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Original Article

# Zonation of Shigellosis and its Relationship With Climatic Factors, Case Study: Chaharmahal and Bakhtiari Province Between 2011 and 2014

**Abdollah Seif[1], Mehrdad Pasandi[2*], Sajjad Saneie[1], Masoud Amiri[3]**

[1]Geographic Sciences and Planning Faculty, University of Isfahan, Iran
[2]Department of Geology, Science Faculty, University of Isfahan, Isfahan, Iran
[3]Social Determinants of Health Research Center, School of Health, Shahrekord University of Medical Sciences, Shahrekord, Iran

*Corresponding Author:
Mehrdad Pasandi, Ph.D.
Department of Geology,
Science Faculty,
University of Isfahan,
Isfahan 81746-73441, Iran
Tel: +98 (31) 3793-4256;
Fax: +98 (31) 3793-2152;
Email:
m.pasandi@sci.ui.ac.ir

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## Abstract

**Background and aims:** Shigellosis or bacillary dysentery is an infectious disease transmitted through water and food. It is a type of infectious colitis caused by *Shigella* bacteria. The aim of this study is to determine the prevalence and the spatial distribution of shigellosis and its relationship with climatic factors in Chaharmahal and Bakhtiari province.

**Methods:** In this study, population of infected people to shigellosis in the province during 2011 to 2014 obtained from reliable sources and analyzed. The statistics were standardized for every city in the event of illness per hundred thousand people. The relationships between incidence of the disease and the climatic factors (temperature, rainfall and humidity) were investigated by Pearson correlation coefficient after generation of zonation map using GIS and analysis of the concentration centers.

**Results:** According to the results, Koohrang, Lordegan and Ardal cities are classified as high risk areas with an incidence more than 400 000 people. Borujen and Faarsan cities are medium risk areas with an incidence less than 250 per 100 000, and Shahr-e-kord city with an incidence less than 100 per 100 000 people is considered a low risk area. The incidence grows with increase in the temperature. Increase in the precipitation and humidity decreases incidence of the disease. Concentration and prevalence of shigellosis mostly occur in west of the province, because this area is located in the neighborhood of Khuzestan province, and also due to nomadic residence of Bakhtiari nomads in this part during summer and their unhealthy lifestyle, limited access to treated water and especially consumption of untreated surface water. The higher concentration of nomadic residence and higher contamination of water increase incidence of waterborne diseases. The frequency increase of the disease in warm seasons can be due to prevalence of *Shigella* dysentery in the region.

**Conclusion:** Based on the results, significant positive correlations exist between the surface water consumption, the temperature increase, the number of pisciculture centers in the area and incidence of the disease. Significant negative correlations are also observed between the rainfall, humidity and incidence of the disease.

**Keywords:** Mapping, GIS, Shigellosis, Spatial epidemiology.

## Introduction

Shigellosis or dysentery bacillus is a bacterial intestinal disease. Shigellosis is a type of diarrhea caused by *Shigella* bacteria.[1] *Shigella* is an intestinal pathogen that may have an extraordinary virulence. These bacteria are the major cause of epidemic or endemic dysentery resulting in high mortality. *Shigella* is considered as the main cause of large-scale epidemic dysentery in various parts of the world. Shigellosis causes about 600 000 deaths around the world every year. Two-thirds of the disease cases, and most of the subsequent deaths occur in children younger than 10 years old.[2] Death of most people infected with AIDS is also caused by shigellosis.[3] Most people in the third world countries are at risk for typical epidemic dysentery caused by shigellosis.

The geospatial analysis of the disease, in addition to formulation and evaluation of etiological hypotheses and also intervention in areas requiring special provision, can play an important role in the allocation of facilities and human resources.[4,5] Moreover, development of geospatial information

systems during the past thirty years, has provided more advanced capabilities to study the geographical patterns.[6,7] Most of the environment-borne diseases are transmitted through water and food.[8] Removal of these pathogens from water is of great priority due to the high mortality and spread rates in communities.[9,10]

Iran is a risky area for this disease and therefore establishment of a comprehensive spatial database of diseases and determination of environmental factors affecting them, are increasingly necessary. Since no study has been carried out on the food and water-borne diseases in Chaharmahal and Bakhtiari province, this study aims to determine the incidence and prevalence of shigellosis in different cities of the province. Analysis of factors influencing the disease would not be possible neglecting spatial distribution and natural factors associated with it. In this study, in addition to mapping the spatial distribution of shigellosis in the province, the influencing climatic factors are also analyzed.

### Background of the Research

Snow[11] investigated the epidemiology of cholera in several cities of the United Kingdom including Birmingham, London and Manchester. He mapped the distribution of cholera and concluded that the disease occurs with spread of a deadly poison in the digestive tract. He noted that the poison could contaminate drinking water. He also pointed out that consumption of healthy drinking water resources, which are not contaminated with domestic waste water, is an effective way to prevent this disease.

Clarke et al[12] assessed prevalence of the gastrointestinal diseases and Guinea worm in central Africa. In this research, the distribution of Guinea worm disease in the eastern state of Benin was studied and influences of sanitation and public awareness on prevalence of the disease were evaluated.

Navarra and Tubiana[13] examined climatic changes and infectious diseases in the eastern Mediterranean region and suggested that climatic changes may cause prevalence of vector-borne diseases not already existed in susceptible areas.

Hooshvar[14] studied common diseases in Iran and concluded that many diseases such as leishmaniosis are highly dependent on the average temperature, moisture and vegetation.

Raeisi et al[15] examined and mapped the spatial distribution of multiple sclerosis in Chaharmahal and Bakhtiari province and concluded that the distribution of the disease is relatively higher in urban areas and main centers of the disease are concentrated in eastern part of the province.

## Methods

### The Study Area

Chaharmahal and Bakhtiari province with an area of 16421 km$^2$ (about 1% of the total area of Iran) is located in southwest of the mountainous belt in west of Iran (Figure 1) between N 31°9'-32°38' and E49°30'-51°26'.

Based on the political division of the country in 2011, Chaharmahal and Bakhtiari province includes 7 cities and Shahr-e-kord is its capital. The latest population of the province was 895263 in 2011.[16] 58.2% of this population reside in urban areas and 41.8% in rural areas.[15]

The data of this disease were gathered by Statistical Centre of Iran, Chaharmahal and Bakhtiari Meteorological Administration and also health centers of the province during 2011 to 2014 were employed to map the distribution of shigellosis and the climatic factors influencing its prevalence. The Pearson correlation coefficient was calculated by SPSS® 14.0 software to determine degree of influence of the climatic factors. According to the statistics,[17] population of patients infected with shigellosis during 2011 to 2014 are as Table 1. The total population of the studied patients in these years was 8758 persons. Out of these, 2134 people were infected in 2011, 2286 in 2012, 1754 in 2013 and 2584 patients were recorded in 2014. Among cities of the province, the maximum and minimum numbers of infected people were recorded in Lordegan with 3180 infected people followed by Farsan with 680 cases (Table 1). Based on Table 2, no noticeable difference was observed between frequency of male and female patients.

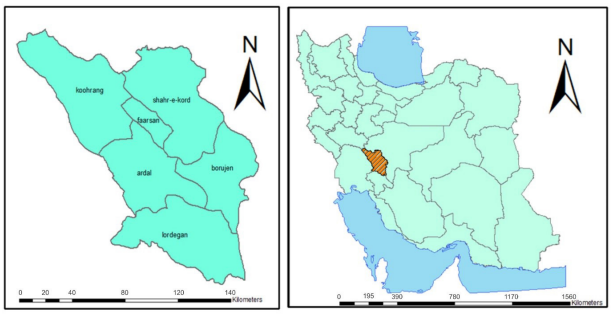


**Figure 1.** Map of Cities of Chaharmahal and Bakhtiari Province and Location of This Province in the Map of Iran.

**Table 1.** The Total Frequency of Patients Infected to Shigellosis in the Studied Period

| Year | No. of Infected People |
|---|---|
| 2011 | 2134 |
| 2012 | 2286 |
| 2013 | 1754 |
| 2014 | 2584 |

**Table 2.** The Total Number of Infected Persons in All Cities of the Province According to Gender and Year

| City | 2011 | | 2012 | | 2013 | | 2014 | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | M | F | M | F | M | F | M | F | |
| Ardal | 156 | 185 | 159 | 163 | 102 | 138 | 134 | 160 | 1197 |
| Borujen | 109 | 120 | 71 | 87 | 111 | 98 | 188 | 227 | 1011 |
| Shahr-e-kord | 187 | 164 | 135 | 117 | 112 | 141 | 176 | 202 | 1234 |
| Lordegan | 277 | 303 | 497 | 570 | 307 | 284 | 491 | 450 | 3180 |
| Faarsan | 133 | 106 | 76 | 81 | 50 | 66 | 91 | 77 | 680 |
| Koohrang | 139 | 121 | 91 | 77 | 69 | 82 | 103 | 89 | 771 |

M and F stand for male and female, respectively.

## Results

As the population of each city is different (Table 1), the frequency of infected persons cannot be employed to find concentration centers of the disease. Accordingly, a logical classification in accordance with the principles of epidemiology is not possible. Incidence of the disease must be calculated to find centers of shigellosis in the province. The incidences in all the cities are based on 100 000 people and the standard classification between the provinces can be carried out in terms of the incidence. Then, the 4-year average of incidences was calculated. Accordingly, the incidences of shigellosis in Koohrang with incidence of 550.71 per 100 000 and Shahrekord with an incidence of 83.83 per 100 000 are the minimum and maximum incidences in the province, respectively (Table 3 and Figure 2).To determine the prevalence centers, the incidence values were classified and the location of high or low risk centers were identified. Then the values were classified in high, medium and low categories.

Koohrang, Lordegan and Ardal have incidences more than 400 per 100 000. These cities are classified as high risk areas. One of the causes of shigellosis is nomadic residence in these areas. According to the 2014 statistics, 14 657 families (i.e., 126 039 persons) had nomadic residence in Chaharmahal and Bakhtiari province. About 14 520 families out of this spent summers in west of the province.

This part is a mountainous area. Limited standard sanitary services can be the main reason for the prevalence of the disease in this region. Settling in the neighborhood of Khuzestan province which high incidences of diseases are always recorded in this area

**Table 3.** The Shigellosis Incidence in the Studied Period (2011 to 2014)

| City | Incidence of Shigellosis (Per 100 000) |
|---|---|
| Ardal | 427.50 |
| Borujen | 219.87 |
| Shahrekord | 83.83 |
| Lordegan | 449.15 |
| Faarsan | 188.88 |
| Koohrang | 550.71 |

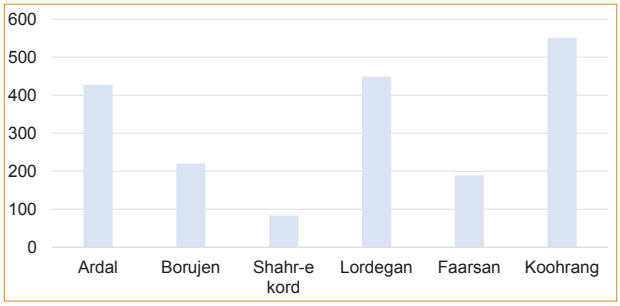


**Figure 2.** The Diagram of Shigellosis Incidence (Per 100 000).

is another reason for the high incidence of shigellosis in the west part. Shahrekord, Faarsan and Borujen with lower incidence of 220 per 100 000 people are the areas with moderate risk (Figure 3). Risk of this disease decreases in these cities because of lower residence of nomads in these areas and also the use of advanced methods of raising livestock. Urbanization also limits exposure of people to this disease. The concentrated and nuclear residence of nomads increases fecal contamination of water and consequently water-borne infectious diseases such as shigellosis.[18]

To evaluate effect of temperature on the incidence of shigellosis, the monthly number of patients was plotted against the average monthly temperature (Figures 1 to 4). A significant relationship can be observed in the graphs.

The Pearson correlation coefficient was also calculated by SPSS® 14.0 software to examine the relationship between the studied factors and the number of infected population (Table 4). There is a significant positive correlation between the temperature and the disease frequency. In other words, the increase in temperature causes increase in risk of the disease. The results of the study are consistent with the findings of Jamalian[19] which indicate that prevalence of the disease in the developing countries is higher during the summer and *Shigella* dysentery occurs in warm seasons due to being endemic.

According to Figure 5, the highest frequency of infected population is during May to September. As indicated in monthly graph of the precipitation (Figure 5), the minimum rainfall has occurred during this

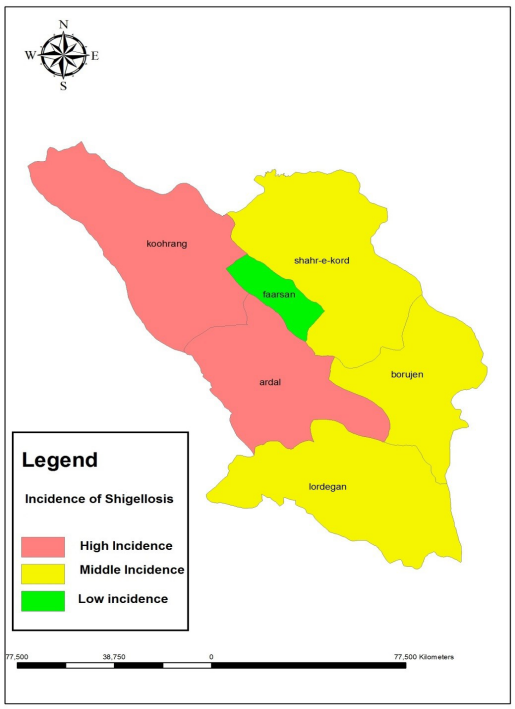


**Figure 3.** The Distribution of Shigellosis Incidence During 2011 to 2014

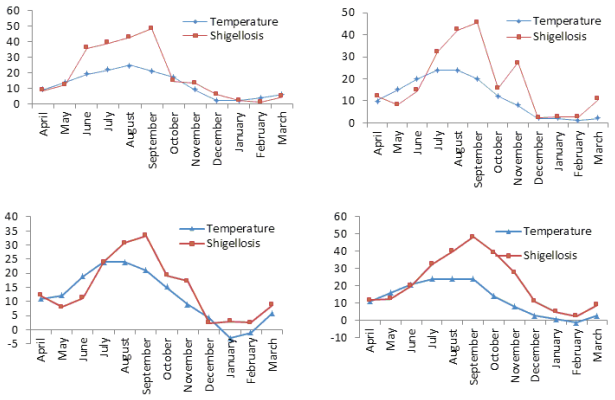


**Figure 4.** Diagrams of Shigellosis Incidence and Average Monthly Temperature During 2011 to 2014.

period. Therefore, rainfall has negatively influenced on incidence of the disease.

There is also a significant negative correlation between the amount of rainfall and frequency of the

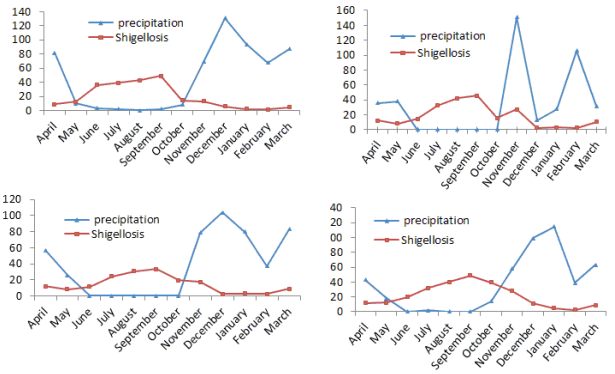


**Figure 5**. Diagrams of Shigellosis Incidence and Average Monthly Rainfall During 2011 to 2014.

disease during 2011 to 2014 (Table 5). This indicates that the frequency of infected people increases with the decrease in the precipitation.

Comparison between the monthly humidity and the number of infected people in the corresponding month indicates a significant consistency between the months with the maximum and the minimum infected people with the months with the highest and lowest humidity (Figure 6). The months with the highest infected people have the lowest humidity.

As indicated in Table 6, there is also a significant negative correlation between the humidity and the disease between 2011 and 2014. The reduction of humidity increases the risk of infection to the disease.

According to Figure 7, there is a consistency between risky centers of the disease and the distribution of pisciculture. The correlation may be due to physical and chemical pollution of water and its subsequent impact on prevalence of the disease.

As previously stated, Shigella mainly have incidences in the warmer areas. This conclusion is true for Ardal and Lordegan but the reason for the high incidence of the disease in Koohrang ,with an average annual temperature less than 10°C, should be different. The other probable influencing factors were examined to find out reason of the high incidence of the disease in Koohrang. The predominance of surface water

**Table 5.** The Correlation Between the Rainfall and Incidences of the Disease

| | | Rainfall 2011 | Rainfall 2012 | Rainfall 2013 | Rainfall 2014 |
|---|---|---|---|---|---|
| Shigellosis 2011 | Pearson correlation coefficient | -0.209 | -0.644* | -0.579* | -0.640* |
| | Sig. (2-tailed) | 0.514 | 0.024 | 0.048 | 0.025 |
| Shigellosis 2012 | Pearson correlation coefficient | -0.495 | -0.782** | -0.762** | -0.762** |
| | Sig. (2-tailed) | 0.101 | 0.003 | 0.004 | 0.004 |
| Shigellosis 2013 | Pearson correlation coefficient | -0.318 | -0.712** | -0.670* | -0.706* |
| | Sig. (2-tailed) | 0.313 | 0.009 | 0.017 | 0.010 |
| Shigellosis 2014 | Pearson correlation coefficient | -0.346 | -0.704* | -0.664* | -0.663* |
| | Sig. (2-tailed) | 0.271 | 0.011 | 0.019 | 0.019 |

*The correlation coefficient is significant at the 0.05 level.
**The correlation coefficient is significant at the 0.01 level.

**Table 6.** The Correlation Between the Humidity and Incidences of the Disease

| | | Humidity 2011 | Humidity 2012 | Humidity 2013 | Humidity 2014 |
|---|---|---|---|---|---|
| Shigellosis 2011 | Pearson correlation coefficient | -0.714** | -0.518 | -0.755** | -0.733** |
| | Sig. (2-tailed) | 0.009 | 0.085 | 0.005 | 0.007 |
| Shigellosis 2012 | Pearson correlation coefficient | -0.872** | -0.763** | -0.898** | -0.882** |
| | Sig. (2-tailed) | 0.000 | 0.004 | 0.000 | 0.000 |
| Shigellosis 2013 | Pearson correlation coefficient | -0.795** | -0.610* | -0.838** | -0.821** |
| | Sig. (2-tailed) | 0.002 | 0.035 | 0.001 | 0.001 |
| Shigellosis 2014 | Pearson correlation coefficient | -0.814** | -0.557 | -0.861** | -0.844** |
| | Sig. (2-tailed) | 0.001 | 0.060 | 0.000 | 0.001 |

*The correlation coefficient is significant at the 0.05 level.
**The correlation coefficient is significant at the 0.01 level.

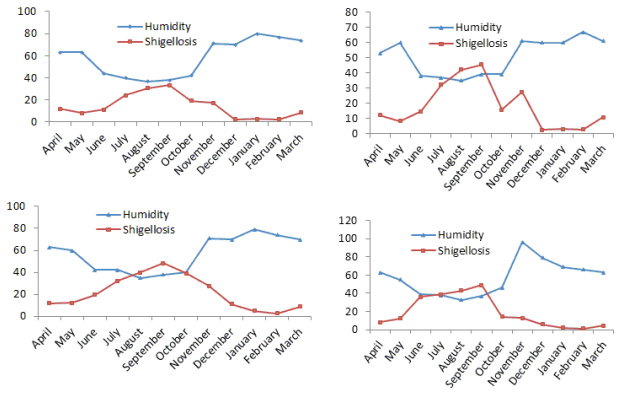


**Figure 6**. Diagrams of The Shigellosis Incidence and the Average Monthly Humidity During 2011 to 2014.

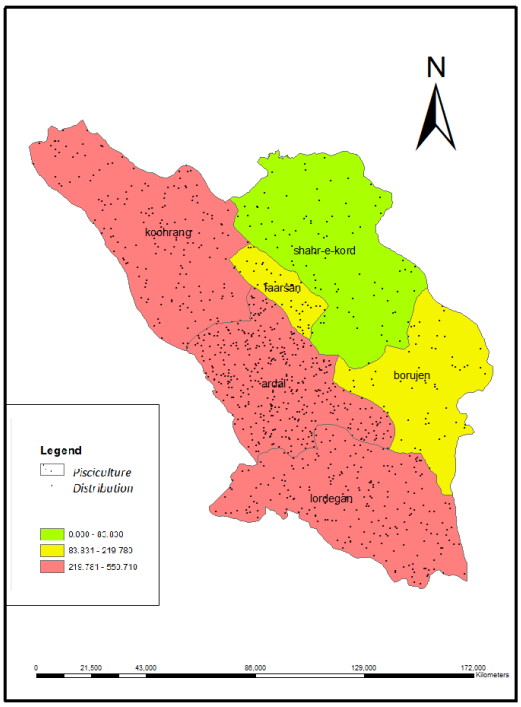


**Figure 7.** The Distribution of Shigellosis and Pisciculture Centers During 2011 to 2014..

consumption is the main difference between this city and other cities of the province (Figure 8). According to the announcement of the World Health Organization (WHO), the highest transmission of infectious diseases is through drinking water.[20] More than 90% of the population of this region consume surface water for drinking and only 5% of the consumed water meet the treatment standards. It can be concluded that the high prevalence of the disease in this city may be due to higher consumption (more than 90%) of untreated surface water by the residents.

## Discussion

Koohrang, Ardal and Lordegan (the cities located west of Chaharmahal and Bakhtiari province) are risky centers of shigellosis concentration. Proximity to Khuzestan province, the nomadic residence of people and limited access to safe water and also inadequate sanitation in these areas can be reasons for the concentration. In this study, the influence of climatological factors such as temperature, precipitation and humidity on the incidence of shigellosis was analyzed using Pearson correlation coefficient. The results indicate that there is a significant positive correlation between the temperature and incidence of the disease during 2011 to 2014. In other words, increase in the temperature increases the risk of shigellosis. This confirms the findings by Jamalian[19] emphasizing the prevalence of diseases in developing countries due to occurrence of the endemic species of infectious diseases during warm seasons. There is a significant negative correlation between the amount of rainfall and the disease during 2011 to 2014. This is indicative of reduction in the frequency of patients with the increases in rainfall. The humidity also shows significant negative correlation with the disease frequency during the study period.

Other studies in agreement/disagreement with the present study were not available. There have been limitations in this study such as unavailability of the disease statistics in a smaller scale and during

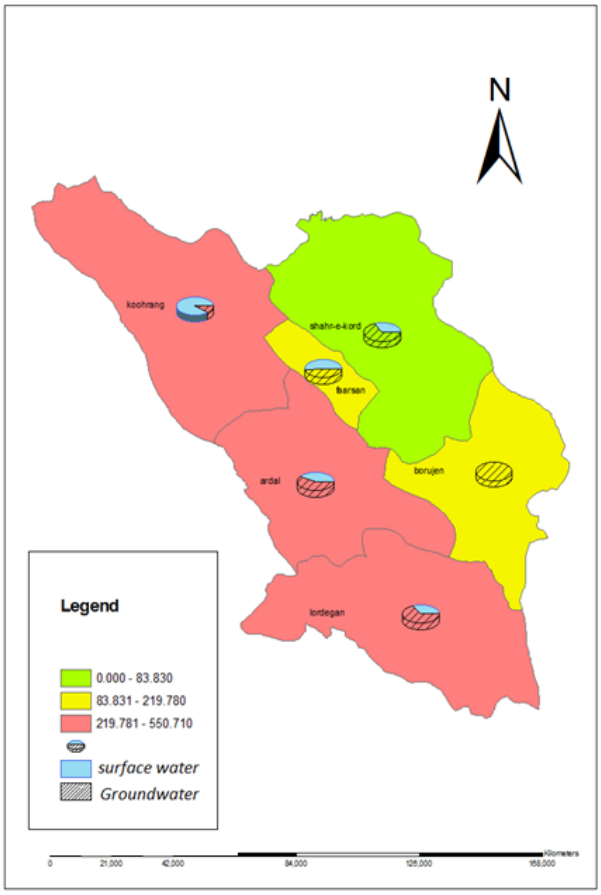


**Figure 8.** Distribution of Shigellosis and Types of Drinking Water Supply During 2011 to 2014.

longer periods.

## Conclusion

Based on the results, significant positive correlations exist between the surface water consumption, the temperature increase, the number of pisciculture centers in the area and incidence of the disease. Significant negative correlations are also observed between the rainfall, humidity and incidence of the disease.

## Ethical Approval

The local ethical committee approved the study.

## Conflict of Interest Disclosures

None.

## Acknowledgement

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