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Javadinejad, Safieh; Dara, Rebwar; Jafary, Forough

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RESEARCH ARTICLE

Potential impact of climate change on temperature and humidity related human health effects during extreme condition

Safieh Javadinejad[1] · Rebwar Dara[1] · Forough Jafary[1]

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Abstract

In this study, in addition to considering the two dominant climatic domains during extreme condition in the study area, temperature and humidity, and determining the correlation and correlation of these two factors with the prevalence of rotavirus gastroenteritis, a statistical model was proposed to predict the prevalence of the disease. Although this research, like many earlier studies, has been based on statistical data for a period of three years, according to its primary objectives, the short-term risk of the disease has been zoned using GIS software, and this point is new. The distinction between the present study and previous studies is considered. Previous studies did not consider the relationship between climate change and gastroenteritis GE. So, the purpose of this study was to investigate the correlation between the number of patients admitted in the hospital with symptoms of gastroenteritis GE and the monthly climatic variables of temperature and humidity of rotavirus, maximum, mean during extreme condition, at least in the city of Ahvaz, in three levels and its suburbs. The results showed a high prevalence of rotavirus infection in children in Ahvaz at low temperature. The maximum rotavirus activity was determined at 13 ° C. Also, the highest number of patients with symptoms of rotavirus gastroenteritis was observed in autumn and early winter. It is suggested that the results of this study should be considered in determining the timing of vaccination during extreme condition.

Keywords Climate change · Impacts · Climatic variables · Extreme condition · Health · Statistical model

Introduction

The mechanism of global climate change and its effects is wide-ranging and includes numerous studies (Ogden and Lindsay 2016; Javadinejad et al. 2019). Today, the seasonal pattern of how many infectious diseases and seasonal sensitivities are well known are well-known (Ludwig et al. 2019). To the extent that one of the 21st century's most important human concerns is to answer the question of what the impact of global climate change on disease patterns is, and how much the changes affect the spread of diseases (Wu et al. 2016; Javadinejad et al. 2020). Rotavirus is the most important cause of viral gastroenteritis in children under 5 years of age in developed and developing countries, which annually cause death of 10 − 5 million children worldwide (Ostfeld and Brunner 2015). Many studies have been conducted around the world to investigate the relationship between climate fluctuations and the epidemic of rotavirus gastroenteritis in children (Levy et al. 2016; Vezzulli et al. 2016; Netshitanini 2017). In Japan, for example, during the study of relationship between temperature and relative humidity parameters, it was concluded that although there is a reverse relationship between the number of hospitalized patients with symptoms of gastroenteritis and temperature, so that the decrease in temperature increases the number of patients, however, the prevalence of rotavirus gastroenteritis is not related to relative humidity (Campbell-Lendrum et al. 2015). Research conducted in Japan shows that rotavirus is not common in the winter alone, and in summer it also has another peak, with a shorter peak than winter. In addition, the study of the relationship between the number of gastroenteritis (GE) and the changes in the surface water level of the current river in the area showed that, for every 10 cm increase in river surface water level, the number of GE cases increased by 5.5.

✉ Safieh Javadinejad
Javadinejad.safieh@pd.iut.ac.ir

Rebwar Dara
rebwar.dara@knowledge.ed.u.krd

Forough Jafary
foroughjafary@yahoo.com

[1] University of Birmingham, Edgbaston St, Birmingham B152TT, UK

In Swaminathan et al. 2017 examined the prevalence of rotavirus gastroenteritis in three cities with different climates. The results showed that in dry and far-sea climates, the number of cases of rotavirus among hospitalized patients was higher than that of a warm coastal or tropical one, however, the number of GE cases increased in each of the three cities as the temperature reached its lowest point. Onozuka et al. 2019 in a different way, investigated the relationship between climatic fluctuations and the number of GE cases, and concluded that the number of GEs in a cold month was 84% more than one month old. Also, low relative humidity in a closed space can be effective in the prevalence of rotavirus. In Iran, correlation between the rotavirus activity and the seasons is not analyzed.

The rotavirus gastroenteritis does not function in all parts of the world seasonally and occurs in tropical regions such as Bangladesh, southern Asia, Bahrain and Costa Rica all year round (American Academy of Pediatrics 2019). These studies, based on 34 studies from 23 countries in six continents, show that there is a slight dependence between seasons and the prevalence of rotavirus diarrhea in the latitudes of 10 degrees to the equator. Background review studies show that research carried out elsewhere in the world mainly based on short-term statistical data (Madhi et al. 2016). In addition, in most of these studies, gastroenteritis is considered as a function of temperature and humidity variables. Finally, in some cases, such as studying Bangladesh, the river is also considered the role of changes in current water levels (Hossain et al. 2020).

Although in none of these studies, the role of latitude has not been studied directly, comparison of their results shows that the pattern of the disease differs in different geographical districts (Vrdoljak et al. 2019). On the other hand, the main focus of research on the epidemiology of rotavirus gastroenteritis in India has been to determine the genetic diversity of the common strains in children with acute diarrhea referred to the hospital or to determine the prevalence of the number of children with rotavirus diarrhea in different groups of ages have been (Gupta et al. 2019). Considering the efforts of all of these researchers in their place of admiration, in this study, in addition to considering the two dominant climatic domains in the study area, temperature and humidity, and determining the correlation and correlation of these two factors with the prevalence of rotavirus gastroenteritis, a statistical model was proposed to predict the prevalence of the disease. Although this research, like many earlier studies, has been based on statistical data for a period of three years, according to its primary objectives, the short-term risk of the disease has been zoned using GIS software, and this point is from the funds The distinction between the present study and previous studies is considered. The purpose of this study was to investigate the correlation between the number of patients admitted in the hospital with symptoms of gastroenteritis GE and the monthly climatic variables of temperature and humidity of rotavirus, maximum, mean, at least in the city of Ahvaz, in three levels and its suburbs.

Materials and methods

In this research, it was tried to investigate the existence or non-existence of the relationship between several variables in a specific time period; therefore, an analytical-cross-sectional method was selected as the study method. According to this method, for the purpose of carrying out the necessary studies, two categories of statistical data are required, each of which is collected in a special way. These two categories are hospital data and meteorological station data.

A. Disease data: For the purpose of obtaining the required disease information, all cases of children with acute gastroenteritis referred to Ahvaz Children's Hospital during the period of 2009 − 2006 were examined. Among all the patients, the number of people with positive rotavirus, which by secondary analysis and analysis of data from rotavirus antigen test in vitro was determined as the statistical population. It should be noted that different methods are used to measure the above, and ELISA is one of them.

More precise methods are used in this world, but given the above mentioned data, only the data were available and used in this study. Since stool sampling was performed randomly from previous studies and all patients with gastroenteritis were not tested for rotavirus diagnosis, therefore, no accurate statistics were available on the number of positive infections of rotavirus. B. Meteorological data: Data needed for this study was obtained from the only synoptic station in the area of Ahvaz. Ahwaz synoptic station with a latitude of 37.56 degrees east and a latitude of 22.27 degrees north, at an altitude of 9.9 m from the sea level. Among the recorded data of the climate experts of the province's meteorological organization, daily reports of two climatic elements including temperature (maximum, minimum) of average humidity were used. It is worth noting that for zoning the risk of rotavirus gastroenteritis in the province, the minimum temperature data were recorded in seven synoptic stations in the province (Table 1).

Table 1 The characteristics of the stations in Ahvaz. Iran Meteorological Organization, 2019

Station	Elevation	Latitude	longitude
Station 1	10	27° 13	56° 22
Station 2	30	57° 05	27° 06
Station 3	193	27° 10	57° 10
Station 4	23	26° 32	54° 50
Station 5	6	26° 55	55° 55
Station 6	5.3	25° 38	57° 46
Station 7	932	28° 19	55° 54

For data analysis, all climatic data as independent variables and disease data were determined as dependent variables by using SPSS software at weekly and monthly intervals. Then, to determine the frequency of GE numbers, they were classified in different temperature ranges of climatic elements. In addition, it is used to identify the governing relationships between variables in the estimation of performance in geographical areas, Pearson correlation coefficient was used. To reduce the number of independent variables, there are a number of variables that have a more role in the dependent variable. A stepwise method was used to compute and present the multivariate linear regression model. In this method, each of the climatic elements of variables independent of the most important variables to the least important ones entered the model, the criterion for determining the importance of the variable in the model is determined by the significance level of the test. At the end of the operation, only the minimum temperature remained as the independent variable affecting GE in the model, and the prediction model was presented using this cluster element. In order to zone GE's risk in the province, climatic data from seven meteorological stations in the province was used. Firstly, climatic data was set up in Excel software during the 12-month period, and then the data, along with the province's map, were inserted into separate digital layers in ArcGIS software. By specifying the coordinate system of meteorological stations, climatic data interpolation by distance image weighing (3IDW) this method is a completely mathematical method presented as Eq. (1).

$$Z * j = \frac{\sum_{i=1}^{n} \frac{zi}{hij}}{\sum_{i=1}^{n} \frac{1}{hij}} \quad (1)$$

Z * j shows value at the point j and Z i shows value at the point I and i indicates coordinates for neighboring points and j is coordinates for points of estimation and hij shows distance between estimated point and neighboring points and β indicates weighted weight by distance. An advanced method is based on the nearest neighbor. Therefore, we tried to use the data recorded in seven meteorological stations in different parts of the province to estimate the weights of interpolation of other missing points. The nearest point to each station thus obtains the highest weight, and vice versa, the farthest point has the lowest weight. In fact, in this way, the value of climate variables and disease was predicted in other parts of the province. According to Table 2, out of 4417 patients with clinical signs of acute gastroenteritis during the three years studied, 870 cases were related to 2006, and in 2007 and 2008, the order of 1740 and 1807 people were referred. Of these, the most cases tested were 2007, and it was found that 68% of the patients were infected with rotavirus infection. Of these, they were infected with rotavirus. The results of the mean temperature classification showed that the highest number of GEs the length of the survey period is 1155 people in the temperature range of 15.6 to 20.5. It can be said that the best conditions for growth, propagation and propagation of the viruses in this temperature range are provided. It is worth noting that in one week from the 2007 temperature class, the level of GE was significantly reduced due to the effects of non-climatic factors such as national holidays. Also, the highest number of weeks of the year belonged to the temperature range above 30 degrees, and the lowest number of patients was related to this temperature class in one week.

Results

Comparison of the classroom distance at each temperature level with the average number of GEs in a week of the year showed that the highest number of GEs was referred to the hospital at a temperature range of 16 to 21 degrees during a week, with a change in temperature of 5 degrees C 10 to 14 people increased or decreased. This trend was observed in 2006 and 2008; however, in 2007, under the influence of non-climatic factors, this trend was not steady.

The maximum, average, analysis of the relationship between the monthly temperature variations (minimum) and the GE number shown in Fig. 1 shows that the minimum temperature is increasing with the beginning of the spring and this ascension continues until July in the summer. From mid-summer, although the temperature is declining, the trend goes slowly and until the end of the summer, the temperature is still 25. Since late September, the downward trend is accelerating and with the onset of the fall season, the steep slope of the temperature begins to decrease. So that the difference in temperature between September and October falls to five degrees Celsius. This downtrend continues until early January and the lowest temperature is about 11 degrees Celsius in winter this month. After that, the four month period of Ahvaz is over, and since February, the temperature has regained. The average temperature fluctuations follow the minimum temperature fluctuations. The average of the three years was the highest and lowest average temperature in July and January, and the difference between the highest average temperature and the lowest temperature was 18. The maximum temperature curve in Fig. 1 shows that the general trend of fluctuations in the months was different with minimum and average temperatures. However, the maximum temperature was observed in May and June. Although the lowest maximum temperature was in January, its value was less than 24 degrees. In the case of the number of cases of GE, the process of oscillation with the temperature elements of the photo mode. The lowest number of GEs was in June and July with the highest temperatures. From the end of September, with the onset of a drop in temperature, the GE curve began to skyrocket steeply, reaching its highest level in December. In the

Table 2 Frequency distribution of patients with gastroenteritis symptoms

Year	Number of referrers with symptoms of GE disease	Case in test	Rotavirus infection cases	Percentage of Rotavirus Infection
2015	880	440	230	55
2016	1750	590	404	69
2017	1808	278	179	64

winter, though the temperature was still low in January, the GE curve declined steeply. Investigating the changes in the number of GEs relative to the minimum temperature fluctuation showed that the lowest number of GEs is when the temperature is at its peak. However, the highest number of GEs did not occur at the lowest minimum temperature. This means that the temperature at least up to a certain threshold is effective on the number of GEs. Pearson statistical test showed a negative significant correlation between temperature parameters and GE numbers, which means that the decrease in temperature would increase the number of GEs. Among the temperature parameters, the minimum temperature had the greatest effect on the growth of rotavirus and the increase in the number of GE. Also Fig. 2 shows the Relationship between monthly changes of mean temperature and GE and according to the R^2 ,there is close relationship between the variables. Table 3 shows that the correlation coefficient between GE and mean temperature and mean humidity is significantly high with p value of 0.001.

The 61% variation coefficient in the GE number indicates a larger dispersion than the mean number, while the coefficient of variation, despite following a similar process, is in the temperature parameters are not very high. The standard deviations of these two cases showed that, unlike the temperature parameters, the standard deviation of the GE number was higher than the average. The lowest deviation was from the maximum temperature. Low standard deviation and coefficient of variation at maximum temperature indicate that the volume of variations is low compared to the mean, and in other words, the difference between the maximum and minimum values of maximum recorded temperature is low.

Analysis of the relationship between monthly variations in relative humidity and GE numbers in Fig. 3 showed that relative humidity parameters, with the exception of relative humidity, were minimal at least during this period. This can be done in the vicinity of the studied area with the Persian Gulf waters and has a permanent source creating moisture. Figure 4 shows the Relationship between monthly changes of mean humidity and GE and according to the R^2 ,there is close relationship between the variables.

The minimum relative humidity of the minimum and the average in February was 54.34% and 54.3%, respectively, and the highest was 53 and 68 respectively, respectively, in November and December, respectively. On this basis, the hydrological fluctuations and GE numbers do not follow the same trend. Although the relative humidity was not significantly altered during the study period, the number of GEs has been plummet, suggesting the low impact of this parameter on the number of GEs and the involvement of other factors in increasing and decreasing it.

The correlation coefficients between relative humidity and GE numbers were very small. Considering the significance level for all three climatic elements-which is more than − 5%, it can be said that relative humidity parameters have a quantitative relation with the number of GEs. The low values of standard deviation and coefficient of variation show that the volume of variations was low compared to the mean, and compared with the amount of coefficient of variation of the

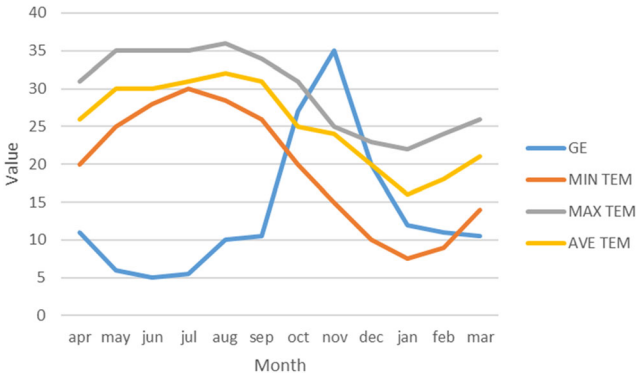

Fig. 1 Relationship between monthly changes in maximum, mean, minimum of temperature and GE

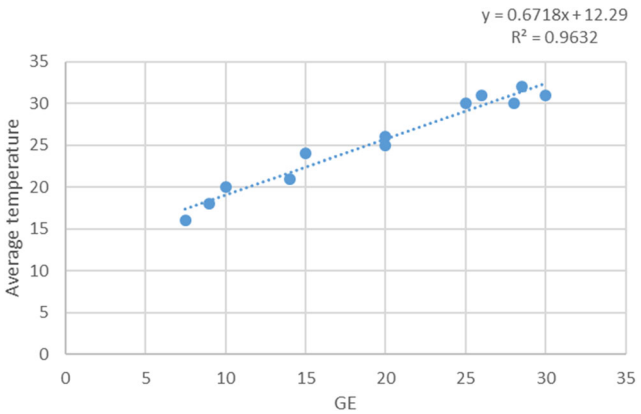

Fig. 2 Relationship between monthly changes of mean temperature and GE

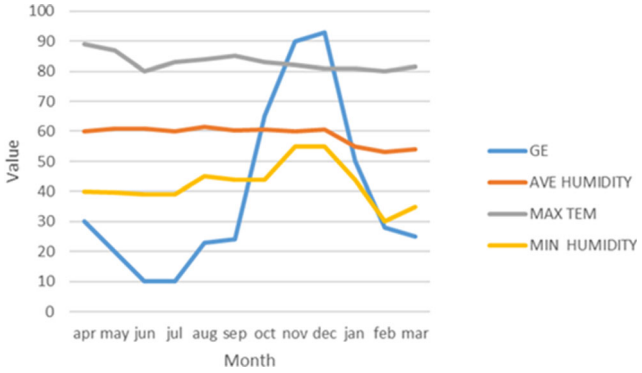

Fig. 3 Relationship between monthly changes of maximum, mean, minimum of humidity and GE

GE number, it was determined that the moisture parameters do not have a significant effect on the number of GE. Using monthly multivariate linear regression model, GE monthly prediction model was presented for a mean period of three years using climatic elements in Ahvaz.

$$\mathrm{GE} = 373 + (-11^{*}\mathrm{TMin}) \quad (2)$$

Based on the calculations, the minimum temperature has had the greatest effect on the number of GE cases during the statistical period. In fact, factors such as geographic location, long period of heat, and direct sunlight fluctuations overnight lead to an increase in maximum values and mean temperatures throughout the year. Therefore, in the monthly review, these two items are not very important and the least value has the most relevance or effect on the number of GEs. The results of the comparison of the actual number of GEs in the referents during the statistical period and the predicted number showed that the accuracy of the proposed model was about 80%.

The zoning of the risk of rotavirus gastroenteritis in Hormozgan province showed that the number of GEs in this three year period was estimated to be 120 to 220 (Fig. 2). The lowest number.

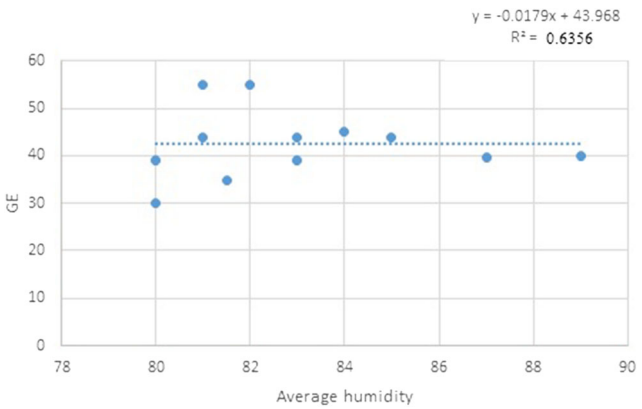

Fig. 4 Relationship between monthly changes of mean humidity and GE

The predicted Jask city and the highest number belonged to Haji Abad city. While the difference in average temperature of Jask and Hajiabad was 10 ° C, the difference was GE number 100. In the vast area of the country, including the Persian Gulf and some islands, which reached a temperature of at least 22 degrees (with the exception of Bandar Lengeh and Jask). The number of GE predictions was between 153 and 142. In fact, with the advent of beaches to the northern provinces, the risk of the occurrence of rotavirus gastroenteritis increased.

In fact, areas with lower geographic latitudes had lower numbers of visitors due to the lower minimum temperature (Jask), and vice versa, at higher latitudes, due to the greater desire for an angle of sunshine or an alternative to reducing the sun's angle And received less energy than lower temperatures. In addition, the role of height in reducing the temperature should not be ignored. Having more heights in the northern regions was effective in lowering the temperature and increasing the number of GEs. The results showed that with each degree of temperature reduction, 10 people were added to the GE number.

In addition Table 4 shows the validation analysis by Nash–Sutcliffe model efficiency coefficient (NSE) for validation the relationship between GE and average temperature and humidity. The value of NSE shows that there is significant relationship between GE and average temperature and humidity.

Discussion

Changes and climatic variations in different time periods (monthly, seasonal and annual) can be effective in reducing or increasing the number of hospitalized patients with symptoms of rotavirus gastroenteritis and determining the element or climatic elements affecting the occurrence of GE and determining the governing relationships between these variables in their performance evaluation In the present study, the study of the relationship between climatic elements and the number of GE, using the Pearson correlation coefficient, revealed that the correlation index between GE and temperature in cold months of the year.

It is negative during the statistical period. This point indicates that the temperature reduction provides the appropriate conditions for the growth, propagation, and transmission of rotavirus, resulting in an increase in the number of GE cases, and it should be noted that decreasing the temperature of the chamber is the least tolerable temperature for rotavirus. The results of the studies of Onzuka and colleagues are consistent with the results of this study. After determining the governing relationships between the number of GE and climatic elements, using the Pearson correlation coefficient, the distribution of GE's number in each of the climatically classified elements was analyzed. Minimum temperature has the highest positive effect on increasing the number of GEs with the

Table 3 Correlation coefficients and statistical properties of temperature parameters relative monthly humidity and GE number

	Correlation coefficient	*p*	Standard deviation	Coefficient of variation
Temperature				
Min temperature	-0.80	< 0.001	23	33
Mean temperature	-0.76	< 0.001	28	24
Max temperature	-0.71	< 0.001	33	19
Number of GE	0	< 0.001	148	62
Humidity				
Min humidity	-0.34	0.074	45	19
Mean humidity	-0.01	0.38	65	10
Max humidity	-0.05	0.78	83	6
Number of GE	0	0	148	61

coefficient of determination and was identified as the most effective element in this number (626/0). This finding is close to the findings of studies conducted in other countries, such as Bangladesh, Japan, and Australia (6.3). We also found that the highest number of GE In October until January), the results of the other studies in Iran coincide with the autumn and early winter.

In the present study, there was no significant correlation between relative humidity parameters and the number of patients with rotavirus infection. In studies conducted in other parts of the world, this relationship was not observed (3–7). In this study, the GE monthly prediction model for a period The average of three years and using climatic elements in the city of Ahvaz was calculated. The rational interpretation of the results shows that GIS software can be used to predict the risk of disease occurrence in the province. The risk of the occurrence of the disease (rotavirus) in Ahvaz with a precision of about 80% showed that as far as the Gulf Fars and Oman to the northern provinces of the province. Due to the lowering of the minimum temperature, the risk of the prevalence of GE also increases. Therefore, the Jask and Bandarlengh coastlines with a mean annual temperature of 6.8 and 23.23 are considered low and GE and Hajiabad with an average temperature of 9.9 ° C as a high risk area. Although in this study, the ultimate effort was made to increase the accuracy of the prediction model, there were some limitations in the way of this study, which reduced the accuracy of the work and Cannot be ignored. It should be noted that most of these limitations relate to statistical data. Children's Hospital Information Collection Patient Information Only from a Medical Center (Ahvaz). The men were of various ethnic groups and social classes, and many of them came to other public and private hospitals, but due to the lack of registration of the patients in these centers, there were no accurate data on the number of patients. In addition, the small number of meteorological stations at the provincial level has caused the surfaces under their cover to be reduced and measurements are limited to areas of the area. Also, the decrease in the number of statistical data led to a decrease in the accuracy of the data related to the statistics, because in all studies based on the statistical data the more data is available, the amount of computational error will also decrease.

Conclusions

This study analyzed the correlation between the number of patients admitted in the hospital with symptoms of gastroenteritis GE and the monthly climatic variables of temperature and humidity of rotavirus, maximum, mean during extreme condition, at least in the city of Ahvaz, in three levels and its suburbs.

This cross-sectional study showed a high prevalence of rotavirus infection in children in Ahvaz at low temperature. The maximum rotavirus activity was determined at 13 ° C. Also, the highest number of patients with symptoms of rotavirus gastroenteritis was observed in autumn and early winter. It is suggested that the results of this study should be considered in determining the timing of vaccination during extreme condition.

Table 4 Nash–Sutcliffe model efficiency coefficient (NSE) for validation the relationship between GE and average temperature and humidity

Nash–Sutcliffe model efficiency coefficient (NSE) for validation the relationship between GE and average temperature	0.93
Nash–Sutcliffe model efficiency coefficient (NSE) for validation the relationship between GE and average humidity	0.61

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