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Mapping and spatial analysis of hypertension and diabetes prevalence in selected rural South African communities

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ABSTRACT

Aims: The widespread prevalence of non-communicable diseases in rural South African communities is concerning. This study aimed to determine the number of cases of hypertension and diabetes reported in rural clinics during the period under review.

Methods: A cross-sectional population-based survey was conducted to determine the prevalence of hypertension and diabetes and the geographical distribution of healthcare facilities in rural communities in the North-West province. Hypertension and diabetes were defined as blood pressure ≥130/80 mm Hg and fasting blood glucose ≥126 mg/dL. The range of values for each district municipality (DM) were used to represent map densities and the number of patients screened for hypertension or diabetes.

Results: Hypertension and diabetes map densities were highest in the Bojanala DM and lowest in Dr. Ruth Segomotsi Mompati DM. The number of patients screened for hypertension was highest in the Dr. Ruth Segomotsi Mompati DM (11955-14940) and lowest in the Ngala Modiri Molema DM (11-2996). The number of patients screened for diabetes was highest in the Bojanala DM (12868-16083) and lowest in the Dr. Ruth Segomotsi Mompati DM and Dr. Kenneth Kaunda DM (1-3218).

Conclusions: Although higher numbers of hypertension and diabetes were reported in urban areas, the numbers were grossly low in rural areas. This difference may be associated with the lifestyle of the residents of each area and the uneven distribution of clinics and health centers for the diagnosis and management of these conditions.

Introduction

Worldwide, approximately 70% of all morbidities and mortality are caused by non-communicable diseases (NCDs) (1,2). These NCDs are major risk factors for stroke, myocardial infarction, blindness, and several other cardiovascular diseases (3). A report by the World Health Organization showed that more than 30% of the entire world population suffers from hypertension, whereas more than 10% suffers from diabetes (4). Unfortunately, the large numbers of morbidities and mortality due to NCDs are borne by low- and middle-income countries, where resources are scarce (2). Some reports indicate that approximately 75% of the people in low-and-middle-income countries will have hypertension or other NCDs by the year 2025 (5,6). Among the older population in most African countries, the prevalence is as high as 60%, and a higher prevalence has been reported in urban settings than in rural settings (7). For diabetes, the prevalence is documented as 67-77% in most parts of South Africa (8). Importantly, a study also reported a comorbidity association between hypertension and diabetes (9). This number is increasing (10) and mortality could increase by 2025 (11).

Studies have indicated the possible devastating impacts of the renewed health and behavioral transitions occurring in South Africa (12,13), which has led to an astronomical increase in the prevalence of hypertension, diabetes, and other NCDs (14). Health transitions have been attributed to a demographic shift from rural to urban centers caused by rural-urban migration (15,16). This rural-urban migration leads to dietary and lifestyle modifications and potentiates the population to develop lifestyle diseases (17,18). These transitions have been reported to change the dynamics of the prevalence of hypertension and diabetes and the use of available clinics in the provinces, typifying the situation in the North-West province of South Africa (19).

Medical geography is a relatively new field of study that characterizes the association between pathological and geographical factors that regulate the evolution of pathogens (20). Its use is still limited and uncommon in South Africa and most parts of Sub-Saharan Africa. Medical geography helps map and carry out spatial analyses of diseases and their spread within a locality, aiming to identify low-risk and high-risk regions of a disease (21). For example, in Luxemburg, a study reported geographical variations in the prevalence of hypertension with the highest odds ratio in the industrialized region of the country (22). This study aimed to determine the geographical presentation of hypertension and diabetes concerning the availability of public and private healthcare facilities in rural communities in the North-West Province of South Africa.

Methods

Study design

This was a cross-sectional population-based survey conducted at health clinics in the North-West province of South Africa between April 2015 and March 2016 to determine the distribution of health services in selected rural communities and the number of patients with hypertension and diabetes. There are four districts in the province. At each location, information was gathered using a data collection form detailing the number of clinics, the number of patients diagnosed with hypertension and diabetes, and any pertinent data. Hypertension and diabetes were defined as blood pressure ≥130/80 mmHg and fasting blood glucose ≥126 mg/dL respectively (23,24). Additionally, a Global Positioning System receiver was used to collect the geographical coordinates for each center in the study area. These coordinates were then linked to the attribute information collected at the centers and a spatial database containing health center locations and their characteristics was created.

Study locations

The survey was performed in eighty-eight local public and private healthcare facilities in the province. The research team visited 38, 26, 17, and 7 healthcare facilities in Bojanala, Kenneth Kaunda, Ngala Modiri Molema, and Dr. Ruth Segomotsi Mompati district municipalities (DM), respectively.

Dataset

Provincial names and boundaries, as well as their longitudes and latitudes, form the main dataset used in this study. Data were entered into GIS ArcMap and merged with clinical data analyses into one database using common codes for mapping and visualization. Geostatistical spatial analysis was employed to predict the spatial variation in hypertension and diabetes in the province (25).

Inverse distance weighting

Interpolation using inverse distance weighting (IDW) operates under the explicit assumption that objects closer to one another share more similarities than those farther apart (26). With evenly distributed points in an area, the IDW method is effective. In this study, greater weight was assigned to the points closest to the target location; thus, the allocated weights change as an inverse function of 'p^{th} power of distance', where the power function (p) is a positive real number. The greater the values closest to the point to be interpolated, the greater the influence. The product of "allotted weights" and "measured values" for all sites was added to provide parameter prediction for the target location (26).

Hotspots analysis

Hotspot Analysis is an analytical technique that combines statistical and spatial methods to measure the concentration of specific elements or attributes. Concerning spatial interpolation, the Hotspot Analysis tool from ArcGIS calculates the Getis-Ord Gi* statistic for individual features in the dataset (27). The generated z scores and p values were used to identify high and low clustered values in space. This process assesses each feature while considering its context with neighboring features. A feature with a high value may be interesting but not necessarily be a statistically significant hotspot. For a feature to qualify as a statistically significant hotspot, it must have a high value and the surrounding features must possess similarly high values provided all points collected are equally dispersed and at equal intervals (27).

Kriging

Kriging is a stochastic geostatistical technique like inverse distance weighted averaging, where a linear combination of weights at known points is used to predict the value at unknown points. The kriging system is expressed as covariances, commonly derived by estimating and modeling a semi-variogram: a measure of the spatial correlation between two points (28). Kriging is a family of estimators used to interpolate spatial data, including ordinary, universal, and indicator kriging, co-kriging, and others. The choice of kriging depends on the data characteristics and desired spatial model. This study used ordinary kriging to predict unobserved values from observations obtained from nearby clinics. Ordinary kriging is the most common kriging type used in spatial data simulations, and it is considered the best because it minimizes the variance of the estimation error and is more accurate when the unobserved value is closer to the observed value (28).

Statistical Analysis

The range of values for each DM was used to represent map densities and the number of patients screened for hypertension or diabetes.

Ethics approval

This study was conducted following the guidelines for human experiments at North-West University (NWU), South Africa. This study is part of a larger study titled: NCDs, physical activities, and quality of life across different populations in the North-West province. The protocol for this study was approved by the NWU Ethics Committee (NWU-HREC) (registration number: NWU-00014-12-A9, date: 08.03.2012). All procedures for this study were carried out with strict adherence to the National Institutes of Health guidelines for human research.

Results

Density map of the North-West province districts for patients with hypertension and diabetes

The outcome is a less concentrated depiction of a phenomenon that is not portrayed through a sequence of distinct points but through an uninterrupted surface. The density map was found to be highest at the city centers of Bojalana District Municipality (BDM), Dr. Kenneth Kaunda District Municipality (DKKDM), and Ngala Modiri Molema District Municipality (NMMDM). This indicates the frequency of reported cases of hypertension compared with the available number of clinics in the more rural municipalities. There appeared to be a general reduction in density from city centers to suburbs. The density map was generally low at Dr. Ruth Segomotsi Mompati DM (DRSMDM). The Kernel density estimation in Figures 1a and 1b takes the value of the data assigned to a specific point and

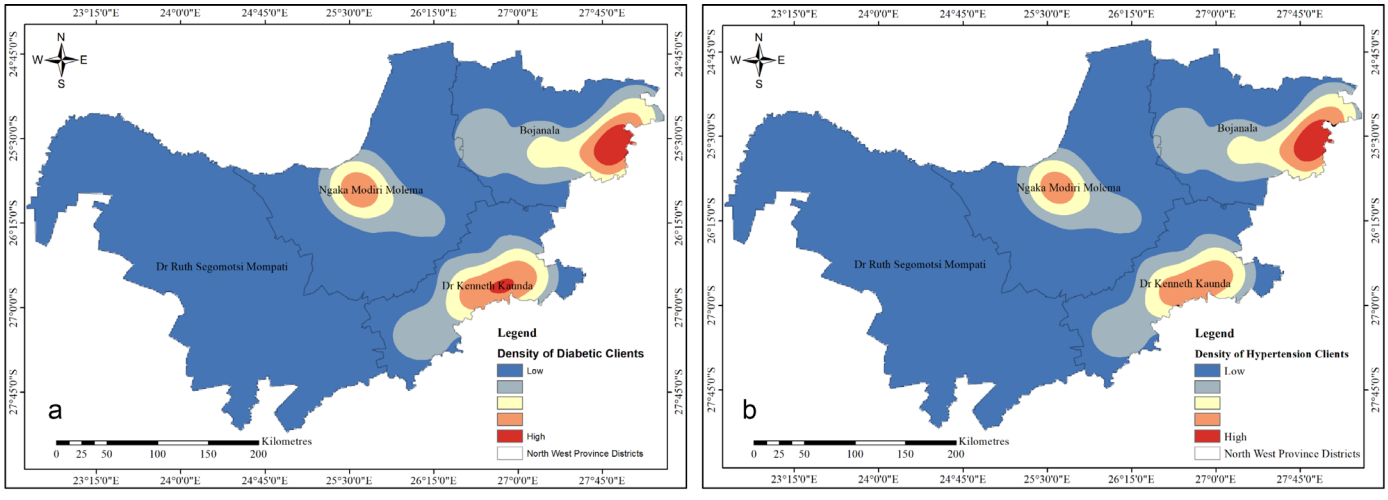

Figure 1. Density map for patients with (a) hypertension and (b) diabetes

spreads across a predefined boundary of the northeastern province. This density pattern was also observed in patients with diabetes, with higher concentrations observed in BDM, DKKDM, and NMMDM and lowest concentrations observed in DRSMDM. This density pattern indicates a possible link between the two studied NCDs.

Number of patients screened for hypertension and diabetes at various clinics in the districts

The study also reported the total number of patients who were screened for hypertension and diabetes at each district. The number of patients screened for hypertension was highest at the Dr. Ruth Segomotsi Mompati DM (11955-14940) and lowest at the Ngala Modiri Molema DM (11-2996). The number of patients screened for diabetes was highest at the Bojanala DM (12868-16083) and lowest at the Dr. Ruth Segomotsi Mompati and Dr. Kenneth Kaunda diabetes clinic (1-3218). This is illustrated in Figure 2a, 2b.

Hotspot map showing the prevalence of hypertension and diabetes

Figures 3a and 3b illustrate the hotspot map of the prevalence of hypertension and diabetes in the districts. The pattern was similar for hypertension and diabetes, with the prevalence highest at DKKDM, followed by BDM, DRSMDM, and finally NMMDM. The map of these hotspots also serves as another pointer to the possible link in the distribution of hypertension and diabetes in the district and the higher presence of these NCDs at urban centers.

Discussion

This study aimed to determine the geographical presentation of hypertension and diabetes in rural communities in the North-West province of South Africa. While a strategic plan to prevent the ever-increasing incidence and prevalence of NCDs like hypertension and diabetes had been developed more than

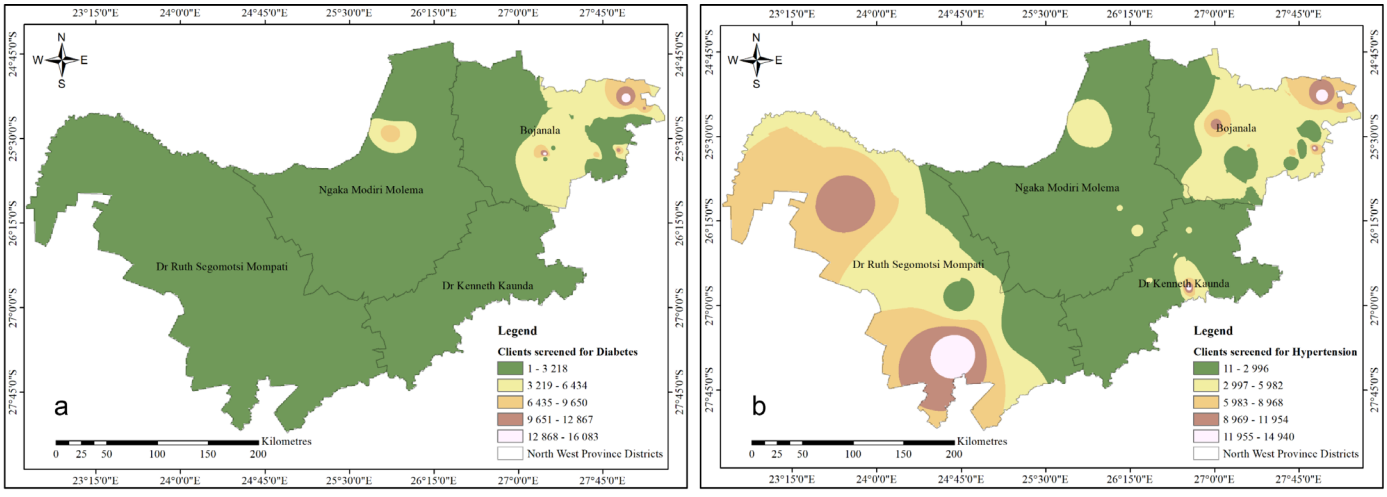

Figure 2. a, b) Number of patients screened for (a) hypertension and (b) diabetes at various clinics in the districts

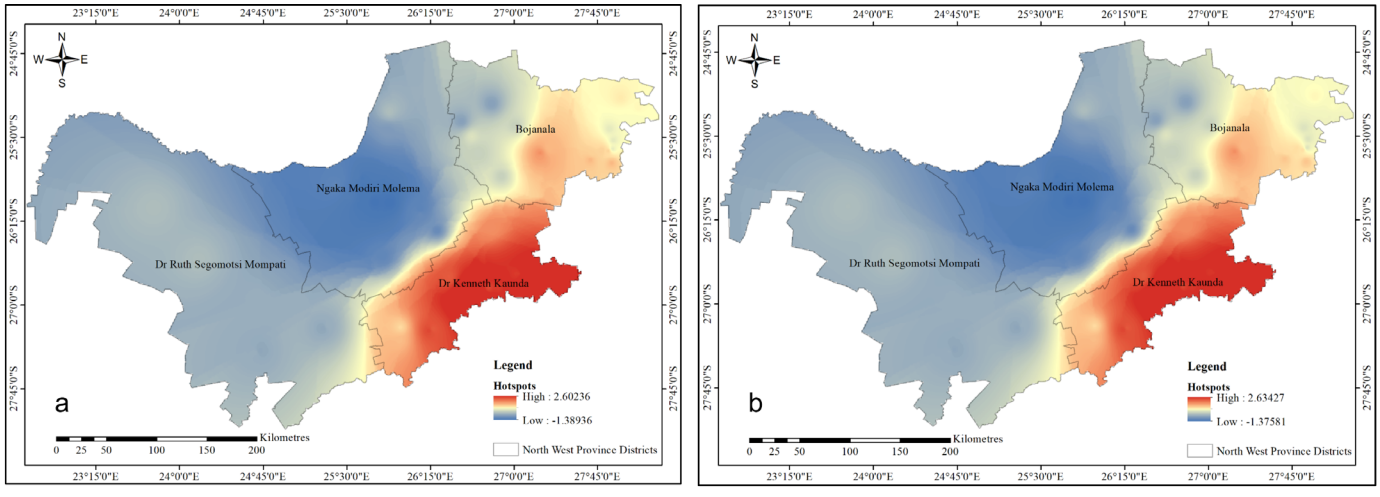

Figure 3. a, b) Hotspot map indicating the prevalence of (a) hypertension and (b) diabetes

a decade ago (29) in South Africa, the continuous increase appears to show a lack of understanding of the exact distribution of the affected patients and possible imbalance in the number of healthcare facilities and providers available to manage the conditions. This is the situation in the North-West province, and it explains why there is renewed interest in the likely factors responsible for the mismatch in the province (30). This study presents the observed uneven distribution of patients with either hypertension or diabetes, concerning the number of clinics in the North-West province of South Africa.

In this study, we observed that the density map for hypertension and diabetes showed higher concentrations of the two conditions in the relatively urban centers of Bojanala, Dr. Kenneth Kaunda, and Ngala Modiri Molema DM. It should be noted that these centers have the highest number of clinics in urban areas. The observed high densities could be due to the high population within the major towns in the different districts, as well as pull factors that contribute to the health risks associated with lifestyle diseases. This geographical distribution could also be due to the recently reported lifestyle transition characterized by increased adoption of urban and western lifestyles (7). Other authors have attributed this distribution to dietary transitions (6,7). The traditional diet has been abandoned because of urbanization and rural-urban migration for almost four decades (31). Thus, there appears to be a gradual shift from rural to urban centers (4,5,32), which typifies the situation in the province (7). A close look at the geographical distribution also revealed a high level of similarity between the density map for hypertension and that for diabetes in the entire province.

Importantly, even with fewer clinics in Dr. Ruth Segomotsi Mompati DM, more people were screened for hypertension than for diabetes. In contrast to this observation, however, the number of patients screened for both hypertension and diabetes at the Bojanala DM mirrors the available number of healthcare facilities. This implies that while the high number of cases reported in the Bojanala district could be due to the available number of clinics, the high number of patients screened for hypertension specifically at the Dr. Ruth Segomotsi Mompati district may be due to a clear-cut high number of cases in the district. Coincidentally, the number of patients screened for hypertension and diabetes was generally reduced at the Ngala Modiri Molema and Kenneth Kaunda DM compared with the available facilities. One major factor that could affect this distribution is the disparity in the level of education and wealth of the people in the province (33). Well-informed and educated people in major towns tend to have regular medical check-ups at public and private clinics (34). However, their counterparts in rural areas may prefer to use traditional herbs for treatment, as earlier studies have reported extensive use of herbal products by South Africans (35). A higher prevalence of hypertension and diabetes was reported in the Dr. Kenneth Kaunda DM, followed by Bojanala, Dr. Ruth Segomotsi, and Ngala Modiri Molema DMs. These are the core city centers dominated by educated people whose level of knowledge could directly affect the observed distribution (36,37) and where interprofessional care is commonly practiced in the management of conditions (38).

Based on these findings, there is an urgent need for a more pragmatic approach to managing the astronomical increase in the number of people with NCDs in the province. There may be a need to create policies to regulate nutritional and behavioral lifestyles at city centers while increasing the number of test centers and creating more awareness at rural centers to control the observed geographical distribution of hypertension and diabetes. However, it should be noted that most NCD data were collected and presented using surveying procedures, which might lead to under- or overestimation and are only applicable on coarse spatial scales (39).

This is one of the first studies in the Southern African region that directly used medical geography knowledge to describe a local challenge. The maps provide a real-time graphical representation of hypertension and diabetes in the province.

This study only reported the density maps, and the number of cases observed in the DM of hypertension and diabetes, among several other NCDs like cancer, chronic lung disease, and stroke. The nutritional and behavioral transition in the province is likely to affect the geographical distribution of these other NCDs. In addition, the study only presented the distribution within a short period of just one year. It would have been better if a report covering at least five years was available to provide a clearer picture of the distribution of NCDs in the province. Nonetheless, the report provides insight into the distribution of the two NCDs during the study period.

Conclusion

While higher numbers of hypertension and diabetes were reported in urban areas, the numbers were grossly low in rural areas. This difference may be associated with the lifestyle of the residents of each region and the uneven distribution of clinics and health centers for the diagnosis and management of these conditions.

Acknowledgments

The authors acknowledge the support from the Provincial Department of Health for their efforts in the collection of data for the study.

Ethics

Ethics Committee Approval: The protocol for this study was approved by the NWU Ethics Committee (NWU-HREC) (registration number: NWU-00014-12-A9, date: 08.03.2012).

Informed Consent: Consent form was filled out by all participants.

Authorship Contributions

Concept: A.A., U.U., M.A., Design: U.U., M.A., Data Collection or Processing: U.U., M.A., Analysis or Interpretation: A.A., U.U., S.B., Literature Search: A.A., U.U., Writing: A.A., U.U., S.B., M.A.

Conflict of Interest: No conflict of interest was declared by the authors.

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