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Spatiotemporal analysis of the spread of meningococcal meningitis in kaduna metropolis, 2007 - 2011

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Abstract. Meningococcal meningitis is an airborne disease that has been a threat to human life for over a century now. This study aims to describe the spatiotemporal spread of Meningococcal meningitis in the population residing in Kaduna metropolis. All the reported cases (suspected and confirmed) within the Kaduna metropolis from 2007 to 2011 were collected from files of the patients. Only patients who are resident in Kaduna metropolis were considered. For each year, the directional distribution, standard distance and the spatiotemporal pattern were explored. The analysis of the directional distribution shows the direction and the angle that the spread is more biased to at the different years. Standard distance shows the different areas of coverage for the spread of the disease for those five years which points to those areas that need more attention. The spatiotemporal results revealed that some specific neighbourhoods within the metropolis had the cases reoccurring within the five year period especially at the western and central parts of the metropolis. This indicates that much more attention is needed in those areas as regards preventive strategies by the policy makers and the stake holders. The spread of Meningococcal meningitis disease in Kaduna metropolis is much more dominant in some specific neighbourhood.

1. Introduction

Meningococcal meningitis is a major cause of grief and mortality in some developing countries with about 4% to 27% case fatality rate [1]. In many parts of the world the outbreaks are sporadic. In Africa, especially the region referred to as "African meningitis belt" the outbreaks there are very excessive and it leads to death of a lot of thousands of people [2] . According to [3], between 1988 to 1997, there were about 704,000 occurrences with over 100 people dying and all were accounted in Africa. About 25,000 presumed case history of meningitis with over 15,000 fatalities globally within January to march of 2009 were found in the "African meningitis belt", with a very high number in Nigeria and Niger,[4].

The way and manner in which the meningococcal meningitis bacteria spread through people, in time and space is unclear. The major factors that are determinant for the spread of the disease in different locations and population are not clearly understood too. Some studies showed that poor housing condition, overcrowding [5,6], education and income level[7,8], age and sex [9,10]. Weather condition [11–13] and urbanization [14–16]. The high risk region of Africa meningitis has a lot to do with season especially the dry season and high temperature[11]. It was suggested that in West Africa region, dry season has relationship with winds and transmission of dust and also assemblage of people in tiny clusters which increases the possibility of person to person spread.

[1] To whom any correspondence should be addressed.

2. Methods

2.1. Data material and tool used

Most of the cases of meningococcal meningitis that were reported to any of the hospital (both public and private) were used in the study. Any case of meningococcal meningitis in Kaduna metropolitan area is reported to the local government authority that the case fell under. Bothe the public and private hospitals are expected to report any case of the disease to the health department of the local government, and the health department forwards the summaries to the epidemiology unit of Kaduna state ministry of health for proper documentation. For the purpose of this study, the case files for each patient were picked out and evaluated. Some vital information was extracted from the records. It includes name, address, date, age, sex, and occupation, level of income and status of survival. Spatial statics tool in ArcGIS 10.1 was used for the spatial statistical analysis.

2.2. Study area and population description

The Kaduna City Region is located in an ecological zone generally described as the northern Guinea Savannah Zone. It has been traditionally characterized by a mono-modal rainfall system and a growing period of 150-180 days. It lays between latitudes 10 and 11 degrees north and longitude 7 and 8 degrees east. Its central location renders communications with the rest of the country relatively easy and facilitates the flow of agricultural inputs and produce.

The united Nation made an estimate on the population for Kaduna metropolis which was based on the National Population Commission of Nigeria's estimate and it was at 1,561000 in year 2010[17]. With an estimate like this, it is the Nigeria's fifth largest city after Lagos, Kano, Ibadan and Abuja.

3. Data analysis

Hotspot analysis was conducted for meningococcal meningitis in all the states in Nigeria. States that are the hotspot for the disease were detected. To be able to identify where those specific hotspot are located, the study was narrowed down to Kaduna metropolis in Kaduna state. Kaduna metropolis is made up of twenty four districts and also 106 neighbourhoods. The districts and neighbourhoods all fall under four local governments. The meningococcal meningitis case data were entered and geocoded into the database with the entire attribute data included.

Directional distribution analysis was conducted for each of the years for the study period to be able to ascertain the angle and the direction of the flow of the disease. Standard distance analysis was also carried out so as to determine the area of coverage of the spread for each of the five year period. Anselin local moran's *I* spatial autocorrelation technique was conducted for the meningococcal meningitis disease for each of those five years. Areas that had high clusters and low clusters were detected. The maps generated were compared to be able to evaluate the spatial process of the flow of disease.

4. Results

4.1. Directional distribution

4.1.1. Standard Deviational Ellipse. The results in table 1 and figure 1 showed the different directional orientation that each of the ellipses has for each of the five years. In 2007 and 2008, the angles of rotation were 176° and 161° respectively. The difference between them was not so much which indicates that the pattern and the number of cases within those two years were minimal. In 2009, there was a drastic change in the angle of rotation from 161° to 13°. This indicates that there was a change in pattern of the disease and also that the cases has increased in some particular locations. In 2010 and 2011, the angle changes slightly to 11°. Year 2010 has the highest standard deviation for the Y axis which indicates that new areas that were not affected by the disease had it that year. The angle of rotation changed slightly to 17° in 2011. It also indicates that those factors that influenced the spread of the disease in 2010 in those new areas are still present in that location, which is why the standard deviation for Y axis is just a little below that of 2010.

Table 1. Direction Ellipse by year.

Year	Standard Distance	Angle	Directional Ellipse	
			Standard deviation X	Standard deviation Y
2007	5684.3999	176.7774	6468.2437	4773.5342
2008	5625.6357	161.32478	6200.7197	4984.6392
2009	6795.437	13.408758	4753.8677	8352.0459
2010	8253.3613	11.341722	5063.3623	10516.573
2011	7238.6128	17.35157	4705.8521	9091.2031

4.1.2. Standard Distance. The result for the standard distance as shown table 1 and figure 2 reveals that there were variations in the standard distances for those five years. The results revealed that year 2010 has the highest standard distance which indicates that new areas that were not affected with the disease were affected that particular year followed by year 2010. Year 2007 had the lowest standard distance which means that it had the lowest area of coverage for the disease.

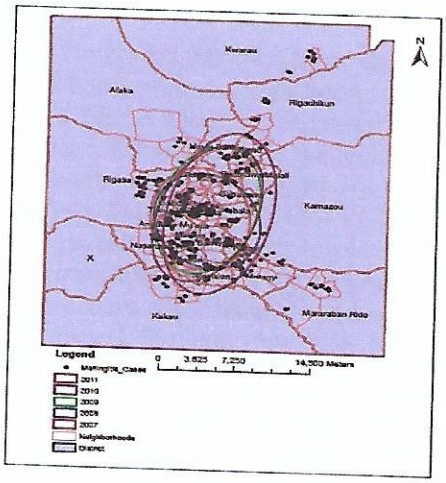

Figure 1. Directional distribution.

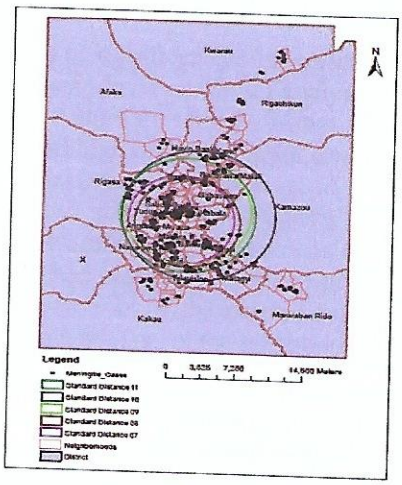

Figure 2. Standard distance.

4.2 Spatiotemporal Analysis

A classification process was explored on the Meningococcal meningitis cases that cover the whole of states in Nigeria. It revealed in Figure 3 that the hotspots for the spread of the disease were more on some states in the northern part of the country. Kano state was the worst hit with over six thousand cases of the disease for a particular year. Kaduna and Sokoto states are the one's following Kano states in terms of the cases.

To be able to detect the particular location that the disease is much more common, the study was narrowed down to Kaduna metropolis which is a metropolitan city under Kaduna state.

Anseli Local Moran's *I* analysis was conducted for each of those years 2007 – 2011 to be able to detect the cluster and outliers of the disease. Figures 3a to 3e is the results of the anselin moran's *I* analysis. In 2007, the result showed that neighborhoods like Bakin ruwa, Anguwan sanusi, Tudun wada, Magajin gari, Anguwan mu'azu low, Kudan dan, Makera, and Nasarawa village had high high level of significance, which indicates that those are the neighborhoods that the spread of the disease is very significant.

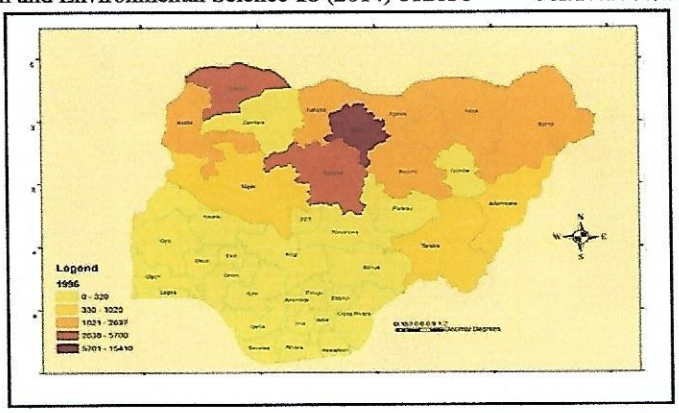

Figure 3. Map of Nigeria showing the hotspot of the spread of meningococcal meningitis.

Kawo and Kwaru neighborhoods had the high low level of significance of the disease spread. The other neighborhoods were not significant. In 2008, the anselin local moran's I analysis revealed that neighborhoods like Kudandan, Anguwan mu'azu low, Anguwan sanusi, Tudun wada, Makera, Nasarawa village, Kurmin gbagyi, Narayi and Sabongari had high high significant level of the disease spread. Neighborhoods like Kawo, Kwaru and Angwan shanu has high low level of significance for the spread. There was no significance in the level of spread in the other remaining neighborhoods. 2009 analysis revealed that Rigasa, Anguwan mu'azu low, Kurmin gbagyi, Nasarawa village, Makera, Sabon gari, Tudun wada, Tudun nupawa and Magajin gari had high high level of significance. Hayin banki, Kawo, Kwaru and Matagyi had high low significant level of the disease spread while only Anguwan mu'azu 1 has only low high level of significance. The other neighborhoods were not significant. Only Rigasa and Tudun wada had high high level of significance of the disease spread in year 2010. Kawo, Badarawa, and Matagyi had high low significant level of the spread while the other neighborhoods had no significance in the disease spread. The result in 2011 showed that Anguwan Mu'azu low, Anguwan sanusi, Tudun nupawa, Magajin gari, Makera and Nasarawa village had a high high significant level of the spread. Hayin banki and Matagyi had high low level of significance.

5. Discussion

The standard deviational ellipse showed that there was significant change in the angle of rotation for the disease between 2008 and 2009. It indicates that the distributional pattern was consistent in the first two years (2007- 2008) but it changed and remained consistent from 2009 to 2011. It is very likely that some of the factors that have influenced the spread of the disease within the first two years have also become present in the other neighborhoods which necessitated the pattern change. The year 2010 had the highest standard distance among the other years. The area of coverage of the disease changed drastically in 2010. Some neighborhoods that were never afflicted with the disease had many cases that particular year. It also indicates that there could be some factors in those newly afflicted neighborhoods that have influenced the spread of the disease. The results in the spatiotemporal pattern analysis revealed that Tudun wada, Rigasa, Kudandan, Anguwan mu'azu low, Anguwan sanusi, Makera, Nasarawa, Kurmin gbagyi and Sabon gari are the neighborhoods that have a consistent high significant level of the disease. Other neighborhoods that have a significant level of the disease include Kawo, Kwaru, Anguwan shanu and Matagyi. It indicates that there could be some factors that are in existence within the locations that have a significant level of the disease that are influencing the disease spread.

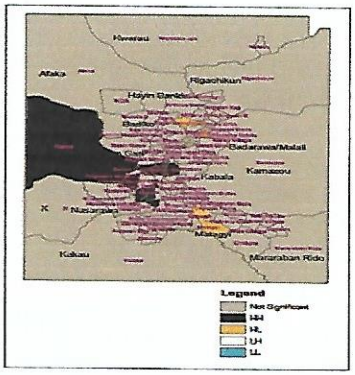

Figure 3a. Spatial Process 2007

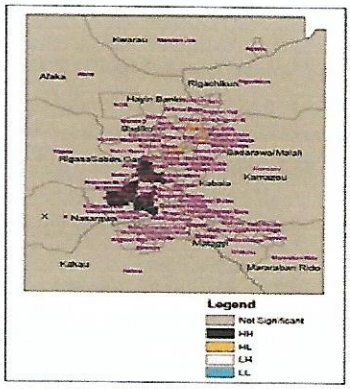

Figure 3b. Spatial Process 2008

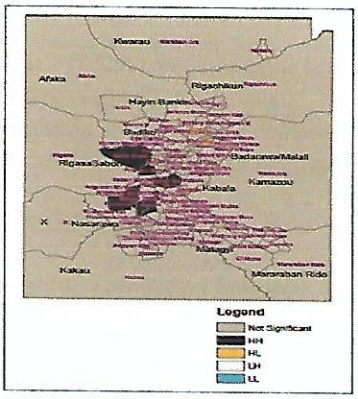

Figure3c. Spatial Process 2009.

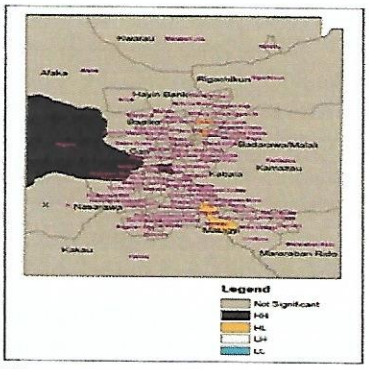

Figure 3d. Spatial Process 2010.

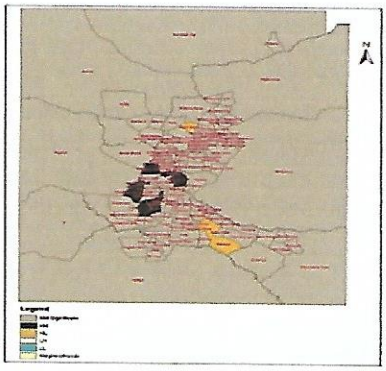

Figure 3e. Spatial Process 2011.

6. Conclusion

The study investigated the distributional pattern and also the spatiotemporal spread of the disease within the period of five years. Neighbourhoods that have significant level of the disease are those ones on the western and central parts of the metropolis. Most likely, there are some factors that influence the spread of the disease that are present in those locations that the disease is most common. The study suggests that future research should be geared towards identifying those factors that influences the disease spread.

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