2.427, 95% CI: 1.606–3.666). The IRR was greater in 2015 (IRR = 8.636, 95% CI: 2.769–26.937) and 2014 (IRR = 5.194, 95% CI: 1.660–16.252).

Table 3 demonstrates the effects of climate factors on the incidence of the MERS-CoV cases. With the exception of cloud, four climate factors were found to be statistically correlated with a reduction or increase in the incidence of the MERS-CoV cases. High temperature (IRR = 1.054, 95% CI: 1.043–1.065) and a high ultraviolet index (IRR = 1.401, 95% CI: 1.331–1.475) were correlated with a higher incidence of the MERS-CoV cases. However, low humidity (IRR = 0.956, 95% CI: 0.948–0.964) and low wind speed (IRR = 0.945, 95% CI: 0.912–0.979) were correlated with a lower incidence of the MERS-CoV cases. Figs. 2–6 support the analysis in Table 3, whereas MERS-CoV detection was high with high temperatures and ultraviolet index values and low MERS-CoV detection, with increased relative humidity and wind speed values.

Discussion

In the eight years since its circulation, the variations in MERS-CoV frequencies over time have been consistently unclear. This study estimated the monthly incidence of MERS-CoV infection and evaluated its correlation with climate factors in the Riyadh region, Saudi Arabia. The MERS viral activity and development is highly influenced by seasonality, as multiple peaks occur in hot seasons (April to August) over the study period. A one °C increase in monthly

average temperature correlated with increasing the monthly incidence of MERS-CoV infection by 5.4%. This finding contradicts the Gardner et al. study, where they reported low temperatures associated with high risk in primary MERS-CoV infections [9]. However, our report was in agreement with the Alghamdi et al. study where they found that high temperatures enhance the spread of MERS-CoV in the population [11]. The effects of temperature on viral viability can be clarified in future research studies.

We found that relative humidity was inversely associated with MERS-CoV cases. The link between the monthly relative humidity and the monthly number of MERS-CoV cases could be described by a 4.4% increase in the monthly incidence of MERS-CoV infections for every percent of increase in relative humidity. This correlation is clearly illustrated in Fig. 3. This is similar to previous reports where MERS-CoV cases increased with low humidity [9,11–13]. Our findings may clarify viral seasonality, as it explains why most MERS-CoV outbreaks occurred between April and August, where temperatures reached the highest and humidity reached the lowest [14]. This timing may facilitate an optimal environment for the virus to survive and transmit.

Another important finding of our study is that the monthly average of the ultraviolet index was found to be positively correlated with the monthly number of MERS-CoV cases. To date, no other studies have considered the ultraviolet index among the climate factors that could increase the risk of MERS-CoV infection. These climate factors must be evaluated in hospitals and community settings, as the virus appears more viable in certain weather [11] conditions and geographic regions [3]. Finding of such studies can serve as source of control measures to prevent and eliminate the risk of infection, particularly in Saudi Arabia.

The incidence of MERS-CoV infection tends to decrease with wind speed. Gardner et al. have shown that low wind speed increased the odds of primary MERS-CoV infections. Risk communi-

cation strategy may improve public's perception about the impact of climate factors on the MERS-CoV infections and outbreaks.

The strength of this study is the large number of MERS-CoV patients included in the analysis, and the study identifies important factors affecting MERS-CoV viral seasonality. In agreement with previous reports [11,13], the study highlights the need for considering climate factors on MERS-CoV guidelines for control measures and prevention. The overall findings of the study are that the higher the temperature and ultraviolet index, the higher incidence of MERS-CoV infections, and vice versa for humidity and wind speed. However, we noted limitations in this study. A number of potential confounding factors such as patient characteristics and source of the infections were not included in our investigation. The climate data were taken retrospectively from Google reports on a monthly basis during the span in which the cases were reported. The authors were not able to assess the influence of climate factors on the source of infection, the route of transmission, or the susceptible population. The impact of climate factors on incidence of MERS-CoV in small environments such as families and hospitals can be addressed in future studies.

Conclusion

The novel coronavirus, MERS-CoV, is influenced by climate conditions with increased incidence between April and August. The virus appears more viable in certain weather conditions. High temperature, high ultraviolet index, low wind speed, and low relative humidity are contributors to increased MERS-CoV cases. The climate factors must be evaluated in hospitals and community settings and integrated into guidelines to serve as a source of control measures to eliminate the risk of infection.

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Competing interests

None declared.

Ethical approval

Ethical approval was obtained from Saudi Ministry of Health. This study has been completed prior to Dr Anwar Ahmed joining the Uniformed Services University of the Health Sciences and Henry M Jackson Foundation for the Advancement of Military Medicine.

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