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Spatial Autocorrelation Analysis of Infectious Disease: A Case Study from Hand, Foot and Mouth Disease

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ABSTRACT: In order to better understand the epidemiology of the hand, foot, and mouth diseases disease, this study intends to investigate the application of the global and local Moran's I statistic in the detection of spatial autocorrelation analysis of hand, foot, and mouth diseases during the 29th and 30th week of July 2024 in Ho Chi Minh City, Vietnam. **Methods:** The global and local Moran's I statistics (LISA) were used to analyze the spatial clusters of hand, foot, and mouth disease, including spatial clusters (high-high and low-low) and spatial outliers (low-high and high-low). **Results:** the city's central and northern districts had the medium prevalence of these diseases. The southern part of the city has the lowest prevalence of hand, foot, and mouth disease. The city's west, center, and south were found to include the high-high, low-low spatial clusters, and low-high spatial outliers, respectively. **Conclusions :** The results of the investigation demonstrated how well LISA worked when examining the spatial clustering of diseases associated with hand, foot, and mouth syndrome.

KEY WORDS : Spatial clustering, the global and local Moran's I statistic, local clusters, hand, foot, and mouth disease, Ho Chi Minh city.

INTRODUCTION

Children today frequently suffer from hand, foot, and mouth diseases. Its principal etiologic agents are Coxsackievirus 16 (CV-A16) and Human Enterovirus 71 (EV-A71) (1). It is now common for children to have hand, foot, and mouth diseases. Human enterovirus 71 (EV-A71) and Coxsackievirus 16 (CV-A16) are its primary etiologic agents (2,3). Global reports of outbreaks of hand, foot, and mouth disease (HFMD) caused by Enterovirus A71 (EV-A71), CVA16, CVA6, and echoviruses have been common throughout the past few decades (4).

Data on hand, foot, and mouth disease and other epidemiological datasets can be examined using spatial statistical techniques (5). A spatial statistic is an essential tool for examining the spatial pattern of spatial objects (6). Tobler's First Law of Geography states that epidemiological studies have successfully employed widely-used statistics for spatial auto-correlation analysis, including local indicators of spatial association (LISA) and global spatial statistics (Moran's I, Getis-Ord G*, and Geary's C) (7–10) in general, and in the study of the spread of hand, foot and mouth diseases (11–13) and the spatial distribution of hand, foot, and mouth disease (14,15) in particular. One of the first research on this subject was carried out in China, the study used SaTScan 9.4.2 to determine the epidemiological characteristics and the temporal and spatial distribution of hand, foot, and mouth disease in Guangxi between 2008 and 2015 (16). The LISA was successfully applied in Qinghai Province, China, to investigate the spatial clusters and epidemiological features of hand, foot, and mouth disease. Numerous attempts have been made to use spatial statistics in research on the hand, foot, and mouth diseases that spread. For instance, northern Thailand has seen the success of studies on the spatiotemporal distribution and hotspots of hand, foot, and mouth disease (17). In order to identify the high-risk pattern of hand, foot, and mouth disease, the reported cases of the disease for the full state of Sarawak were interpolated later in 2016 using the Inverse Distance Weighted technique. Determining the disease's geographic spread pattern for both urban and non-urban divisions was the aim (18).

The purpose of this study was to examine how hand, foot, and mouth disease incidence in Ho Chi Minh City is spatially clustered. The spatial autocorrelation analysis of hand, foot, and mouth diseases were examined using the global and local Moran's I statistic. The first and second order of contiguity will be used to identify the spatial clusters, which include spatial clusters (high-high and low-low) and spatial outliers (low-high and high-low).

2.1. Materials and study area

Hand, foot, and mouth disease has emerged in Vietnam since 2003 in which Ho Chi Minh City is particularly a southern city with the highest cases and mortality numbers of hand, foot, and mouth disease in the whole country (19). Several districts in the city, such as Binh Tan, Binh Chanh, Tan Phu, District 6, and District 8, have seen a high rate of hand, foot, and mouth disease infections per 100,000 inhabitants since 2024 (20). There has been a rapid outbreak of hand, foot, and mouth diseases, according to Ho Chi Minh City's health sector. As a result, analyzing the geographic clustering of hand, foot, and mouth diseases in metropolitan areas is crucial to controlling the disease. The study's data were collected in Ho Chi Minh City on the 29th and 30th week of July 2024.

METHODS

This study employed the global and local Moran's I statistic to determine the spatial clustering of hand, foot, and mouth disease at global and local scale (21,22). The definition of the global Moran's I statistic is shown in the following equation:

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n} \sum_{j=\mathrm{i}}^{n} W_{ij} \sum_{i=1}^{n} (x_i - \bar{x})^2} \quad (1)$$

where x_i and x_j are the number of new hand, foot and mouth confirmed cases for district *i* and district *j*; $\bar{x}$ is the mean of hand, foot and mouth cases and be given by $\bar{x} = \sum_{i=1}^{n} \frac{x_i}{n}$; *n* is the total number of districts in the whole study area; and W_{ij} is a $(n \times n)$ spatial weight matrix (23).

The values of the global Moran's I coefficient range from -1 to +1 (23). Global Moran's I values are positive in the presence of positive geographic autocorrelation in the data, and negative in the presence of negative spatial autocorrelation (24). A global Moran's I coefficient value of zero suggests that there is neither geographic autocorrelation nor a random distribution of the hand, foot, and mouth epidemic.

The global Moran's I indicates whether spatial autocorrelation is present overall or not. The regional Moran's I statistic was used to quantify the spatial clustering of low and high hand, foot, and mouth pandemic levels in each district (23). The following formula provides the local Moran's I statistic (I_i) for the hand, foot, and mouth epidemic at district *i* (25):

$$I_i = \frac{(x_i - \bar{x})}{\sigma^2} \sum_{j \# i, j \in J_i}^{N} W_{ij} (x_j - \bar{x}) \quad (2)$$

where x_i, x_j, $\bar{x}$, and W_{ij} are defined in equation (1); N is the total number of neighborhood districts (23); J_i denotes the district's hand, foot, and mouth case count from the neighborhood i; $j \# i$ implies that the sum of all $(x_j - \bar{x})$ of nearby neighbourhood districts of district *i* but not including x_j; and σ^2 is the variance of x, given in equation (3). W_{ij} defines neighbor connection and is buildable with both first- and second-order contiguity.

$$\sigma^2 = \frac{1}{N} \sum_{j=1}^{N} (x_i - \bar{x}) \quad (3)$$

The degree of spatial clustering of the hand, foot, and mouth epidemic at each district is shown by the local Moran's I statistic. The local Moran's I value at district *i* (I_i) shares a range of -1 to +1 with the global Moran's I statistic. The hand, foot, and mouth cases have no spatial autocorrelation if the local Moran's I coefficient at district I is 0 (I_i = 0). If I_i> 0 then The spatial autocorrelation in the hand, foot, and mouth cases will be positive (23). If I_i< 0 then There will be a negative correlation in the geographic autocorrelation of the hand, foot, and mouth cases. A high positive I_i shows the district *i* has a similarly high or low number of hand, foot and mouth cases as its neighbors and called the ‘‘spatial cluster’’(24).

In this work, Anselin's spatial statistics and a randomization test developed by (26) were used to assess the significance of spatial autocorrelation statistics using GeoDA software whereas 999 permutations were used to create and test spatial autocorrelation statistics at the significance level of 0.05.

RESULTS AND DISCUSSION

Spatial distribution of the hand, foot, and mouth disease confirmed cases

The map in Figure 1 shows the spatial distribution of the incidence of hand, foot, and mouth disease in Ho Chi Minh City collected from the 29th week to the 30th week in July 2024. The data in Figure 1 show that the high incidence of hand, foot, and mouth disease confirmed cases were found in districts in the west of the city. Medium rates of hand, foot, and mouth disease confirm cases were found in districts in the center and north of the city. Meanwhile, low rates of hand, foot, and mouth disease confirmed cases were found mainly in the south of the city.

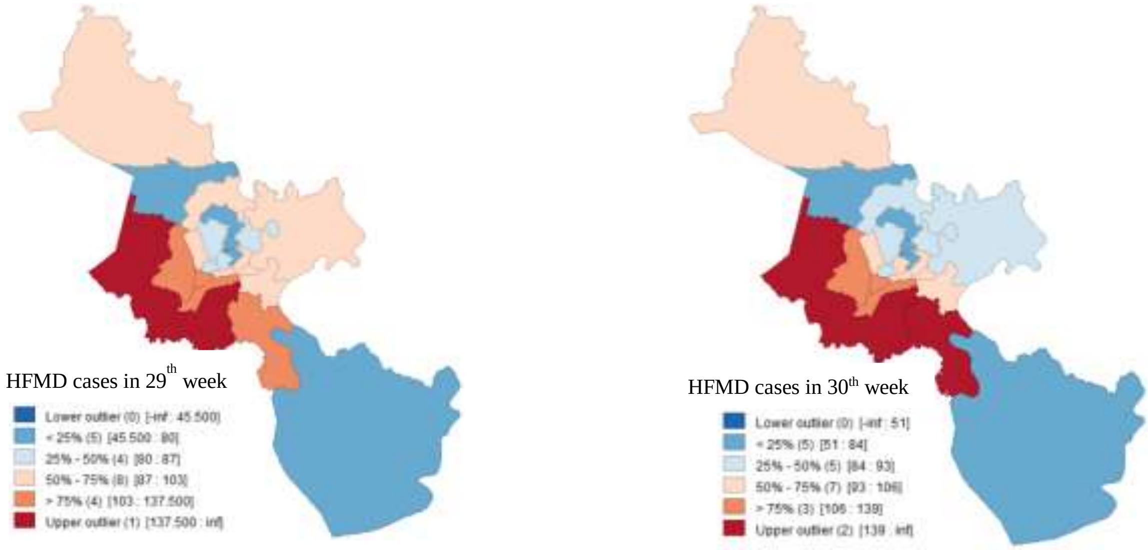

Figure 1. Spatial distribution of the incidence of hand, foot and mouth diseases.

The boxplot in Figure 2 shows the distribution of the incidence of hand, foot, and mouth disease confirmed cases in Ho Chi Minh City obtained from the 29th week to the 30th week in July 2024. Data from the both of boxplots show that the data are skewed to the right, indicating that the incidence of hand, foot, and mouth disease were more concentrated at high levels. This shows that many districts have medium and high hand, foot, and mouth disease rates.

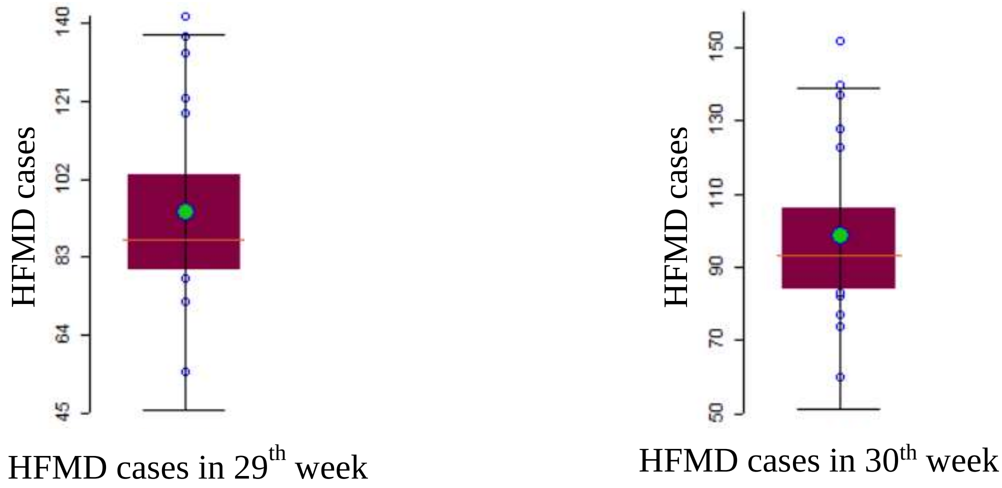

Figure 2. Boxplots of the incidence of hand, foot and mouth diseases.

Spatial clustering of the hand, foot, and mouth disease confirmed cases

Data from Moran scatter plots in Figure 3 illustrates the degree of globally spatial autocorrelation of the incidence of hand, foot, and mouth disease confirmed cases obtained from the 29th week to the 30th week in July 2024 using the first order of contiguity. The global Moran's I values were 0.355 and 0.338 corresponding with the first period (Figure 3, left) and the second period (Figure 3, right), respectively. It was found that the value of spatial autocorrelation coefficient in the first period was higher than that obtained in the second period. This shows a higher degree of spatial autocorrelation between the incidence of hand, foot and mouth diseases in the first period.

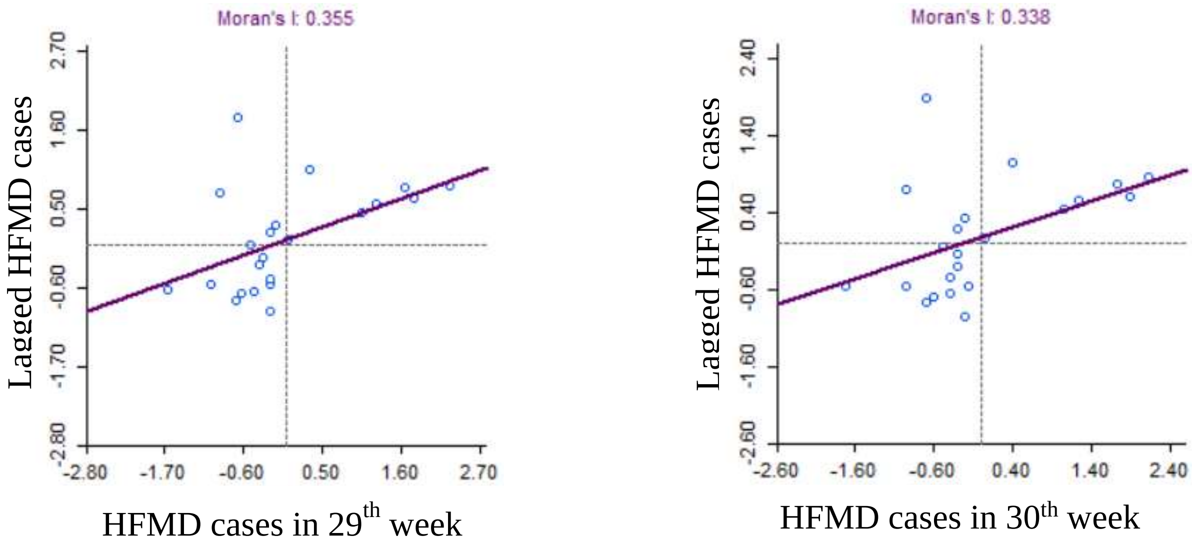

Figure 3. The Moran's I scatter-plots of the incidence of hand, foot and mouth diseases.

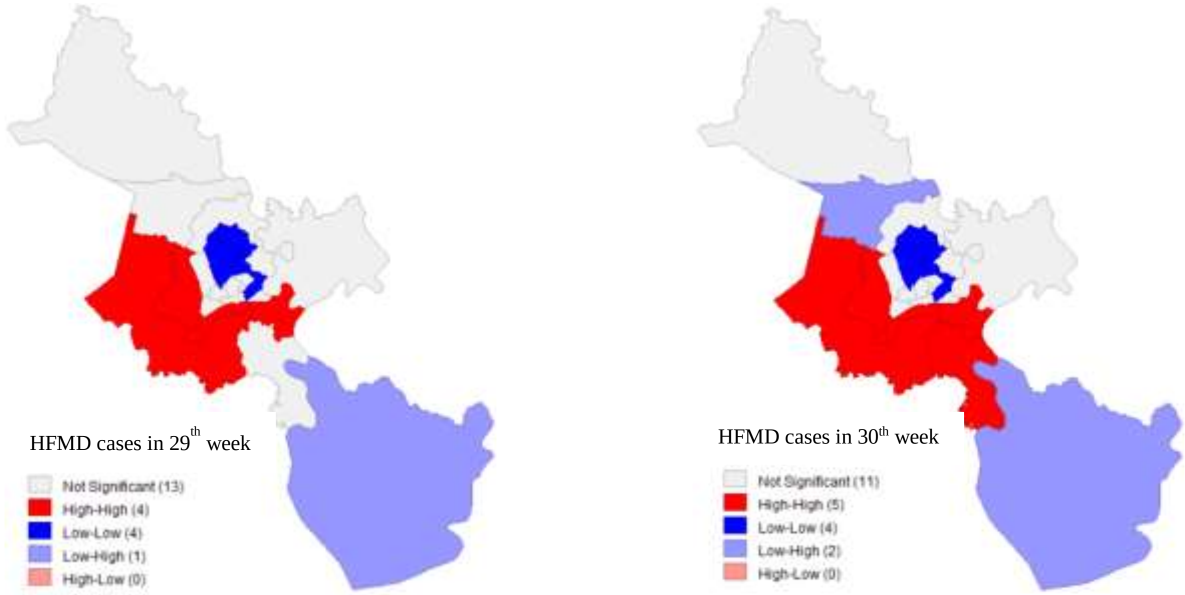

Figure 4. Spatial distribution of local Moran's I of hand, foot and mouth diseases.

The results of hand, foot, and mouth disease spatial cluster identification are shown in Figure 4. Overall, the data from the cluster map in Figure 4 shows that the clusters are mainly detected in the city center. The changes in spatial clusters from the 29th week to the 30th week in July 2024 are as follows: 04 high-high and 04 low-low were detected concentrated in the city center in the 29th week. The high-high spatial clusters include Binh Chanh (142 cases/100,000 people), Binh Tan (122 cases/100,000 people), District 7 (103 cases/100,000 people) and District 8 (133 cases/100,000 people). Four low-low spatial clusters appeared in Phu Nhuan (55 cases/100,000 people), District 1 (85 cases/100,000 people), Tan Binh (80 cases/100,000 people) and Go Vap (78 cases/100,000 people). One low-high spatial cluster was detected in Can Gio district with 78 cases/100,000 people. Meanwhile, in the 30th week of July 2024, high-high, low-low and low-high clusters still mainly appeared in the west, center and south of the city, respectively. Specifically, the five high-high clusters include Nha Be (140 cases/100,000 people), Binh Chanh (152 cases/100,000 people), Binh Tan (128 cases/100,000 people), District 7 (106 cases/100,000 people) and District 8 (137 cases/100,000 people). Four low-low spatial clusters were found in Phu Nhuan (60 cases/100,000 people), District 1 (93 cases/100,000 people), Tan Binh (84 cases/100,000 people) and Go Vap (82 cases/100,000 people). Two low-high clusters were detected in Can Gio district with 83 cases/100,000 people and Hoc Mon with 77 cases/100,000 people.

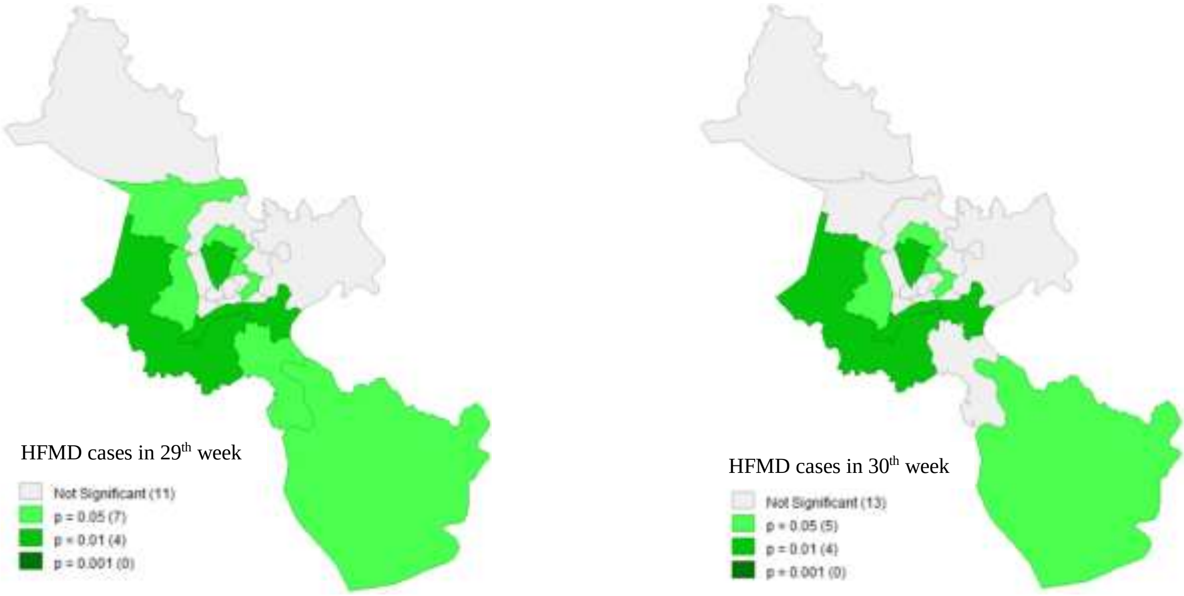

Figure 5. Spatial distribution of the significance of local Moran's I.

Data from Figure 5 shows the statistical significance level for each district of Ho Chi Minh City calculated for hand, foot, and mouth disease data collected from the 29th week to the 30th week in July 2024. The statistical levels are also shown on a 4-point scale from not reaching statistical significance (> 0.05) to achieving statistical significance at levels 0.05, 0.01 and 0.001. Data from Figure 5 shows that most of the statistical significance levels at levels 0.001 and 0.01 are found in districts in the west and the city center. Meanwhile, the statistical significance level of 0.1 is achieved mainly in districts in the south of the city.

Significant psychosocial impacts of hand, foot, and mouth diseases have been documented in a variety of rural workers and residents. According to a different study, there was a decline in the value of local knowledge, unhappiness, sorrow, dread of a new calamity, and loss of trust in authorities and control mechanisms following the foot and mouth disease outbreak. A wide range of groups, far outside the farming community, were in distress. Human enterovirus 71-related hand, foot, and mouth diseases are severe, quickly disseminated, and highly susceptible to sequelae. Certain hazardous consequences may arise, such as impacting a child's nervous system.

CONCLUSION

The goal of this study is to investigate how hand, foot, and mouth diseases are distributed geographically in Ho Chi Minh City, Vietnam. The spatial auto-correlation of the spatial clusters of hand, foot, and mouth diseases, comprising spatial clusters (high-high and low-low) and spatial outliers (low-high and high-low), was measured using the global and local Moran's I statistic. A case study of hand, foot and mouth diseases locally transmitted cases reported in the 29th week to 30th week in July 2024 in Ho Chi Minh city has indicated that the city's north and center areas had the median incidence of hand, foot, and mouth diseases. The low frequency of hand, foot, and mouth diseases was concentrated in the southern section of the city. The low-high spatial outliers, low-low spatial clusters, and high-high spatial clusters were discovered to be located in the west, center, and south of the city, respectively. The results of the study imply that LISA is a helpful method for examining how hand, foot, and mouth diseases are spatially clustered. he results of this study have a significant impact on the fight against diseases of the hands, foot, and mouth which is greatly impacted by the findings of this study.

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