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Geo-Spatial Analysis of Cardiovascular Disease and Biomedical Risk Factors in Ibadan, South-Western Nigeria

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A B S T R A C T

The burden of the cardiovascular disease (CVD) is increasing in both developing and developed countries. CVD is now a major cause of death globally killing people in their productive years more than any other disease. In Nigeria, CVDs account for about 12% of all deaths recorded among the low and middle income group. This study examined the spatial pattern of the CVD disease burden in Ibadan city and among neighbourhoods and the spatial pattern of biomedical risk factors. Hospital records, population data and geocode map of Ibadan were acquired for the study. Global Moran, Anselin Moran, Geographically Weighted Regression (GWR) and logistic regression were employed to examine the spatial pattern of CVD, and correlation between CVD and biomedical risk factors. At the global level a random pattern was observed at a significance level of 0.05, the spatial pattern of CVD at Moran's I of -0.04 is random, while a clustered pattern was observed at neighbourhood level. The relationship between the spatial pattern of CVD and the biomedical risk factors was statistically significant (R^2= 0.634) which indicated a very strong positive spatial autocorrelation in the study area.

1. INTRODUCTION

The term cardiovascular is derived from 'cardio' meaning heart and 'vascular' meaning blood vessel. According to WHO (2013), cardiovascular diseases are a group of disorders that affect mainly the heart and blood vessels [1]. Smith (2012) opines that CVD is a global health emergency that is affecting all ages and socio-economic clusters [2]. CVD is therefore a disease that occurs irrespective of age or socio-economic status and this negates the general belief that CVD is a disease of the rich. CVDs are manifested in different forms such as coronary heart disease, cerebrovascular disease (e.g. stroke), peripheral arterial disease, rheumatic heart disease, congenital heart disease, heart failure, hypertensive heart disease, deep vein thrombosis and pulmonary embolism (WHO, 2013) [1].

The burden of the cardiovascular disease is global as it is the number one cause of death, globally killing more people than any other cause (WHO, 2013; Gersh et al., 2010) [1], [3]. An estimated 17.3 million people died from CVDs in 2008, representing 30% of all global deaths out of which an estimated 7.3million were due to stroke. Africa is not left out of this burden as noted by Thomas et al. (2012) and this constitutes a growing threat to health among Africans as most developing African countries are in the second and third stages of the epidemiological transition model/theory [4]. According to Gaziano (2008) [5]; Ansa et al. (2008) [6]; Van der Sande (2003) [7]; Onwubere and Ike (2000) [8]; Alikor et al. (2013) [9] and WHO (2011) [10] the risk factors for deaths resulting from cardiovascular diseases are precipitated by risk factors such as hypertension (Mukadas and Misbau, (2009) [11]; Ekanem et al. (2013) [12]; Alikor et al. (2013) [9];

high cholesterol (Ogbera, et al., 2009) [13] obesity (World Heart Federation (2013) [14]; WHO, (2011) [10] (WHO, 2013) [1]; Ijezie et al. (2013) [11]; Mbewu and Mbanya (2006) [17], diabetes, (Ogbera et al., 2009) [13] physical inactivity (Adegoke and Oyeyemi, 2011; WHO, 2013) [18], [1], high alcohol consumption (WHO, 2011) [10] and tobacco use (Bloomfield et al., 2013) [5]; WHO (2013) [1]. Most cardiovascular diseases have been discovered to be preventable if risk factors are sufficiently addressed by concerned individuals such as tobacco use, unhealthy diet and obesity, physical inactivity, high blood pressure, diabetes and raised lipids.

A study carried out in Ghana revealed that the mean age of patients affected by stroke was 63.7% years. The study employed the use of patient records from the hospital and these were analyzed to determine stroke morbidity and mortality. The risk ratio and the 95% confidence interval were estimated by the means of Poisson regression analysis from the same study in Ghana. It was observed that stroke constituted 9.1% of total medical adult admissions and 13.2% of all medical adult deaths over the period under review. The stroke case fatality rate was 5.7% at 24 hours, 32.7% at 7 days, and 43.2% at 28 days (Agyemang et al., 2012) [20].

In a similar study carried out in Kenya to determine the cardiovascular related death, data collected from selected autopsy were analysed for disease type, age and gender distribution using statistical techniques. It was observed that CVD contributed 13.2% of all deaths (Ogeng'o et al., 2011) [21]. This is very similar to what was obtained in the study that was carried out in Ghana by Agyemang *et al.,* (2012) [20].

In Nigeria, a study carried out by Ansa et al. (2008) revealed that the leading CVD predisposing factor in Uyo is hypertension, which accounted for 55.7% of the causes of CVD while the leading CVD was heart failure (44.3%) [6]. In another study carried out in the south-western part of the country, hypertension accounted for the most prevalent risk factor for cardiovascular admissions into the hospital and about 70% of cardiovascular deaths were recorded among the elderly (Ogunmola and Akintomide, 2013) [22]. This was higher that what were obtained in Kenya and Ghana, though the sample was selected from the elderly population.

In a similar study in rural Nigeria, Igbo-Ora in Oyo state, between 1996 and 2001, CVD accounted for about 17% of deaths recorded in the area (Cooper *et al.,* 2003) [23].

Although several studies have been carried out in Nigeria and even in Ibadan regarding cardiovascular diseases, these studies were basically analysing the occurrence of the disease, disease burden and fatality while omitting the spatial correlates of the predisposing factors and the disease (such studies include Oladapo, et al., 2010, Ogunmola and Akintomide, 2013) [24], [22]. The spatial correlation of the CVD disease burden can be analysed and examined through the spatial analytical techniques available in GIS. The application of GIS to health has been used widely in health studies in Nigeria and even Ibadan, but its application in the studies of CVD has been very limited to basic visualization using choropleth maps to present the disease pattern. The application of GIS to CVD study particularly in the area of the spatial correlation that exists between the risk factors and the pattern of disease occurrence has not been fully exploited in the South Western part of Nigeria.

This approach has the potential for revealing a hidden pattern of occurrence and the impact of certain spatial factors on the burden of CVD.

This study therefore seeks to spatially examine the pattern of CVDs incidence in Ibadan region and the spatial pattern of the biomedical factors. It also seeks to examine the spatial correlation that exists between the pattern of the predisposing factors and the pattern of CVD disease occurrence in Ibadan using geospatial analytical techniques of GIS

2. IBADAN CITY AND SURROUNDINGS

The study area is Ibadan city and its adjoining hinterlands, in the South Western part of Nigeria. It covers a total of eleven local government areas that constitutes the Ibadan land. These are: Akinyele, Lagelu, Egbeda, Ona-Ara, Oluyole, Iddo, Ibadan North-West, Ibadan North-East, Ibadan South-East, Ibadan North and Ibadan South-West. Ibadan lies between 7°23'47" N to 7°39'64"N and 3°55'0"E to 3°91'67" E. It is an area of 3,080 km². It has a population of about 1,338,659 according the population census result of 2006 (Fig. 1).

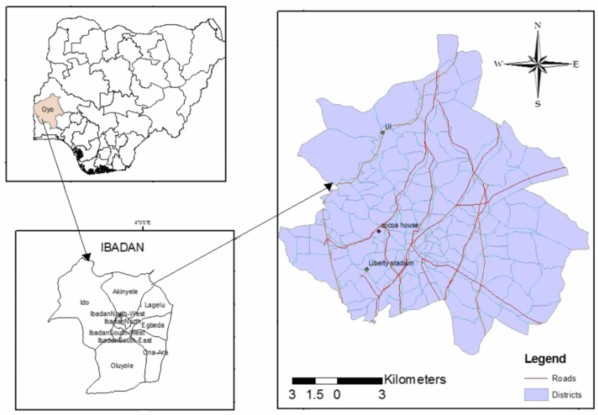

Fig. 1. Study area.

Ibadan is a typical developing country urban settlement with large number of poor population and over a million heterogeneous people living and working in one of the largest indigenous urban area in Africa. There are series of economic enclaves in Ibadan which makes the city a relatively segregated city in Nigeria along economic line. The segregation enclaves of Ibadan city have been extensively described in Fabiyi (2006) [25]. These segregation enclaves have economic undertones and could be used as demarcation criteria for income status.

The geocode was used by the valuation and rating department of Oyo state to divide the city into different manageable geo-zones which however do not coincide with the electoral wards but with different valuation ratings for residential buildings (Fig. 2).

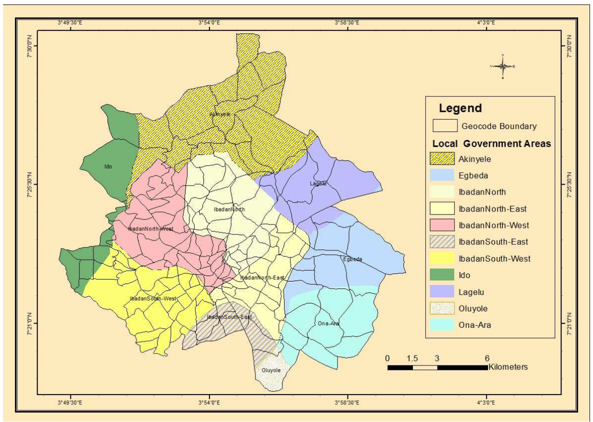

Fig. 2. Valuation and rating geocode in Ibadan city.

Figure 2 shows the valuation rating geocodes of Ibadan city-region and the Local Government Area Boundaries.

3. RESEARCH METHODOLOGY

3.1. Data compilation and data analysis

Data used for this study were secondary data. They are hospital records of CVD patients for the period of 2010 to 2013 which were obtained from records departments of the selected hospitals. Two major hospitals in Ibadan city that served as referral centres which include: Oyo state Government Hospital, Adeoyo and the University college Hospital (UCH), Ibadan. Data extracted from these records/patients files (the data were extracted after a pledge of confidentiality was made by the researchers) include sex, occupation, address and the history of any of the biomedical risk factors for CVD (hypertension, diabetes, high blood cholesterol, and obesity). A geocode map of Ibadan was obtained from the valuation department of the Oyo state ministry of Lands and Housing, Ibadan. The 2006 population data of the study area was obtained from the National Population Commission (NPC) aggregated to the level of Local Government Area and projected to 2013. The population data was later aggregated to the geocode level using the sizes and the urban status of each geocode. These were used to estimate the prevalence rate of the CVD and the risk factors within and among the study geocodes. All data sets were compiled into the ArcGIS 10.1 where they were used for the spatial distribution of the disease and the risk factors in the study area.

The Moran's I and LISA (Local Indicator of Spatial Autocorrelation) were employed to measure the spatial autocorrelation and thus to examine the spatial pattern of the disease in the study area. The same analysis that was employed for the identification of the spatial pattern of CVD was also employed in the identification of the spatial pattern of the biomedical risk factors. The relationships between the spatial pattern of the predisposing factors (BRF) and the spatial pattern of CVD in Ibadan, was examined through a multivariate regression analysis. Weights were assigned to areas that had recorded cases of CVD. Where there cases are recorded, a score of 1 is assigned while a score of 0 is assigned to where there are no recorded cases of CVD. The same weighting was done to the biomedical risk factors which were used as variables in the logistic regression analysis.

A Geographically Weighted Regression (GWR) analysis was performed to examine whether the relationship that exists between the spatial pattern of the BRF factors and the spatial pattern of cardiovascular disease in the study area is stable over space or if there is a noticeable change reflecting the characteristics of different areas in the study area. The number of the CVD cases recorded for each area and that of the four biomedical risk factors were imputed into the attribute table of the shape file containing the districts within the study area.

4. RESULTS AND DISCUSSIONS

4.1. Spatial distribution of CVD disease burden and biomedical risk factors in the study area

The study shows a high concentration of the CVD disease burden in the urban centres and the highly populated parts of the city.

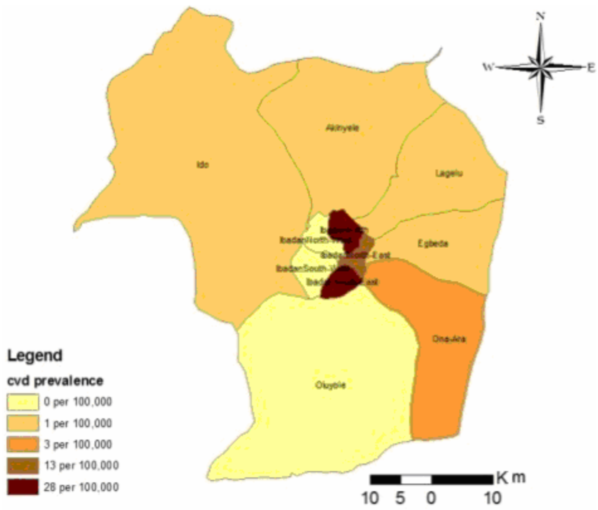

Fig. 3. Spatial distribution of CVD patients.

It also shows a preponderance of the disease burden in the elitist neighbourhoods and middle-class neighbourhoods. Therefore CVD is particularly high in highly rich and extremely poor neighbourhoods in Ibadan city. The middle-income neighbourhoods and more rural/urban sprawl neighbourhoods have generally low cases of CVD in the city.

It was observed that Ibadan North Local Government area registered the highest number of CVD cases with a prevalent rate of 28 persons per 100,000. This is followed by Ibadan North West Local government with a prevalence rate of 13 persons per 100,000; while areas like Akinyele Local Government areas (representing largely urban sprawl settlement and peripheral development part of Ibadan) have the least prevalence rate of 1 person per 100,000. Ibadan North and Ibadan North west are largely urban and mid-class population whose largely engaged in elitist sedentary work such as office work, retail shops and wholesale shops petty trading and other jobs that require less physical activities (Obasuyi and Agwubike, 2012) [26].

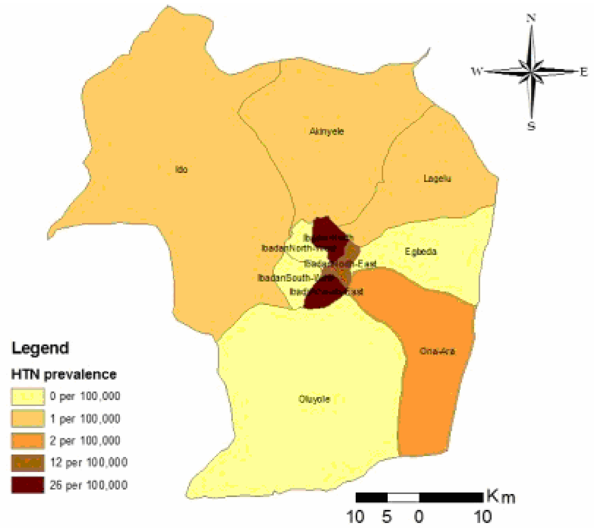

Fig. 4. Spatial distribution of HTN.

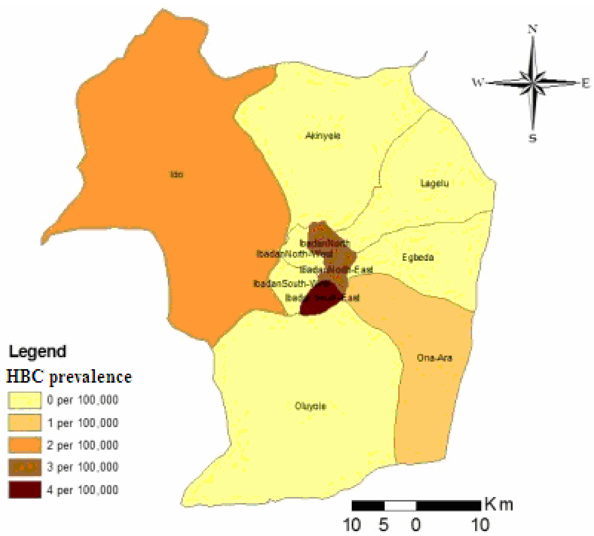

Fig. 5. Spatial distribution of HBC.

4.2. Spatial distribution of biomedical risk factors in the study area

Figure 4 shows the spatial distribution of hypertension (HTN) among the identified CVD patients in the study area. The Ibadan North local government had the highest prevalence rate of 26 persons per 100,000. Rural local government areas (LGAs) such as Lagelu and Ona-Ara recorded the least prevalence of hypertension among CVD patients in the study area with a prevalence of 2 persons per 100,000. The occurrence of CVD also follows the same pattern of the predisposing biomedical risk factors.

Figure 5 shows the spatial distribution of high blood cholesterol (HBC) among the CVD patients in the study area. The highest prevalence of HBC was recorded in the Ibadan South East local government area with a prevalence rate of 3 persons per 100,000, while Ibadan North and Ibadan North East had a prevalence rate of 2 persons per 100,000.

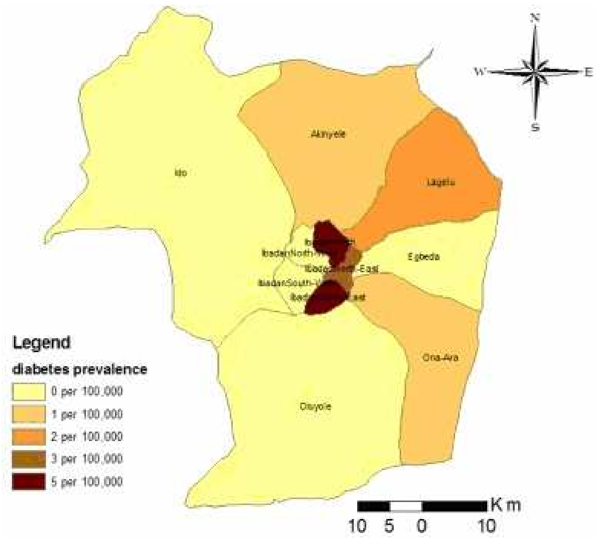

Fig. 6. Spatial distribution of DM.

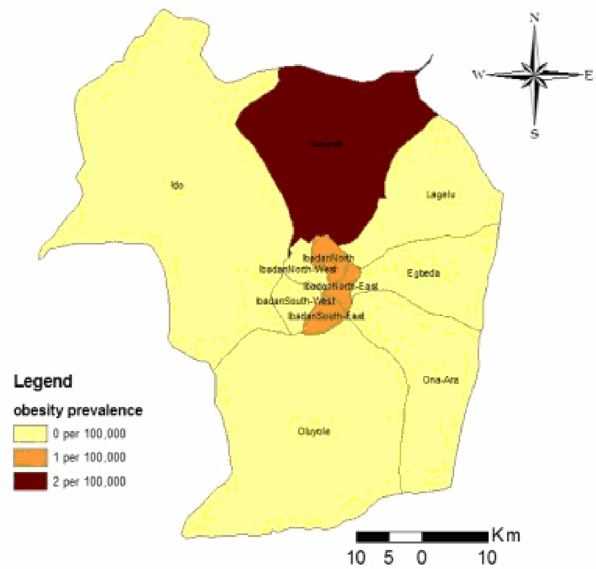

Fig. 7. Spatial distribution of Obesity.

Although the prevalence rate of HBC is not as high as that recorded for hypertension, areas that had the highest prevalence of hypertension (Ibadan North and Ibadan North-East) in the study area still exhibited a high prevalence with respect to the HBC prevalence in the study area. The spatial distribution of diabetes mellitus (DM) is shown in Figure 6 and it was observed that Ibadan North local government and Ibadan South East had the highest prevalence rate of 5 persons per 100,000 for diabetes mellitus. Akinyele and Ona-Ara had the least prevalence of diabetes which is 1 person per 100,000. The spatial distribution of Obesity as shown in Figure 7 indicates that obesity has a very low prevalence rate as compared to other biomedical risk factors. Akinyele local government had a prevalence rate of 4 persons per 100,000 followed by Ibadan South East local government with a prevalence rate of 3 persons per 100,000.

4.3. Spatial pattern of CVD in the study area

Spatial autocorrelation was used to measure the spatial clustering of the incidence of CVD in the study area. Figure 8a and 8b give the spatial pattern of CVD in the study area. The result given (-0.04) at 0.05 level of significance indicated that the spatial pattern of CVD is random (Fig. 8a).

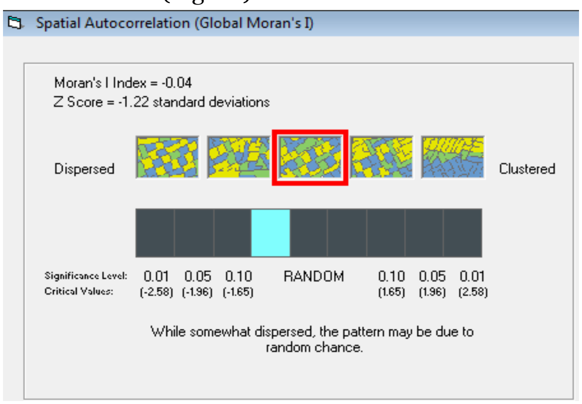

Fig. 8a. Spatial pattern of CVD.

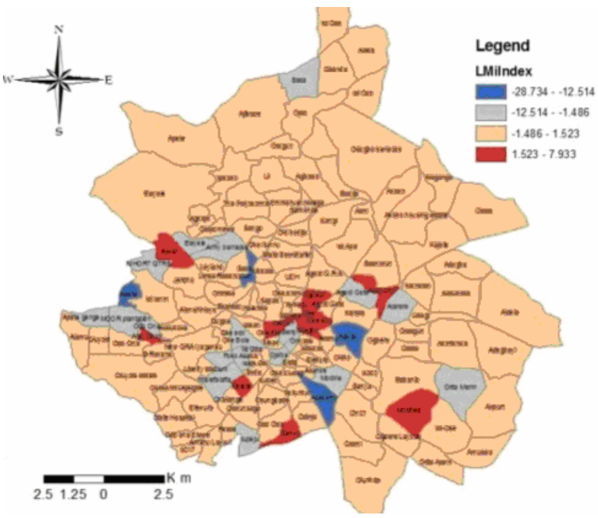

Fig. 8b. Local spatial autocorrelation of CVD.

However, within the study area as shown in Figure 8b, there was an observed pattern of clustering of the disease spatial clustering is (Oke Are, Molete, Ago Taylor, Igosun, Oke Ado, Oja'gbo, Motala and Oje) and in some other areas (Academy, Agugu, Apata, and Sabo) the pattern observed were random.

4.4. Spatial pattern of biomedical risk factor in the study area

The spatial pattern of hypertension as given in Figure 9a indicates that at Global Moran I of -0.02 and significance level of 0.05 is random. Hypertension has been identified as a disease whose cause has remained unknown but certain factors such as stress do increase its incidence. Therefore, the reason for this random spatial pattern of hypertension in the study area can be hinged upon the fact that it is a function of the lifestyle of an individual. This is because individuals who have a medical history of hypertension or whose parents had hypertension coupled with a stressful lifestyle are very likely to develop the disease.

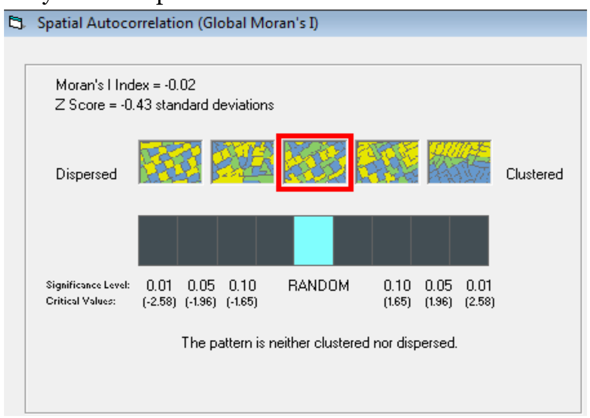

Fig. 9a. Spatial pattern of HTN.

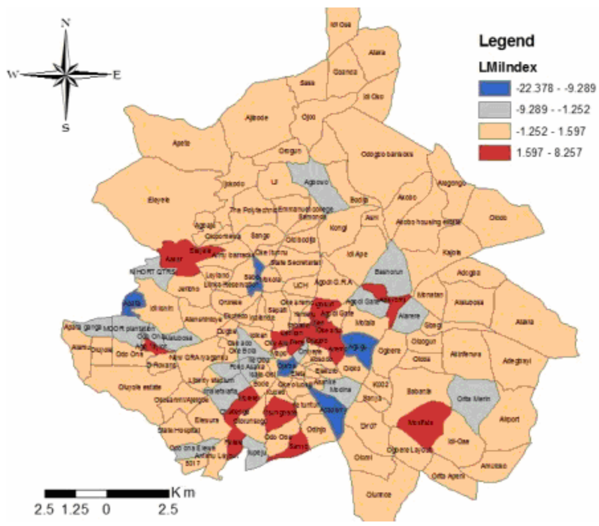

Fig. 9b. Local spatial autocorrelation for HTN.

Figure 9b gives the result of the LISA that was used to identify the spatial pattern of hypertension within the study area. It showed that there exists some form of spatial clustering in the pattern of hypertension in some areas (Molete, Abayomi and Oje) within the study area; while areas like Apata, Academy and Oke Are exhibited spatial randomness. This is an indication that the spatial pattern of hypertension within such neighbourhoods is random and occurring without any significant influence on adjacent neighbourhoods.

The spatial pattern of biomedical risk factors examined revealed similar pattern with the pattern of the CVD burden in the city. The pattern of hypertension shows a random pattern (Global Moran 1 = 0.02) significant at 0.05.

Figure 10a gives the result of the Global Moran that was used to examine the spatial pattern of diabetes in the study area. From the result it was observed that at Moran's I of -0.01 and at a significance level 0.05, the spatial pattern of diabetes is random. The result of the local indicator of spatial autocorrelation (see Fig. 10b) also indicates the spatial pattern of diabetes within the study area is random, as positive spatial autocorrelation was observed in only two neighbouring areas within the study area (Bashorun and Abayomi).

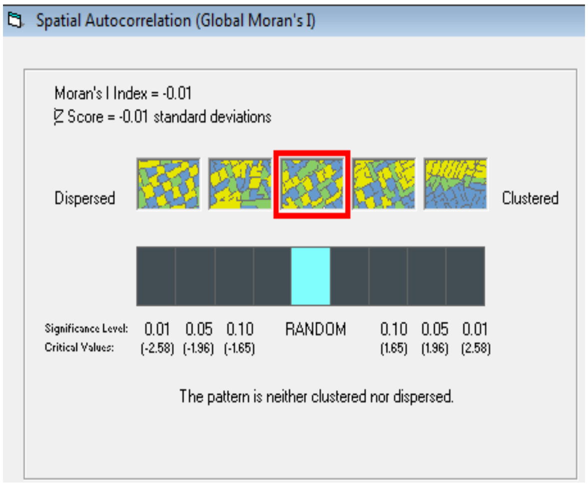

Fig. 10a. Spatial pattern of DM.

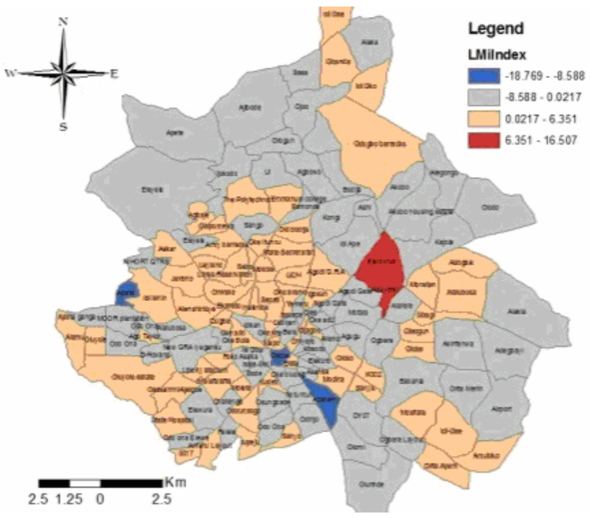

Fig. 10b. Local spatial autocorrelation for DM.

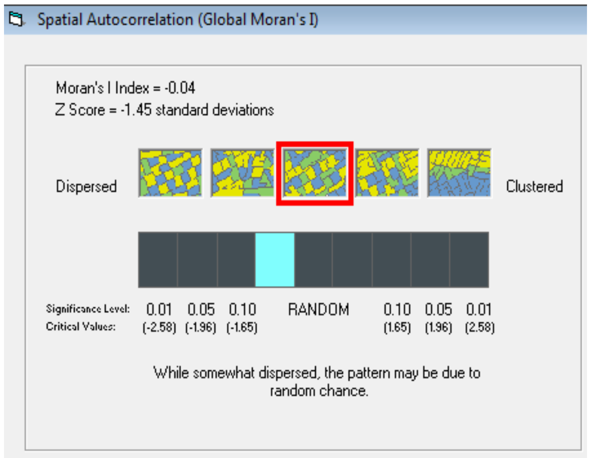

Fig. 11a. Spatial pattern of Obesity.

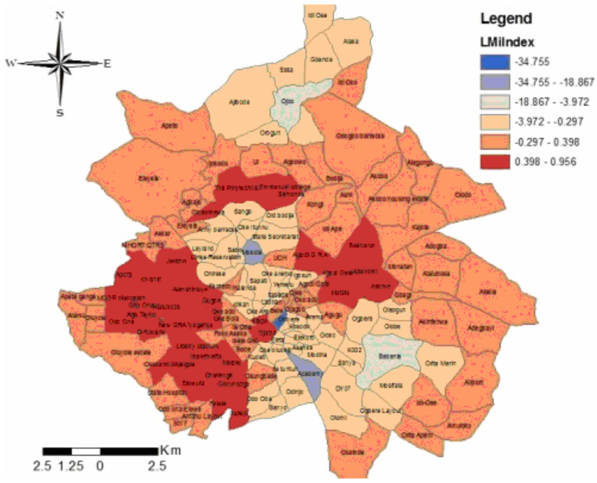

Fig. 11b. Local spatial autocorrelation for obesity.

The result of the spatial pattern of obesity given in Figure 11a indicates that the spatial pattern of obesity is dispersed at Moran's I of -0.04 and at a significance level 0.05. This suggests that the pattern of obesity is due to chance and there is no clustering or regularity in the pattern. It is likely due to the habits and the lifestyle of the people. Generally, a weak spatial autocorrelation was observed for obesity within the study area indicating that the spatial pattern is somewhat tending towards random (Fig. 11b). Some form of spatial randomness was observed in areas like Ojoo, Babanla and Academy; while areas like OdoOna, Dugbe, Aleshinloye, Alalubosa, Bashorun and Samonda exhibited clustering.

The global measure of spatial autocorrelation that was employed for the identification of the spatial pattern of high blood cholesterol gives a result of Moran's I of -0.02. This is an indication that the spatial pattern of high blood cholesterol within the study area is neither dispersed nor clustered. From Figure 12a, it can be observed that at significance level 0.05, the spatial pattern of high blood cholesterol is random and its occurrence might not be due to any particular underlying cause that characterized the study area. The result given in Figure 12b indicates that there are areas of clustering of CVD patients with HBC such as Abayomi, Apata, Osungbade, Oke Bola and Oke Ado; while areas like Ashi, OritaMerin, Oja'ba, Molete and Sango exhibited a dispersed pattern of CVD patients with HBC within the study area.

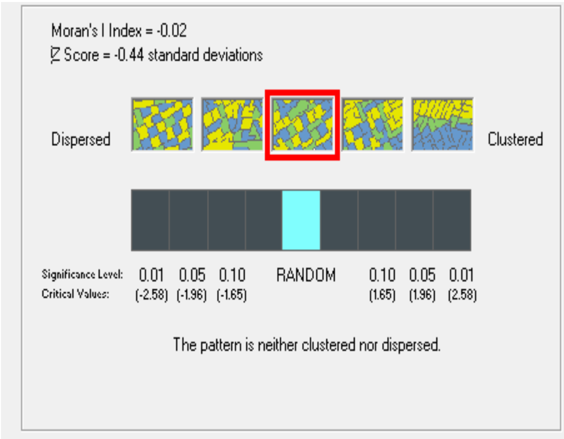

Fig. 12a. Spatial pattern of HBC.

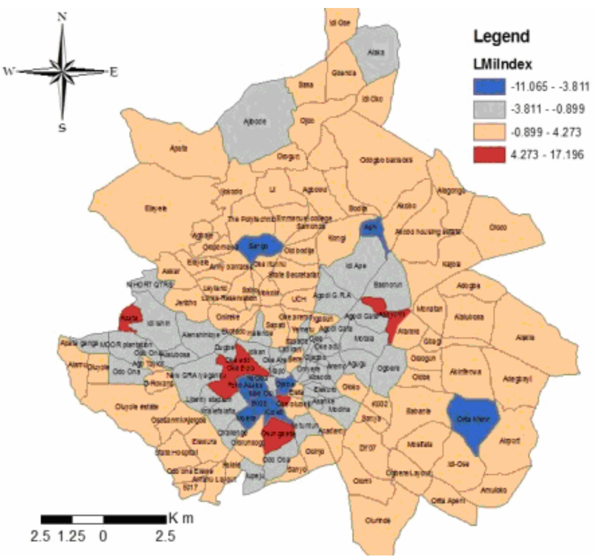

Fig. 12b. Local spatial autocorrelation of HBC.

4.5. Relationship between the spatial pattern of CVD and the spatial pattern of CVD biomedical risk factors in the study area

The research further identified the relationship between the global spatial pattern of CVD and global spatial pattern of biomedical risk factors of CVD. The result of the logistic regression shows R^2 value of 0.634 which indicates that approximately 63.4% variation in the spatial distribution of CVD in the study area can be predicted from the combination of the spatial distribution of the four identified predisposing factors (hypertension, diabetes mellitus, high blood cholesterol and obesity). The result indicates that all the predictor variables together have a significant combined effect on the incidence of CVD in the study area.

The beta values for HTN (0.871) and Obesity (0.544) show that these two factors have significant contribution to the spatial pattern of the CVD while the pattern of HBC, Diabetes have low contribution to the spatial pattern of CVD in Ibadan city (see Table 1)

Table 1. Result of regression analysis of the spatial pattern of CVD and Biomedical risk factors.

Model	Beta	t	Sig.
(Constant)	0.209	1.353	0.179
HTN	0.871	15.421	0.000
HBC	0.223	0.967	0.336
Diabetes	0.310	1.979	0.050
Obesity	0.544	1.090	0.278

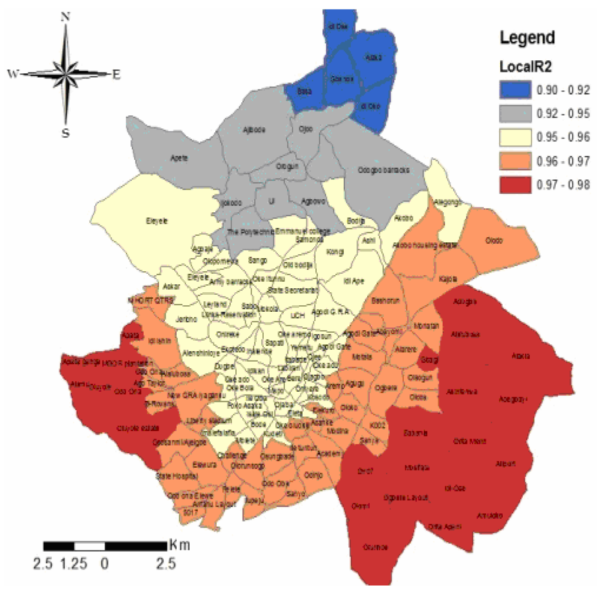

Fig. 13. GWR for the spatial relationship between CVD and the risk factors.

The GWR went further and also examined the type of spatial relationship that exists between the incidence of CVD and the incidence of the predisposing factors in the study area.

From the figure it can be observed that there is a strong spatial relationship between the pattern of CVD and the biomedical risk factors in the study area as the regression coefficient (R^2) obtained for the model is between 0.911 – 0.98, indicating non-stationary across the study area. However, the relationship observed increases towards the southern part of the study area with the strongest relationship existing at the south and the weakest positive relationship existing at the northern part of the study area. Areas like Apata Ganga, Oluyole and Amuloko exhibited the strongest positive spatial relationship between CVD and its risk factors.

These areas had regression coefficients (R^2) of 0.9811, 0.9815 and 0.9835 respectively. This means that for an increase in the CVD risk factors in Apata Ganga, Oluyole and Amuloko, there is an expected 98.11%, 98.15% and 98.35% variation respectively in the incidence of CVD within these areas in the study area.

Also, within the study area, some areas were identified as having a weaker positive spatial relationship compared to other areas. These areas have regression coefficient (R^2) of 0.920.

Areas that exhibited the least positive spatial correlation are Idi Ose, and Alaka. The regression coefficient (R^2) obtained for these areas were 0.9028 and 0.9036 respectively. These areas are observed to exhibit approximately about 90-92% variation in the incidence of CVD for an observed variation in the risk factors. It can thus be concluded that within the study area, there is a very strong positive spatial relationship between CVD and the biomedical risk factors but the strength differs across the entire study area.

5. CONCLUSION

From this study, it was discovered that the spatial pattern of CVD in Ibadan is largely random but the spatial pattern within the study area and the surroundings is random in some urban neighbourhood and dispersed in some low density neighbourhood; but, going further in the analysis, it was also observed that although the pattern of CVD in the entire region is somewhat dispersed within the regions of the study area, some areas exhibited some pattern of clustering while some exhibited some pattern of randomness. The same spatial pattern was also observed for the biomedical risk factors in the study area. The relationship between the disease incidence and the biomedical risk factors indicates a 63.4% variation in the pattern of the biomedical risk factors.

There exists a relationship between the spatial pattern of the disease and the spatial pattern of the biomedical risk factors and this relationship varies across the entire study area. Though it is a general assumption that nearby things are more related, it is not the case for the pattern of CVD and its risk factors within Ibadan and this is an indication that the unique characteristics possessed by the individual areas within the study area did not pose an influence on the incidence of CVD. This can be due to the fact that the risk factors for CVD are not contagious but rather influenced by an individual's choice of lifestyle (Stampfer, et al., 2000) [27].

There is evidence of local spatial dependence of CVD and Biomedical risk factors among neighbourhood in the study area. High density and low density areas have proportionally high prevalence levels of CVD cases while the middle income neighbourhoods have low CVD prevalence. It could therefore be inferred that it is a disease associated with the low and high class neighbourhoods in the study area.

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