Original Article

The Impact of Meteorological Factors on COVID-19 Trends: Evidence from Time-series Modeling in East of Iran

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Abstract

Aim: This study investigates the association between meteorological factors (pressure, humidity, and temperature) with COVID-19 hospitalization and mortality in Gonabad city of Iran, from April 2019 to January 2021. This study aimed to prediction of weather pattern's impact on the COVID-19 monthly trend in a region of Iran. **Methods:** COVID-19 cases and meteorological factors data were collected over the Gonabad University of Medical Science registration bank and Meteorological Organization of Gonabad from April 2019 to January 2021, respectively. Multivariable time series autoregressive integrated moving average (ARIMA) models and correlation in multiplicative was used for forecast COVID-19 incidence and combines both a long-term upward trend and a pronounced seasonal pattern in COVID-19 cases, respectively. **Results:** Descriptive analysis revealed that the highest temperature and humidity were recorded in the summer and autumn 2020, respectively. Moreover, coronary hospitalization and mortality peaks were occurrence at 2020 in autumn (1059 cases) and summer (133 deaths), respectively. Time-series analysis showed. Seasonal amplitude indicates regular rise and fall in the number of cases over distinct periods (~10.73). The ARIMA model highlighted fluctuations in COVID-19 cases, closely tied to changes in humidity and temperature. Residual standard deviation (1.62) highlighting the presence of unaccounted for factors influencing case variability. **Conclusion:** Meteorological factors significantly influence on coronary mortality trends that are highlighting to need public health strategies to consider climatic conditions. Future research should integrate more detailed meteorological data and explore additional environmental factors to enhance predictive models for healthcare planning.

Keywords: Autoregressive integrated moving average model, climatic conditions, COVID-19, time-series analysis

Introduction

Since the beginning of the COVID-19 pandemic in late 2019, more than 634 million confirmed cases and over 6.5 million deaths due to COVID-19 have been documented globally. Todays, there are significant concerns regarding new variants with the emergence of several variants recognized on a global scale. In the pandemic, Iran managed to control a significant portion of the challenges faced by other regions globally during the initial 18 months of the COVID-19 pandemic.[1] However, the rapid spread of COVID-19 was observed following the rise of the extremely infectious Delta variant that putting significant pressure on the healthcare system.[2] Therefore, despite extensive efforts to control the spread, the number of infections quickly escalated. In this regard, the continuing threat of a possible renaissance of epidemic, precise and quick predictive modeling plays a vital role in establishing early warning systems for COVID-19.[3] Most importantly, comprehensive quick-notice mechanisms employing "big data" and environmental variables for on-time reorganization of the rising COVID-19 viruses are crucial. Moreover, timely and precise information is crucial for updating public health decision-makers and enabling the application of nonpharmaceutical interventions, vaccination strategies, and public health preparedness for flow capability and resource distribution in pandemics.[4] The last research demonstrated that traditional methods are depended on test alerts and

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providing partial effectiveness for immediate responses while utilizing available data and meteorological elements hold great promise for improving viral information, enabling rapid disease outbreak identification.[5] Therefore, this outcome can serve as a valuable indicator for monitoring behavioral trends related to health-seeking behaviors for infectious diseases and may be used as alternatives to COVID-19 health-seeking patterns. Furthermore, changes in movement patterns due to risk perception and public health interventions may help inform predictive modeling.[6] According to the findings, limited research have been published using the method of time-series model including autoregressive integrated moving average (ARIMA), Predictive analytics for time-series forecasting (PROPHET) model, and autoregressive distributed lag to make predictions about the impact of social and environmental factors in COVID-19 mortality in epidemiology documents. Wuhan, Huang *et al*. used susceptible-infectious-recovered (SIR) model analysis discharged patients during the period of isolation and control.[7] Zareie *et al*. used the SIR model to explore factors affecting COVID-19's spread in Iran.[8] Similarly, as part of another study, Chen *et al*. predicted the spread of COVID-19 using a time-dependent SIR model.[9] Deldar *et al*. used the SIR model to determine variables to calculate the epidemiological characteristics of the coronavirus in Iran. Their findings showed that Iran reached the peak of the infection earlier than the global SIR model, but it performed better in improved and susceptible cases.[10] To our knowledge, the use of ARIMA models for anticipating COVID-19 mortality in associated few studies with weather factors. This research is innovative as it is the first to compare and evaluate the weather variables in predictive time series models in COVID-19 mortality in Gonabad city.

Materials and Methods

Overview of Ganabad's climate

Climatic conditions significantly influence geographical health outcomes. Gonabad city located in the region that is characterized by arid and semi-arid zones and experiences extreme temperatures, particularly in the Great Salt Desert areas where temperatures even reached a record 70.7°C at most times. These conditions contribute to environmental health risks, including air pollutants and particle matter, which are exacerbated by climatic conditions such as ambient temperature and lack of air movement.

Area of study

Descriptive cross-sectional study was conducted in the Gonabad city, which is located in the southeast of Iran with an area of about 105801 km^2 and 52810 populations.

Data and methodology

Data collection

COVID-19 cases and meteorological factors data were collected over the Gonabad University of Medical Science registration bank and Gonabad Meteorological Organization of from April 2019 to January 2021, respectively

Time-series modeling techniques used

The analysis employed time-series modeling techniques that were used for handling the number of COVID-19 cases data, offering insights into the incidence and their fluctuations over the time.[6] Moreover, the study incorporated advanced time-series modeling techniques such as ARIMA, Holt's trend method, and multilayer perceptron neural networks to forecast future trends based on past data. These methods are critically used for understanding and predicting the behavior of COVID-19 cases under varying climatic conditions and demographic changes.

Results

Descriptive analysis

The weather situation of Gonabad city during 2020–2021 was quantified by analyzing meteorological data (humidity, temperature, pressure, and wind speed). Following the descriptive statistics approach, the maximum, mean, and minimum of each factor in the study period were summarized. According to the result, the highest temperature, humidity, pressure, and wind speed data were recorded for summer (2020), autumn (2020), winter (2020), and spring (2021), respectively. While the lowest level has recorded in winter (2020), autumn (2021), summer (2020), and winter (2020–2021), respectively. Table 1 presents the total hospitalization and mortality cases for each of the study years separately. According to obtained data, Gonabad city experienced the highest number of hospitalization cases (1059 cases) in autumn 2020 and in summer 2021 (884 cases). Similarly, mortality cases were 133 and 59 persons in autumn 2020 and summer 2021, respectively.

Autoregressive integrated moving average model COVID-19 cases forecast

Obtained data in time series plots reveal significant insights into the patterns of COVID-19 cases (A), relative humidity (B), and mean temperature (C) over the time [Figure 1]. According to obtained data, substantial fluctuations with distinct peaks and troughs COVID-19 cases were observed [Figure 1a]. As it can observed in result, trend was starting with lower trend and then continue with a sharp rise around mid-2020, culminating in a prominent peak in late 2020. Then, it is followed by smaller

Table 1: Descriptive statistics Covid-19 mortality cases

Season	Mortality		
	2020	2021	2020-2021
Spring	15	44	59
Summer	42	59	101
Autumn	133	31	164
Winter	55	5	60
Spring	15	44	59
Variable	**B**	**S.E.**	**Wald**
Gender	0.142	0.111	1.643
Age	0.049	0.003	205.3

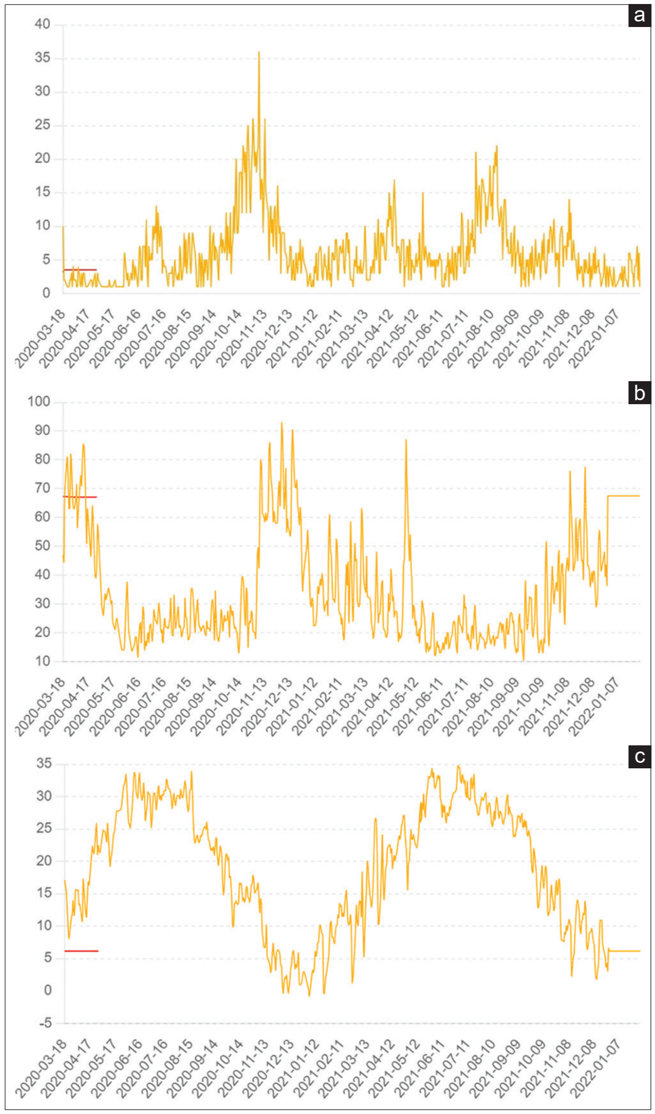

Figure 1: Autoregressive integrated moving average (ARIMA) model COVID-19 cases forecast (a), ARIMA Model - Relative Humidity Forecast (b) ARIMA Model - mean temperature Forecast (c)

peaks and a gradual decline toward early 2022. In addition, the highest number of cases reached approximately 35 during the peak periods. Figure 1b illustrates relative humidity over the same timeframe. It exhibits a cyclical pattern with multiple peaks and troughs. Initially, the humidity is high but drops significantly around mid-2020. Several peaks indicate periods of increased humidity, followed by declines, with the variability slightly decreasing toward the end of the observed period. The humidity values range from around 10%–90%. Moreover, Figure 1c represents mean temperature, displaying a clear seasonal pattern with repeated cycles of rise and fall. Starting with moderate values, the temperature gradually increases, peaking in mid-2020, then dropping and rising again in a cyclical manner. The overall trend shows multiple cycles of temperature changes, with values ranging from about 0°C to 35°C.

Serial correlation in each variable data

The time-series plots provide valuable insights into the patterns of COVID-19 cases over time. Figure 2a illustrates an increasing trend in COVID-19 cases, characterized by periods of stability followed by sharp increases. Numerically, this is represented by a trend slope of approximately 0.094, indicating a steady upward trend in the number of cases. The fluctuations observed in the plot become more pronounced over time. Moreover, data on Figure 2b reveal a strong cyclical pattern in COVID-19 cases, with consistent peaks and troughs occurring at regular intervals. The seasonal amplitude of this series is around 10.73, reflecting the range of these periodic fluctuations. This pattern suggests that the number of cases rises and falls in a regular, cyclical manner. However, Figure 2c combines both a long-term upward trend and a pronounced seasonal pattern in COVID-19 cases. Similarly, the seasonal amplitude indicated that regular periodic fluctuations in the number of cases. In addition, the residual standard deviation of 1.62 reflects the variability in the data that cannot be explained by the trend or seasonal components.

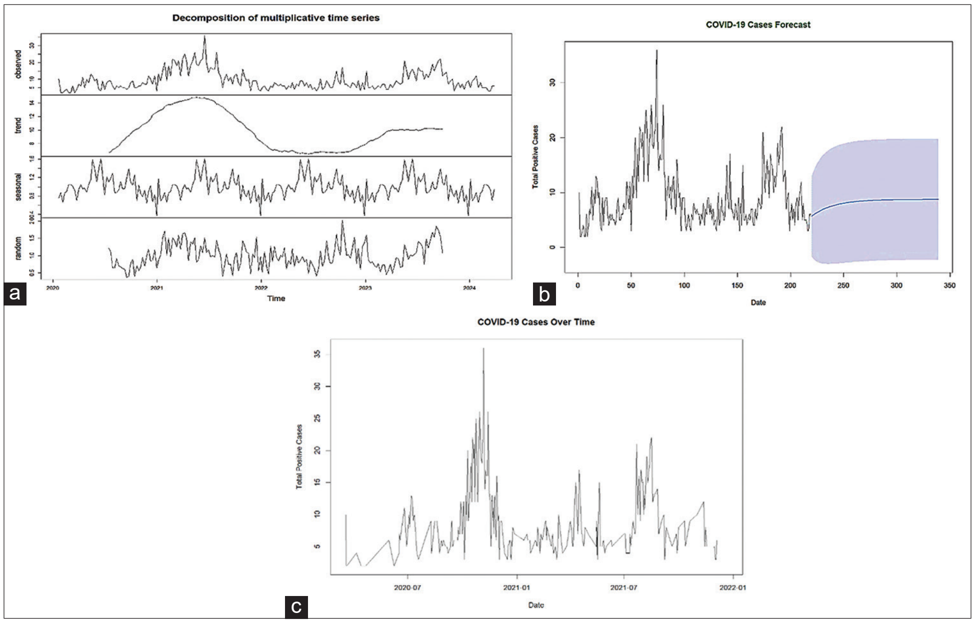

Figure 2: Serial Correlation in multiplicative (a), COVID-19 cases factor (b), and COVID-19 over the time (c) variable data

Discussion

This study investigates the association between meteorological factors (pressure, humidity, and temperature) with COVID-19 hospitalization and mortality in Gonabad city of Iran. According to the results, the time-series analysis of COVID-19 cases, relative humidity, and mean temperature reveals significant insights into the dynamic patterns of these variables over time. The substantial fluctuations in COVID-19 cases, characterized by distinct peaks and troughs, reflect the evolving nature of the pandemic.[11] Similarly, the cyclical patterns observed in relative humidity and mean temperature underscore the influence of environmental factors on the dynamics of the pandemic. This result is similar to the study that has been done in Dhaka, Bangladesh, by time-series method.[12] The sharp rise in COVID-19 cases around mid-2020, culminating in a prominent peak in late 2020, suggests the occurrence of significant outbreaks during this period. Similarly, another document has recorded the same result.[13] However, the observed cyclical pattern of relative humidity, with multiple peaks and troughs, indicates the variability in environmental conditions that may influence the transmission and persistence of the virus.[14] Furthermore, the clear seasonal pattern of mean temperature highlights the role of seasonal variations in temperature in shaping the patterns of COVID-19 transmission. Moreover, the sharp rise in COVID-19 cases around mid-2020, culminating in a prominent peak in late 2020 that is suggests the occurrence of significant outbreaks during this period. The observed cyclical pattern of relative humidity, with multiple peaks and troughs, indicates the variability in environmental conditions that may influence the transmission and persistence of the virus.[15] The extensive data and research literature presented underscore the complex association between meteorological factors and mortality and hospitalization of COVID-19 cases.[16-18] Multiple studies have investigated the impact of temperature, humidity, and other meteorological variables on spread of the virus, yielding diverse and sometimes conflicting findings.[19-21] Numerous studies have highlighted the potential influence of temperature and humidity on COVID-19 transmission.[22-24] In addition, some studies have reported significant associations between low temperatures, low absolute humidity, and increased COVID-19 incidence, which are emphasizing the role of meteorological factors in shaping the dynamics of the pandemic.[17,25,26] A comprehensive global analysis, as detailed by Zhang *et al*. encompassed data from 455 cities across 20 countries, revealing that low temperatures and low absolute humidity were associated with higher COVID-19 incidence. This meta-analysis considered the effects of air temperature, relative and absolute humidity, and UV radiation, emphasizing the heterogeneity of these associations across different countries.[27] On the other point of view, the trend of coronary cases forecast [Figure 1a] shows increasing trend in COVID-19 cases, characterized by periods of stability followed by sharp increases, is indicative of the evolving nature of the pandemic. The observed trend slope of approximately 0.094 signifies a steady upward trend in the number of cases, underscoring the persistence of the pandemic over time. The pronounced fluctuations further accentuate the dynamic nature of the pandemic, suggesting the influence of various factors on case incidence. According to the obtained data in Figure 1b, the strong cyclical pattern in COVID-19 cases, with consistent peaks and troughs occurring at regular intervals, points toward the presence of seasonal fluctuations in case incidence. The seasonal amplitude of approximately 10.73 reflects the range of these periodic fluctuations, indicating the regular rise and fall in the number of cases over distinct time periods. These cyclical patterns may be attributed to seasonal variations, behavioral factors, or other external influences impacting case numbers. Figure 1c presents a comprehensive view of COVID-19 case patterns, integrating both a long-term upward trend and pronounced seasonal pattern. The coexistence of these components suggests a multifaceted influence on case dynamics, with both gradual increases over time and recurrent seasonal fluctuations. The residual standard deviation of 1.62 reflects the variability in the data that cannot be explained by the trend or seasonal components, highlighting the presence of unaccounted-for factors influencing case variability. Existing literature has emphasized the complex interplay of environmental, demographic, and behavioral factors in shaping case trajectories.[28] The residual variability in the data, as indicated by the residual standard deviation, aligns with research highlighting the presence of unaccounted-for factors influencing case variability, including variations in testing, reporting, and community-level dynamics.

Conclusion

This study utilized time-series modeling to forecast COVID-19 cases, focusing on key predictors such as pressure, temperature, and humidity. Results of the current study indicate that K-nearest models were the most effective, with temperature being the most significant predictor, followed by relative humidity. However, the geographic specificity of data limits, so, models may not accurately capture sudden changes in virus transmission due to new variants or public health interventions. Future research should expand the geographic scope and incorporate real-time data to improve model accuracy. Including additional predictors such as population density and mobility data could provide a more comprehensive understanding. Longitudinal studies on the impact of emerging variants and vaccination would also be beneficial. In conclusion, our research highlights the potential of machine learning models in predicting COVID-19 cases, aiding policymakers in proactive monitoring and control strategies. Understanding the environmental and temporal factors influencing virus transmission can help better prepare for future outbreaks.

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Ethics code

IR.GMU. REC.1402.117. AQ5.

Conflicts of interest

There are no conflicts of interest.

Authors' contributions

Laleh R. Kalankesh: Conceptualization, Data collection and analysis, and Manuscript drafting; Reza Ahmadi: Conceptualization; Ali Alami: Provided epidemiology expertise; Yeganeh Azhdary Moghaddam: Data collection, and Manuscript drafting.

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