

Spatial Modeling of Hypertension Disease in the Kumasi Metropolitan Area of Ghana

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Abstract Hypertension is a major health burden worldwide. In Ghana, the Health Service reports that since 2008, hypertension continuous to be the third most common cause of morbidity and mortality in the Ashanti region with the Kumasi Metropolitan Area leading the pack of endemic areas. The aim of this paper was to examine the spatial distribution of the disease in the Kumasi Metropolitan Area using patients' medical records. Using both quantitative and qualitative approaches, the research revealed that the disease was more profound in low-income suburbs of the metropolis than the high income communities. Again, the research further revealed that prevalence was high among females than males. Lastly, the high incidence of Hypertension was due to sedentary life style due mainly to the higher rate of urbanization. The research concludes that Hypertension is gradually emerging as a leading cause of death in the metropolis and therefore more efforts and resources should be made available to help manage the disease situation.

Keywords Hypertension, Kriging, Incidence Rate, Metropolis, Blood Pressure

1. Introduction

Hypertension, also referred to as high blood pressure, is a condition in which the arteries have persistent elevated blood pressure[4]. Blood pressure is the force of blood pushing up against the blood vessel walls. The higher the pressure, the harder the heart has to pump. The normal level for blood pressure is below 120/80, where 120 represent the systolic measurement (peak pressure in the arteries) and 80 represents the diastolic measurement (minimum pressure in the arteries). Blood pressure between 120/80 and 139/89 is called pre-hypertension (to denote increased risk of hypertension), and a blood pressure of 140/90 or above is considered hypertension[23]. Though the exact causes of hypertension are usually unknown, there are several factors that have been highly associated with the condition. They include: smoking, obesity, diabetes, sedentary lifestyle, lack of physical activity and high levels of salt intake. Extremely high blood pressure may lead to some symptoms such as severe headaches, fatigue or confusion, dizziness, nausea, problems with vision, chest pains, breathing problems, irregular heartbeat and blood in the urine[17].

As of the beginning the year 2000, more than a quarter of the world's adult population (nearly one billion) had hypertension, and this is projected to increase by almost 40%

in 2025[10]. The high cases and prevalence makes hypertension the single most important cause of morbidity and mortality in the world[18]. A study by Fuentes et al indicated that in the lower and middle- income countries, there seems to be a sharp increase in the prevalence rate of hypertension[8]. Again, the World Health Organization reports that in the Sub-Saharan Africa (SSA) there is a high prevalence of hypertension[21], although the awareness and treatment in African setting is still very low[2]. Hypertension is the number three killer in Ghana today. The prevalence rate of high blood pressure is estimated at 30-40% (MOH, 2010). Knowing the pattern of this detrimental disease could help public health workers and government to organize educative programs for citizens on causes of hypertension and its associated problems. Similar studies by[1] on the changing patterns of hypertension in four rural communities in Ghana observed prevalence of 25.4%. Statistics from the Korle Bu Teaching Hospital indicate that almost 70 percent of all deaths at the hospital are caused by hypertensive conditions. The report further states that the disease affects nearly one out of every five Ghanaian adults. A recent report by the Ghana Health Service says more people are becoming hypertensive due to unhealthy lifestyles.. The disease silently damages the brain, the heart, the kidneys and the eyes. Commonly referred to as high blood pressure or BP, hypertension is the major cause of strokes, heart attacks, heart failure and chronic renal failure. These and other blood pressure related diseases constitute more than half of all admission cases at Korle Bu Teaching Hospital[15].

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Table 1. Top Ten OPD Morbidity, 2008- 2010

No.	2008		2009		2010 Half Year	
	DISEASE	CASES	DISEASE	CASES	DISEASE	CASES
1	Malaria	814,998	Malaria	1,449,260	Malaria	797,629
2	Cough	119,490	Acute Respiratory Inf.	259,701	Acute Respiratory Inf.	148,366
3	Hypertension	80,429	Hypertension	125,453	Hypertension	66,098
4	Skin Disease	70,694	Diarrhoeal Disease	123,107	Diarrhoeal Disease	65,858
5	Diarrhoeal Disease	57,252	Skin Disease	115,212	Skin Disease	62,839
6	Rheumatic Conditions	42,617	Rheumatic Conditions	94,531	Rheumatic Conditions	51,229
7	Urinary Tract Inf.	33,900	Urinary Tract Inf	58,324	Intestinal Worms	34,102
8	Intestinal Worms	28,258	Intestinal Worms	54,719	Urinary Tract Infection	32,300
9	Home/Occup. Injuries	26,363	Acute Eye Infection	49,509	Acute Eye Infection	26,619
10	Chicken Pox	22,552	Home/Occup. Injuries	43,820	Anaemia	21,574

Source: GHS, 2012

Hypertension morbidity is regionally pervasive in Ghana. According to [3], the prevalence of hypertension in urban Accra is estimated to be 28.3% (crude) and 27.3% (age-standardized). The Ghana Health Service reports that hypertension was the second most reported medical condition in the Greater Accra Region in the year 2011 and the cases were traceable to the poor lifestyles of urban dwellers [9]. A survey conducted on blood pressure in the Volta Region of Ghana reported a frequency of 32.8% for hypertension with percentages of male and female been 30.7% and 39.4% respectively [6]. The Ashanti region has continuously recorded high cases of Hypertension since 2008 [9]. Data from the GHS indicate that hypertension has been the third common OPD cases since 2008. Again the disease is the third common cause of morbidity in the Region, Table 1.

Of all the districts and municipal areas in the region, the Kumasi metropolis sits on top. Statistics from Internal Medicine unit of the Komfo Anokye Teaching Hospital (KATH) show disturbing upsurge of cases of hypertension in the metropolis [11] see Table 2.

Table 2. Hypertension Cases in the Ashanti Region 2008-2010 Half Year

District	2008	2009	2010 Half Year
	Cases	Cases	Cases
Kumasi	38,388	36,605	15,721
Asante Akim North	2,092	2,855	7,581
Obuasi	20,614	26,750	7,121
AtwimaNwabiagya	3,363	7,555	4,564
EjisuJuaben	3,588	5,304	4,101
Sekyer South	2,940	5,025	3,988
Mampong Municipal	588	1,073	3,475
Sekyer East	3,672	4,389	2,734
Sekyer Afram Plains	2,339	4,728	2,221

Source: GHS, 2011

The Komfo Anokye Teaching Hospital has been seeing 120 new cases of hypertension every week. Again, 25 per cent of deaths at the referral facility are attributed to the abnormally high blood pressure disease and its related infections [11]. Furthermore, the statistics show that 28.7 per cent of people in the Kumasi Metropolis and its outlying communities have the disease. It is one of the leading causes of pre-mature deaths and disabilities and also account for 62 per cent of all stroke cases. Hypertension is described as a silent killer because many have it for years without realizing it.

This study which was conducted in the Kumasi metropolitan area (KMA) is aimed at examining the spatial dimensions of Hypertension by mapping the geographical distribution of the disease using patients' medical records obtained from the various medical facilities in the metropolis. It is important that the geographical spread of patients is determined because there has been a long held perception that the disease is associated with affluence and that it is a disease of the rich and wealthy in society. For this reason, many residents in the low and the middle income communities and suburbs of the metropolis do not seek regular medical check up, do not exercise regularly, and do not participate fully in health education programmes that are organized by health workers, that is according the Ghana Health Service. Contrary, the World Health Organization latest report indicates that almost 80% of the global Hypertension morbidity is contributed by the middle and low income countries. This negates the long held view that it is a health problem exclusively for the western world. The ultimate intention of this paper is to help public health officials determine the appropriate intervention strategies to help reduce the prevalence of the disease in the metropolis.

2. Methods

2.1. Study Area

Kumasi is located in the transitional forest zone and is about 270km north of the national capital, Accra. It is between latitude $6.35^{\circ} - 6.40^{\circ}$ and longitude $1.30^{\circ} - 1.35^{\circ}$. The unique centrality of the city as a traversing point from all parts of the country makes it a special place for many to migrate to. Kumasi is the second populous metropolitan area in Ghana after the capital, Accra. Over 2,022,919 people are estimated to live in the metropolitan area with a growth rate of 5.4 per cent annually[13]. The high population growth has serious consequences on health care delivery because it is not accompanied by improvement and increase in health oriented infrastructure and service provision. The Metropolitan Health Service is organized around five (5) Sub Metro Health Teams; namely, Bantama, Asokwa, Manhyia North, Manhyia South and Subin. The city has a number of health facilities in both the public and private sectors. Notable among them are the KomfoAnokye Teaching Hospital (KATH), which is one of the two (2) national

autonomous hospitals, four (4) quasi health institutions, five (5) health Care Centres owned by the Church of Christ and the Seventh-Day Adventist Church. In addition, there are over two hundred (200) known private health institutions and 13 Industrial Clinics in the metropolis. There are also 54 trained Traditional Birth Attendants (TBAs), nine (9) Maternal and Child Health (MCH) points and 119-outreach sites. These facilities are evenly distributed in space. The number of infants who die per 1,000 live births each year continues to grow. It increased from 21 in 2003 to 29 in 2004 and 36 in 2005 representing an increase in percentage of 27.6 and 19.4 respectively. The implication for development is that the population will not be replacing itself and the result will be an ageing population with a low human resource base. It will also impinge on productivity and the overall development of the metropolis. The common diseases in the Metropolis include; malaria, diarrhea, hypertension, diabetes mellitus, Septic abortion and road traffic accident. The population hospital ratio is 1:48,276[9].

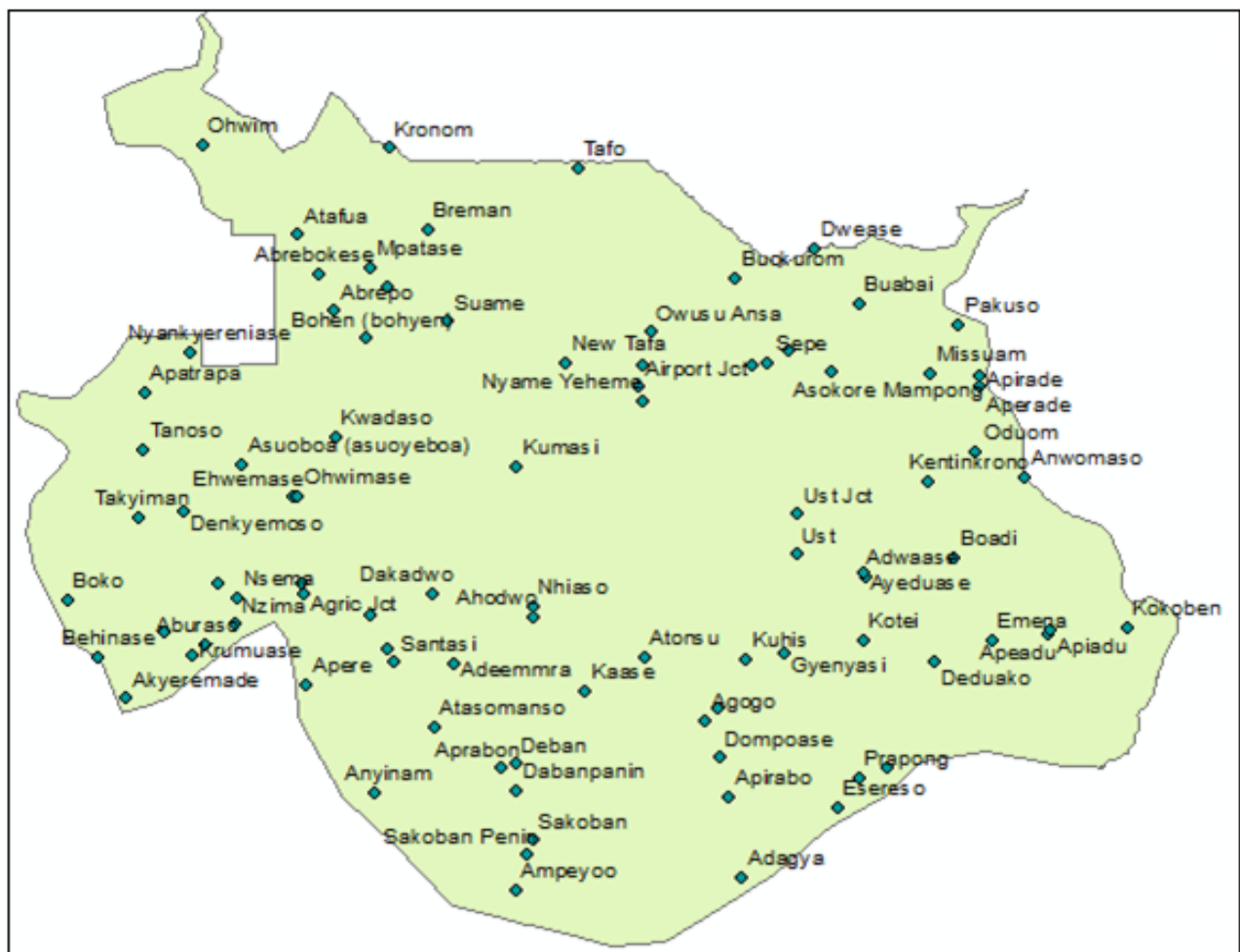


Figure 1. Map of the Study Area

2.2. Data Sources

Data for the study was obtained from the Disease Control Units (DCU) of the Ghana Health Service in the Ashanti Region. The confirmed cases of hypertension disease as of the time of the study were 15,721 made up of 6856 for males and 8865 for females. The data classification on the basis of sex was to find out the incidence rates between the two sex groups at the various suburbs in the metropolis. Population data obtained from Ghana Statistical Service was used in computing the raw rates of hypertension disease. Raw rates were calculated as the number of hypertension cases in each suburb divided by the estimated Population in 2010. In order to make better appreciation of the risk of the disease; the raw rates were rescaled by multiplying it by a factor of 1000. This expresses the raw rates as per 1000 people.

2.3. Spatial and Non-Spatial Data Input

The basic data inputs were geographic location of the study area where hypertension cases of patients have been reported and topographic map of the metropolis which was drawn at a scale of 1:25000. This map which was obtained from the planning department of Kumasi metropolitan assembly was geo-referenced and digitized in ArcGIS 10.0 version where coordinates per settlement were extracted. Reported cases of hypertension obtained from the regional disease control unit were entered as attributes of the point features (i.e. the settlement) in the software. The application softwares used for this research were ArcGIS 10.0 version and SpaceStat 3.6.1 developed by BioMedware USA.

2.4. Geostatistical Analysis of High Blood Pressure Rates

For a given number $N=840$ of settlements, let the number of recorded hypertension cases be $d(x_\beta)$ and the size of the population at risk also be $n(x_\beta)$, where x_β is the size of the risk entities at β .

Following Oliver *et al.*, (1998), towns are referenced geographically by their centroids with the vector of spatial coordinates $u(x_\beta) = (x_\beta, y_\beta)$, which leads to the actual spatial support (i.e. size and shape of the towns) is not taken into account in the analysis. The empirical incidence rates of Hypertension disease written as :

$$z(x_\beta) = \frac{d(x_\beta)}{n(x_\beta)} \quad (1)$$

We let each geographical location be x_β and can be expressed as the realization of a random variables $D(x_\beta)$ that follows a Poisson distribution with one parameter (expected of number of count of hypertension disease). This implies the product of the population size $n(x_\beta)$ multiplied by the local risk $R(x_\beta)$:

$$D(x_\alpha) / R(x_\alpha) = \text{Poisson}(n(x_\beta)R(x_\beta)) \quad \beta=1, \dots, N \quad (2)$$

The risk variable $R(x_\beta)$ is modelled as a stationary random field with mean m , variance σ^2_R and covariance function $C_R(h)$.

The conditional mean and variance of the rate variable $Z(x_\beta)$ are expressed as:

$$E[Z(x_\beta) / R(x_\beta)] = R(x_\beta) \quad (3)$$

$$\text{Var}[Z(x_\beta) / R(x_\beta)] = R(x_\beta) / n(x_\beta) \quad (4)$$

Poisson kriging

The risk over a certain settlement with centroid x_β is estimated as the following linear combination of K neighbouring observed rates:

$$\hat{rpk}(x_\beta) = \sum_{i=1}^K \lambda_i(x_\beta) z(x_i) \quad (5)$$

The weights $\lambda_i(x_\beta)$ are determined in order to minimize the mean square error of prediction under the constraint that the estimator is unbiased. These weights are the solution of the following system of linear equations, Poisson Kriging system:

$$\sum_{i=1}^K \lambda_j(u_\beta) \left[C_R(u_i - u_j) + \delta_{ij} \frac{m^*}{n(u_i)} \right] + \mu(u_i - u_\beta) \quad (6)$$

$$\sum_{i=1}^K \lambda_j(u_\beta) = 1$$

$$\delta_{ij} = 1 \quad \delta_{ij} = 1 \text{ if } x_i = x_j \text{ and } 0 \text{ otherwise } m^* \text{ is the}$$

population-weighted mean of the rates. The term $\mu(x_\alpha)$ is a Lagrange parameter that is achieved from the minimization of the estimation variance subject to the unbiased constraint on the estimator. The addition of the term, $m^* / n(x_i)$, for a zero distance deal with variability obtain from population size, leading to smaller weights for less reliable data. This term exactly stand for the difference between the variance of the risk and rate variables. We applied kriging to filter the noise from the observed rates aggregated to the settlement level, but not to estimate the risk within the settlement itself. The prediction variance based on Poisson kriging is computed using the traditional formula for the ordinary kriging variance:

$$\sigma^2 pk = C_R(0) - \sum_{i=1}^K \lambda_i(x_i) C_R(x_i - x_\beta) - \mu(x_\beta) \quad (7)$$

The determination of kriging weights and kriging variance, that is Equations (6) and (7) requires knowledge of the covariance of the unknown risk, $C_R(h)$ or equivalently its semivariogram $\gamma_R(h) = C_R(0) - C_R(h)$. The semivariogram of the risk is estimated as [14]:

$$\hat{\gamma}_R(h) = \frac{1}{2 \sum_{\beta=1}^{N(h)} \frac{n(u_{\beta})n(u_{\beta}+h)}{n(u_{\beta})+n(u_{\beta}+h)}} \sum_{\beta=1}^{N(h)} \left\{ \frac{n(u_{\beta})n(u_{\beta}+h)}{n(u_{\beta})+n(u_{\beta}+h)} [z(u_{\beta}) - z(u_{\beta}+h)]^2 - m^* \right\} \quad (8)$$

Where $N(h)$ is the number of pairs of communities separated by vector h . The different spatial increments $[z(u_{\beta}) - z(u_{\beta}+h)]^2$ are weighted by a function of their respective population sizes, $n(u_{\beta})n(u_{\beta}+h) / n(u_{\beta}) + n(u_{\beta}+h)$, a term which is inversely proportional to their standard deviation. We gave preference to pair data with small standard deviations. A permissible model $\gamma_R(h)$ is then fitted to the experimental variogram so that we obtain the variogram, covariance value. In this work, we modeled using the weighted least-square regression procedure implemented in the SpaceStat 3.5.6 version software developed by BioMedware USA. Weighting scheme is employed to the least-square in fitting of a variogram model to experimental values. This is to ensure that the selected model is the one that minimizes the weighted sum of squares of differences between the experimental and model curves. The L which is the number of classes of distance is expressed as.

$$wss = \sum_{l=1}^L w(h_l) [\gamma(h_l) - \gamma(h_l)]^2 \quad (9)$$

3. Results and Discussions

Figure 2 shows the omni-directional variogram of Hypertension disease for females and males. The figure also shows the risk computed from district-level rates using estimator (7). The experimental variogram was fitted using a spherical model with a range of 1.6 km for females. This means that given a radius of 1.6km, one could find all the attributable factors leading to the high rate of the disease which may include a higher concentration of fast foods joint among others. For that of males the Cubic model had a range of 1.1 km and a similar spatial distribution in the metropolis.

The solid curve denotes the anisotropic (i.e. direction-dependent) model fitted using weighted least-square regression.

Table 3. Anisotropic Semivariogram Parameters for Females and Males Hypertension Disease

Name	Model type	Sill	Nugget	Range(m)	MSS Error
Hypertension for males	Spherical	0.074	0.027	1613.35	0.047
Hypertension for females	Cubic	0.0706	0	1108.146	0.0318

There is no difference between the parameters values for both Omni-directional (Table 4) and Anisotropic (Table 3). The changing of direction had no influence on the parameters values of both male and female semivariograms.

Hence we generated one interpolation surface for both Omni and anisotropic semivariogram.

Table 4. Omni-directional Semivariogram Parameters for Females and Males Hypertension Disease

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Hypertension incidence for females has a better range of spatial autocorrelation than incidence for males in each suburb. This explains the fact that the geographical spread of Hypertension among females in the Kumasi metropolis is larger than that of males in the city. This finding is consistent with a similar study conducted in Nairobi by [18]. He found that there was female domination in hypertension in populations in low and middle-income suburbs than males. The sill for both variograms is very short as far as the two models are concern. The nugget variance that explains the error in the models is very low with Cubic model having 0.0706 for male and spherical model for Female with 0 errors. There was no direction influence on the range for both models. Hence weighted least square estimated was used to fit the models in both variograms.

The class boundaries of the color legend correspond to the deciles of the histogram of risk estimates. The Figure 4 indicates both the Poisson risk estimate and that of Poisson variance estimates for females. The Poisson risk map (Figure 4) shows that there is higher incidence of Hypertension risk among females in the southeast portion of the Kumasi metropolis than the other areas. The risk area covers communities such as Kronom, Tafo, Adwase, Ayedua, Atons, Aburaso, Kumasi, Esereso and Prapong. These areas are highly populated indigenous suburbs where access to basic social amenities including health care is limited. There is unavailability of land for livelihood activities such as farming due to the fact that the high population growth and the expansive nature of the city have replaced farm lands with settlement development. Majority of the residents therefore trek daily to engage in hawking and petty trading in the central business centre for their survival. The struggle for survival put pressure on the individual and thus increases the blood pressure. The study revealed that patronage of fast foods for both lunch and supper was the norm. One woman had this to say in an interview, “*when I close from selling, I organize some of these fried rice from the boys and off I go. After all, every satisfaction is satisfaction*”. According to reports from the Ghana health service the continuous patronage of such highly fat saturated diet could have a profound adverse effect on the functions of the body arteries

and this may also affect the circulation of blood to the heart. In the long term this can affect the functioning of the heart and thus increases the chances of getting Hypertension. Again the hustle and bustling life in the city, coupled with heavy traffic situation means that city dwellers have to leave home very early and return very late. The implication is that such people are unable to have the eight hours of mandatory sleep or rest to relax the body system. This could enhance the spread of Hypertension disease. Furthermore, the low level of awareness resulting from the general low level of education among residents of these suburbs predisposes them to the disease. It was therefore not surprising to note that many women do not report to health facilities to receive the needed care and only do so when the disease has reached advance stage. This revelation is consistent with a study by [7] that large proportions of the urban population in low-income suburbs of developing countries are living in slums. The living conditions in these slums impose major psychosocial constraints such as violence, insecurity and stress on them and this increases their risk of contracting cardiovascular disease. Similarly, some studies in the slums of Dar es Salaam, the capital of Tanzania, have reported alarming results of increasing and high prevalence of hypertension [6]. The risk map in figure 4 however shows

that the communities in the western portion of the metropolis have relatively lower incidence of the disease. These communities include Ampayoo, Sokoban, Dabanpanin and Buabai. Some of these communities like Sokoban are an emerging and fast growing community following the development of the wood village and the subsequent relocation of all carpenters in the metropolis to the area. With Dabanpanin, the inhabitants are mostly middle class citizens with the possibility of regular exercise and also routine visit to health facilities for medical checkup. This may explain the low incidence of the disease in these suburbs. The lack of visibility of the Hypertension disease for females in the western part does not mean there is no spread but rather at a very low pace. In the case of Ahodwo, a first class residential area where most of the elites in the city reside, the general higher level of education and their ability to afford quality health care may have accounted for the low incidence of the disease. [18] found in Nairobi that well educated and high income areas reported low incidence rate of the disease. Contrary to the spatial spread of the disease for females, the geographical spread of Hypertension for males (Figure 5) is concentrated in both central and northern part of the metropolis.

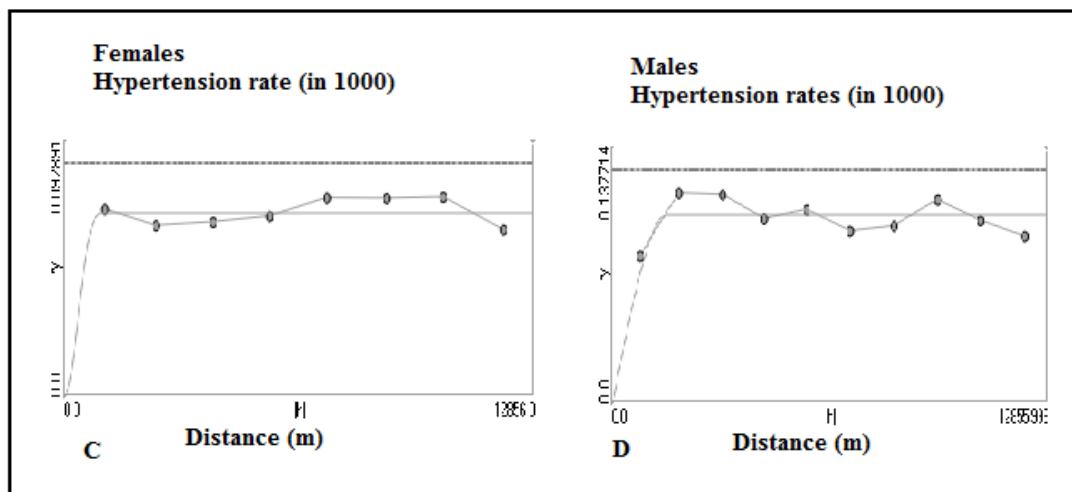


Figure 2. Directional variograms for Females and Males hypertension mortality rates and risks with the model fitted

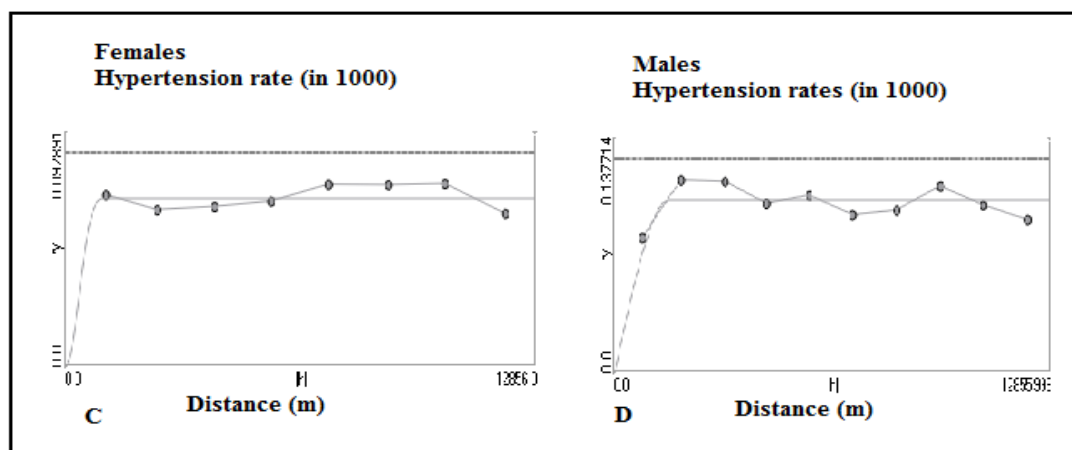


Figure 3. Omni-directional variograms for Females and Males hypertension mortality rates and risks with the model fitted

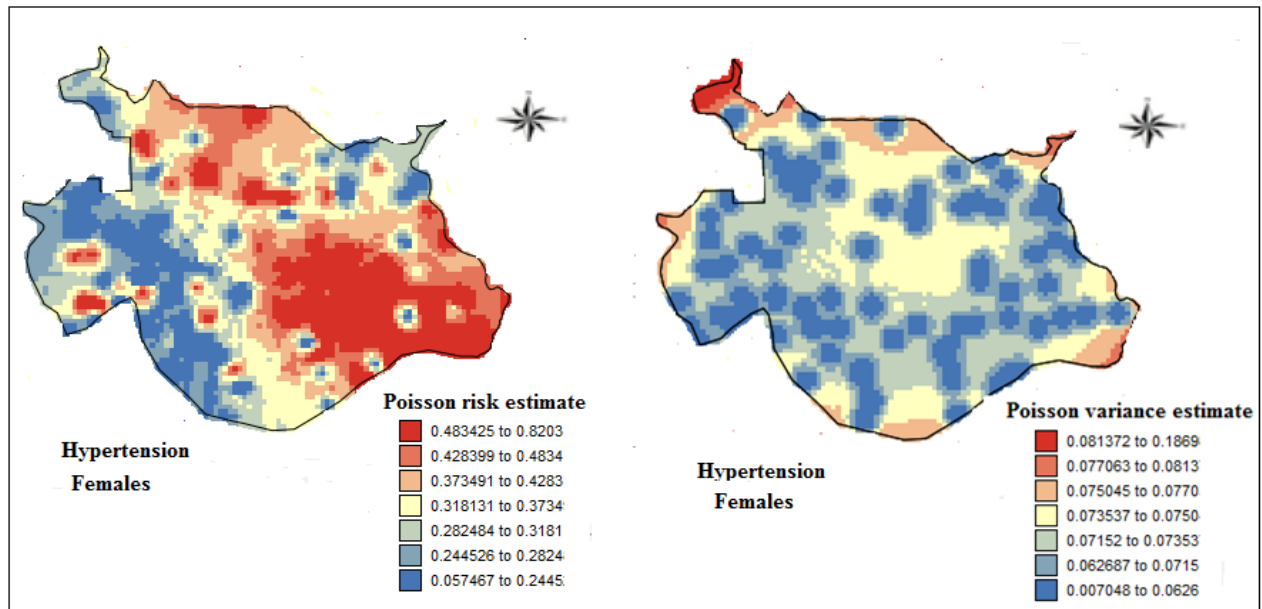


Figure 4. Maps of Females hypertension mortality risks estimated by Poisson kriging and the corresponding kriging variance

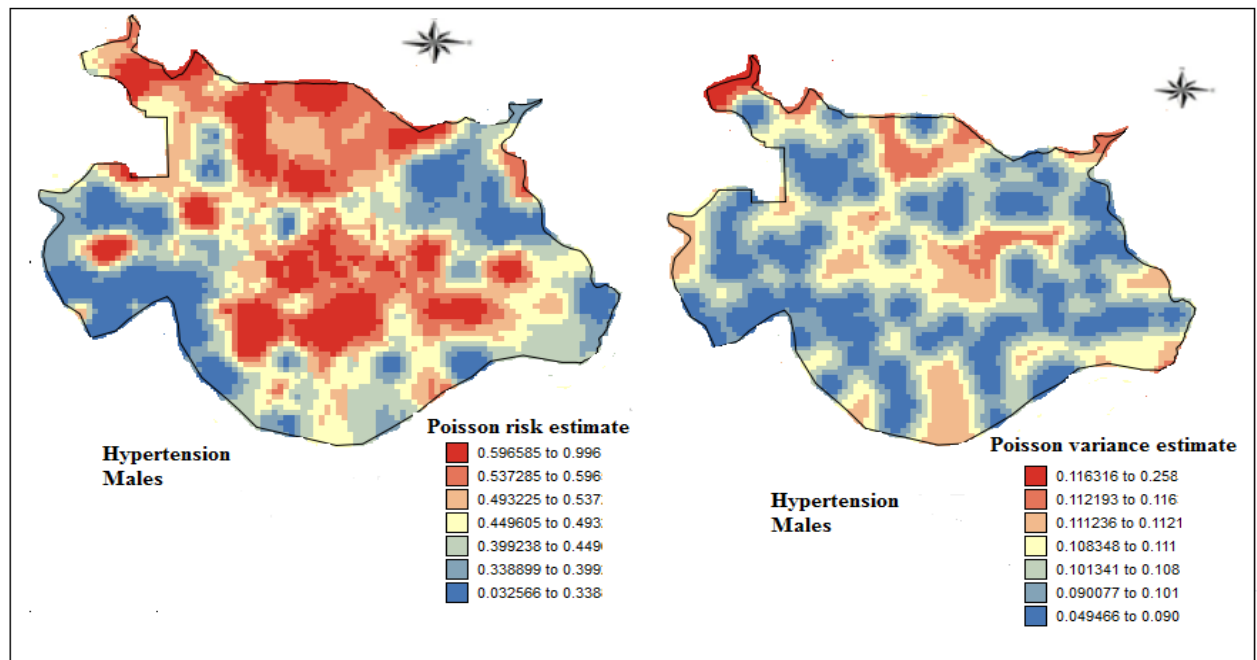


Figure 5. Maps of Males hypertension mortality risks estimated by Poisson kriging and the corresponding kriging variance

The class boundaries of the color legend correspond to the deciles of the histogram of risk estimates. The central part of Kumasi metropolis constitutes the Central Business District. The cluster covers suburbs such as Adum, Kejetia and parts of Asafo market. These areas are characterized by all kinds of business activities ranging from commercial banking, shopping malls, and exotic and local food joints to petty trading and hawking. The brisk business activities are more male oriented. Some of these male business people ply their trade deep into the night. The sedentary life style like alcoholism and patronage of fast foods among most of the men may help the spread of the disease. This is consistent with studies by [12] who found that contextual and

behavioural reasons like life style and dietary changes together form a complex system for developing hypertension [12]. Besides the central business district, some other endemic areas included Ohwim, Kronom, Tafo, Boukurom, New-Tafo and Kasse which are located on the northern part of the risk map for males Table 4. These communities are densely populated with poor environmental condition. Again, access to basic health care in these communities is a bigger challenge and this does not encourage the men to visit health facilities for early treatment. Furthermore, playing grounds and open spaces that could have been reserved for recreational activities have been modified and built for commercial purposes. This situation has negatively affected

ability of residents to organized regular exercise to reduce weight and minimize the chances of contracting heart related diseases.

The risk map for males, Figure 4 shows that communities like Ampayoo, Apiadu and Deduako are located very close to Kwame Nkrumah University of Science and Technology where most of the residents are students. These are young men who are less susceptible to Hypertension because of their background. In addition, their proximity to the University Hospital could enable them have regular medical checkup. The life style of these young men maybe better than the adults giving the fact that they are in school and being taken care of by their parents.

Strikingly, the western part of the risk map representing communities such as Krumuasi, Akyeremade, Apere, Emena reported fewer incidence of Hypertension. These communities consist of new expanding communities and therefore, the hardships imposed by economic realities are not so much as is the case in the highly populated indigenous communities in the metropolis. The natural environment has not been destroyed that much and therefore, access to quality foods grown locally is available. The unadulterated food reduces the risk of contracting the Hypertension disease.

4. Conclusions

This study has shown that hypertension exists in substantial rates in low-income communities of the KMA. The research further revealed that the incidence of HP was higher for females than for males. This female domination in hypertension is seen more often in densely populated low-income communities in the metropolis. There was however, a marked difference in the geographical distribution of the disease between both sexes. The research shows that there was higher incidence of Hypertension risk among females in the southeast portion of the Kumasi metropolis than the other areas. Conversely, the geographical spread of Hypertension for males was concentrated in both central and northern part of the metropolis. Despite the sexual dichotomy in the spatial spread of the disease, what has been established for a fact is that HP is on the increase and therefore urgent steps need to be taken to reduce the current incidence rate. The research has again shown that changing life style due to rapid urbanization and the struggle for livelihood activities is a strong determinant responsible for the high incidence of the disease in the metropolis. This research recommends that since many more people have the disease without knowing their status public education should be intensified so that residents freely and voluntarily avail themselves for regular check up. Again people should be encouraged to exercise regularly. Finally, alcoholism, smoking and sedentary life style should be reduced to lowest level.

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