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The distribution of cardiovascular diseases in Tanzania: a spatio-temporal investigation

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Abstract

Cardiovascular Disease (CVD) is currently the major challenge to people's health and the world's top cause of death. In Tanzania, deaths due to CVD account for about 13% of the total deaths caused by the non-communicable diseases. This study examined the spatio-temporal clustering of CVDs from 2010 to 2019 in Tanzania for retrospective spatio-temporal analysis using the Bernoulli probability model on data sampled from four selected hospitals. Spatial scan statistics was performed to identify CVD clusters and the effect of covariates on the CVD incidences was examined using multiple logistic regression. It was found that there was a comparatively high risk of CVD during 2011-2015 followed by a decline during 2015-2019. The spatio-temporal analysis detected two high-risk disease clusters in the coastal and lake zones from 2012 to 2016 (p<0.001), with similar results produced by purely spatial analysis. The multiple logistic model showed that sex, age, blood pressure, body mass index (BMI), alcohol intake and smoking were significant predictors of CVD incidence.

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Introduction

Cardiovascular Disease (CVD), currently the major challenge to people's health and the world's top cause of death (Rajabi *et al.*, 2018), caused approximately 17.9 million deaths in 2015 and is expected to approach 23 million deaths in 2030 if preventive measures are not taken (Roman *et al.,* 2019). In the past, CVD affected high-income countries more than the developing countries but the opposite has been observed in recent years (Amini *et al.*, 2021). Indeed, there is a noticeable emergence of Non-Communicable Diseases (NCDs), including CVD, in sub-Saharan African countries (Hamid *et al.*, 2019). In order to reduce this burden it is important to determine high-risk areas and institute proper management for the allocation of scarce resources.

Tanzania is among the countries experiencing the burden of NCDs, with CVD being a leading cause of mortality. The World Health Organization (WHO) has stated that the death rate due to CVD, cancer, chronic respiratory disease and diabetes in Tanzania is approximately 34% (WHO, 2016). With respect to the NCD risk, WHO has introduced a stepwise approach factor surveillance (STEPS) and the latest Tanzania STEP survey showed CVDs to be 13% of its total number of NCD deaths (Mayige & Kagaruki, 2012). A study that investigated the burden of CVD in Tanzania revealed that people aged 25-64 years old are more affected by the disease because they are more exposed to the risk factors (Roman *et al.*, 2019). The growth of CVD risk factors accelerates mortality and morbidity and thus the probability of an individual developing CVD incidence (Amini *et al.*, 2021).

The distribution of diseases is generally heterogeneously located (Baptista & Queiroz, 2022) and knowing the spatio-temporal distribution of disease enables identifying where and when the population is at risk of developing CVD. Spatial and spatio-temporal pattern analysis of diseases is increasingly used to address these issues (Kiani *et al.*, 2021; Yan *et al.*, 2023). The spatio-temporal distribution of diseases is based on different phenomena, e.g., Azimi et al. (2021) used Local Moran's I (Anselin, 1995) to identify the space-time distribution of hospital time spent to respond to CVD emergence calls. Another study assessed the effect of different air pollutants on daily CVD outpatients, who visited hospitals in Ganzhou, China from 2016 to 2020 (Yan *et al.*, 2023). They analyzed the spatio-temporal distribution of CVD-related hospitalization rate and the CVD risk factors using ArcGIS

(ESRI, Redlands, CA, USA) and scan statistics (Kulldorff, 1999). A similar approach based on Local Moran's *I* (Anselin, 1995) and Getis-Ord Gi* (Songchitruksa & Zeng, 2010; Jana & Sar, 2016) reported mortality hotspots due to CVD in Iran's western, southern and eastern areas in 2017 to 2019 (Zangeneh *et al.*, 2024), while Şener and Türk (2021) used geographical information systems (GIS) to identify the spatio-temporal distribution of CVD mortality rates at the provincial level in Turkey between 2009 and 2018. This study found a high temporal distribution of CVD mortality rate in 2011 descending over time towards 2018, with high spatial clusters near Black Sea in the West and Centre including Eastern Anatolia and low ones in the south-eastern parts of the country (Şener & Türk, 2021). Another study examined the spatio-temporal distribution of cause-specific CVD admissions in Beijing-China at the district level between 2013 and 2017 (Amsalu et al., 2021). They identified CVD-clustered admissions in various districts based on the Kulldorff's spatial scan statistics (Kulldorff, 2015) in which, clusters due to coronary heart disease in Daxing, atrial fibrillation in Fangshan and heart failure in Xicheng were observed (Amsalu *et al.*, 2021). Keino & Carrel (2023) studied the spatio-temporal distribution of obesity and the use of tobacco in sub-Saharan African countries from 2003 to 2016 using adaptive kernel density (Zhang *et al.*, 2017) and logistic regression (Ranganathan *et al.*, 2017) in sub-national and rural/urban settings. They observed that tobacco use decreased in the rural areas and that obesity increased both in urban and rural areas (Keino & Carrel, 2023).

The distribution of CVD based on the mortality rates (Baptista & Queiroz, 2022; Mena *et al.*, 2018), hospital admission rates (Rajabi *et al.*, 2018b) and incidence rates (Kiani *et al.*, 2021) have been examined by spatio-temporal methods, and outpatient data have been used to study CVD events (Azimi *et al.*, 2021; Tang *et al.*, 2023; Yan *et al.*, 2023). We used outpatient data from Tanzania to examine the spatio-temporal variation of CVD incidences at the regional level and analyzed the incidence of CVD-clustering.

Materials and Methods

Time and site of the study

The retrospective research was employed to study the distribution of CVD in Tanzania's mainland from 2010 to 2019. The mainland has an area of 945,087 Square Kilometers, is situated at latitude 6°23′31.20″ South and longitude 35°00′07.20″ East and has an approximate population of 59,851,347 (United Republic of Tanzania, 2024). The spatial analysis of CVD incidence was conducted at the regional level. There are four zonal referral hospitals as shown in Figure 1 (adapted from Sawe *et al.*, 2014)

Design and data collection

The data were extracted from the records department at the four designated referral hospitals from 2010 to 2019 comprising Jakaya Kikwete Cardiac Institute (JKCI), which is located in the same environment as the Muhimbili National Hospital (MNH) hospital, Mbeya Zonal Referral Hospital (MZRH), Kilimanjaro Christian Medical Centre (KCMC) and Bugando Medical Centre, a referral and university teaching hospital for the Lake and Western zones. These hospitals were purposely selected because they are zonal referral hospitals that receive many patients from different regions, which increase the probability of high-quality data availability for the disease condition under study. In Tanzania, an individual can visit a referral hospital without being referred from any other hospital, making it possible to find people without CVD in the cardiac units. The hospitals store patient's data in hand-written files or in e-medical computer systems, sometimes in both. The list for each hospital of all outpatients aged between 25 and 64 years, who attended the cardiac unit for the first time between 2010 and 2019 from Tanzania mainland was extracted and individuals sampled using a simple random sampling method based on the registration numbers, which allowed access to the data for each patient. We noted whether the persons in the lists were diagnosed as a case, with special reference to the presence of diseases causing morbidity and mortality, such as ischemic heart disease, acute myocardial infarction, stroke, rheumatic heart disease, congestive heart failure and coronary artery disease.

The region's population data were obtained from the Tanzania National Bureau of Statistics (NBS) to calculate the CVD incidence rates. The population for the years 2010 and 2011 were projected from the 2002 census, that of 2012 was obtained from the census conducted that year and for the years 2013 to 2019, it was projected from the 2012 census.

Data processing and analysis

STATA software (Schissler, 2019) was used to analyse the data, with Kulldorff's SaTScan (Kulldorff, 1997, 1999; Rao *et al.*, 2017) used for cluster detection and QGIS for plotting the maps. The dependent variable was dichotomous, *i.e.* describing whether or not an individual had experienced a CVD event. Clusters of high-risk areas due to CVD incidences were identified based on the retrospective temporal, purely spatial and spatio-temporal analysis. Clusters with higher CVD incidences than expected under spatial randomness were identified. The significant clusters were evaluated by gradually scanning the circular window spanning the study area and the one with maximum Log-Likelihood Ratio (LLR) was selected. The maximum spatial cluster size of 50% of the total population and *p*-values were reported through 999 Monte

Figure 1. Location of the national hospital and zonal referral hospitals in Tanzania (adapted from Sawe *et al.,* 2014).

Carlo simulations (Hung, 2023) to ensure no loss of power at the 5% level (Rodrigues *et al.*, 2015). The Relative Risk (RR) that compares the risk of the disease to the population inside and outside the clusters was recorded. RR>1 indicate a higher likelihood of CVD risk inside the cluster than in the population outside and RR<1 otherwise.

The chi-square test (Rana & Singhal, 2020) examined significant categorical individual patient's covariates with the outcome variable, which were fitted using a multiple logistic regression model (Ranganathan *et al.*, 2017) to assess their collective effects on the outcome variable. The odds ratio (OR), *p*-values and 95% or 90% Confidence Intervals (CI) were computed, whereby covariates with *p*-values <0.05 or p-values <0.1 were considered significantly associated with the outcome variable.

Results

Demographic variables

A collection of 3,553 CVD incidences was sampled between 2010 and 2019. This total included 1,116 (31.4%) from JKCI1, 802 (22.6%) from KCMC, 729 (20.5%) from Bugando and 906 (25.5%) from MZRH. The results in Table 1 show that, more males (53.3%) attended the cardiac unit for the first time compared to females (46.7%). Most of the respondents (46.7%) were aged between 44-59 years old followed by age groups 25-43 (30.8%) and 60-64 (22.5%).

Temporal trend

The purely temporal analysis results revealed a significant high-risk cluster of CVD incidence during the year 2011 to 2015 (*p*=0.001). The observed CVD cases were 1,251 against the expected 1,173.34 with RR=1.14 and LLR=15.77. Also, the CVD incidence rate decreased from 2010 to 2013, rose from 2014 to 2015 finally decreased to 2018 with a small increase in 2019 (Figure 2).

Spatial clusters

The purely spatial analysis identified two significant high-risk clusters (*p*-value<0.001). These clusters comprised sixteen regions of Tanzania mainland. The first high-risk cluster was the one with

Table 1. Demographic characteristics.

Variable	Observation (N)	Outcome (%)
Sex		
Male	1,895	53.3
Female	1,658	46.7
Age group		
25-43	1,093	30.8
44–59	1,658	46.7
60-64	802	22.5

Table 2. Bivariate analysis results.

Variable	Outcome	Chi square	*p*
Age		5.50	0.064*
25-43	30.8		
44-59	47.7		
60-64	21.5		
Sex		8.27	0.048**
Male	53.3		
Female	46.7		
Smoking		55.84	0.000****
No	69.4		
Yes	30.6		
Diabetes		0.0357	0.850
No	35.7		
Yes	64.3		
Pulse rate		1.3438	0.246
Normal	72.5		
High	27.5		
Alcohol intake		23.22	0.000****
No	62.4		
Yes	37.6		
Body mass index		273.56	0.000****
Underweight	4.8		
Normal	18.0		
Overweight	33.4		
Obesity	43.8		
Blood pressure		107.405	0.000****
Normal	36.0		
Hypertensive	64.0		

**** p<0.001, ** p<0.05, * p<0.1.*

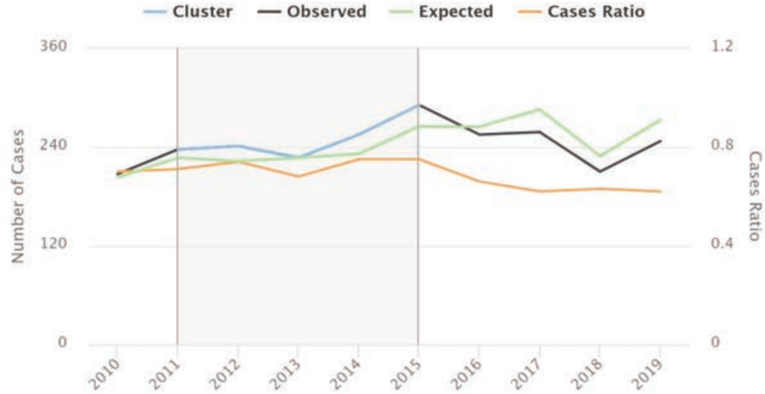

Figure 2. Number of cases and cluster ratio of the incidence of high-risk of cardiovascular incidence by purely temporal analysis.

the largest LLR called the primary. This primary cluster included six regions, Dar-es-salaam, Pwani, Tanga, Morogoro, Lindi and Dodoma with RR=1.45 and LLR=159.03. The secondary cluster comprised nine regions, Shinyanga, Mwanza, Geita, Tabora, Simiyu, Mara, Kagera, Kigoma and Singida with RR=1.23, LLR=43.50. These two clusters had higher rates of CVD incidence than other regions of Tanzania mainland (Figure 3).

Spatio-temporal clusters

Two significant high-risk clusters were detected from 2012 to 2016 (p<0.001). The first one was located in Mwanza, Shinyanga, Geita, Simiyu, Mara, Kagera, Tabora, Arusha, Kigoma, Singida and Manyara regions and had RR=1.28 and LLR=32.12. The second high-risk cluster comprised five regions, namely Pwani, Dar es Salaam, Tanga, Morogoro and Lindi and showed RR=1.25 and LLR=23.96. This result indicates that people in these clusters had a higher risk of CVD than those outside from 2012 to 2016. The spatial analysis of CVD incidence over time showed clusters in similar locations. Moreover, the central zone showed a high risk of CVD in 2019 (Figure 4).

Factors associated with the CVD incidences

The chi-square analysis identified the significant covariates at 95% or 90% CIs. Covariates significantly associated with CVD incidence were used to fit the multiple logistic regression model. The heart pulse rate and diabetes covariates were insignificant in this respect (Table 2).

The multiple logistic analysis in the four hospitals found that at 5% and 10% CIs, hypertension was significantly related to CVD incidence in all hospitals, alcohol intake, smoking and the body mass index (BMI) in three of the hospitals, and that sex and age were significantly associated with CVD incidence in only one hospital (Table 3).

Discussion

The results of this study revealed that there was a decline in the CVD incidence rate from 2015 to 2019. The decrease in this period may be the positive impact of implementing the government's 2009-2015 plan for reducing the incidence of NCDs, including CVD (Roman *et al.,* 2019). Also, the Tanzanian Government has recently invested in improving health infrastructure by strengthening health service provisions (Kapologwe *et al.*, 2020).

Our observation of a high rate of CVD incidence during the years 2012 to 2016 in the Coastal and Lake zones of Tanzania shows similarities with a study that evaluated the factors associated with cardiovascular health among adults infected with the Human Immunodeficiency Virus (HIV) in Dar es Salaam (Ottaru

Figure 3. Location of the purely spatial high-risk CVD incidence clusters.

Table 3. Multiple logistic regression results.

Variable	Bugando OR [95% CI]	MZRH OR [95% CI]	KCMC OR [95% CI]	JKCI OR [95% CI]	p
Age					
25-43 (Ref)					
44-59	1.19 [0.40, 1.74]	1.29 [0.47, 1.58	0.94 [0.61, 1.91]	1.18 [0.71, 2.07]	p=0.064
60-64	2.26 [0.41, 5.46]	1.39 [0.60, 2.40] *	0.72 [0.42, 1.55] *	0.87 [0.58, 1.34]	
Sex					
Male (Ref)					
Female	3.50 [1.93, 5.65] *	1.17 [0.91, 1.83] ***	1.35 [0.99, 1.93] *	1.09 [0.75, 3.75]	p=0.048
Smoking					
Non-Smoker (Ref)	2.42 [1.51, 4.37] *	1.70 [1.18, 2.41] **	1.39 [0.98, 2.33] **	1.03 [0.70, 1.52]	p<0.001
Smoker					
Alcohol intake					
Non-Alcohol (Ref)					
Alcohol	2.16 [1.16, 3.13] *	1.79 [1.39, 2.76] **	1.42 [1.04, 2.08] **	1.02 [0.71, 1.54]	p<0.001
Body mass index					
Normal (Ref)					
Underweight	0.10 [0.017, 0.249] *	0.58 [0.19, 1.49]	0.31 [0.19, 1.58] *	1.43 [0.55, 3.75]	p<0.001
Overweight	3.34 [1.62, 6.46] **	7.67 [4.69, 17.13] ***	5.84 [3.60, 10.24] ***	1.44 [0.84, 2.69]	
Obesity	1.71 [0. .81, 4.74]	2.70 [1.84, 7.97] **	1.49 [1.012, 3.81] *	1.30 [0.69, 2.84]	
Blood pressure					
Normal (Ref)					p<0.001
Hypertension	0.95 [2.88, 9.20] ***	2.11 [1.48, 3.41] ***	1.82 [1.24, 4.96] **	1.14 [0.63, 1.22] *	

*OR, Odds Ratio; CI, Confidence interval; Ref, Reference category, Significance level: p<0.001 = ***; p<0.05 = **; p<0.001 = * .*

et al., 2022). Their study revealed that CVD deaths between 2012 to 2016 increased from 9% to 13%, as finding supported by the fact that at this time there was a higher CVD mortality rate (13%) in Tanzania (Roman *et al.*, 2019) which must have been associated with high CVD incidences.

Both the purely spatial and spatio-temporal analyses exhibited a high rate of CVD incidences concentrated around the Coastal and Lake Zones. The reasons for this observation may be due to the high income per capita in these regions reflected by their higher gross domestic product (GDP) (United Republic of Tanzania, 2020). A higher GDP is an indicator of increased wealth which can be associated with CVD (Chaiyasong *et al.*, 2018). Regions like Dar es Salaam, Tanga, Mwanza and Dodoma are urban areas where a high risk of CVD problems can be expected (Wang *et al.*, 2022) due to high use of processed foods, sedentary life and air pollution because of industrialization and overcrowding. This finding is similar to a study by Xiao-dong *et al.* (2022), which found that people living near the coastal areas had 24% increased risk of myocardial infarction compared to those living inland.

The risk factors associated with CVD incidences for patients in each hospital revealed by the logistic regression in our study demonstrated that adults (60-64 years) are more vulnerable to CVD problems than middle-aged people (44-59 years). This finding can be explained by the fact that adults (60-64) start to reduce the immunological ability making them vulnerable to various diseases (Kundu & Kundu, 2022), something which is corroborated by Rodgers *et al.* (2019), who found an increased risk of CVD incidences for both sexes in an ageing population.

Our study revealed that females were more likely to have CVD incidences than males, which is consistent with previous studies (Colpani *et al.*, 2018; Vaccarezza *et al.*, 2020). This may be the result of hormonal impairment, particularly during the postmenopausal stage, caused by the decline of oestrogen and testosterone hormones which regulate the cardiovascular system (Kundu & Kundu, 2022). Women in the postmenopausal stage should be encouraged to a habit of regular physical exercises to reduce vasomotor symptoms and CVD risk.

Overweight people have an increased likelihood of developing CVD. This result is similar to a study by Julin *et al.* (2018), which reported that overweight and obesity were highly associated with CVD risk. Increased body weight leads to excess body fat, which may cause metabolic abnormalities and increased cardiac work load (Koliaki *et al.,* 2019). We also found that people who drink alcohol and smoke regularly had an increased likelihood of developing CVD incidences, compared to counterparts who do not, which can be explained by the fact that alcohol affects the brain and human physical body because of its neurotoxicity even at low quantities (Roerecke & Rehm, 2014).

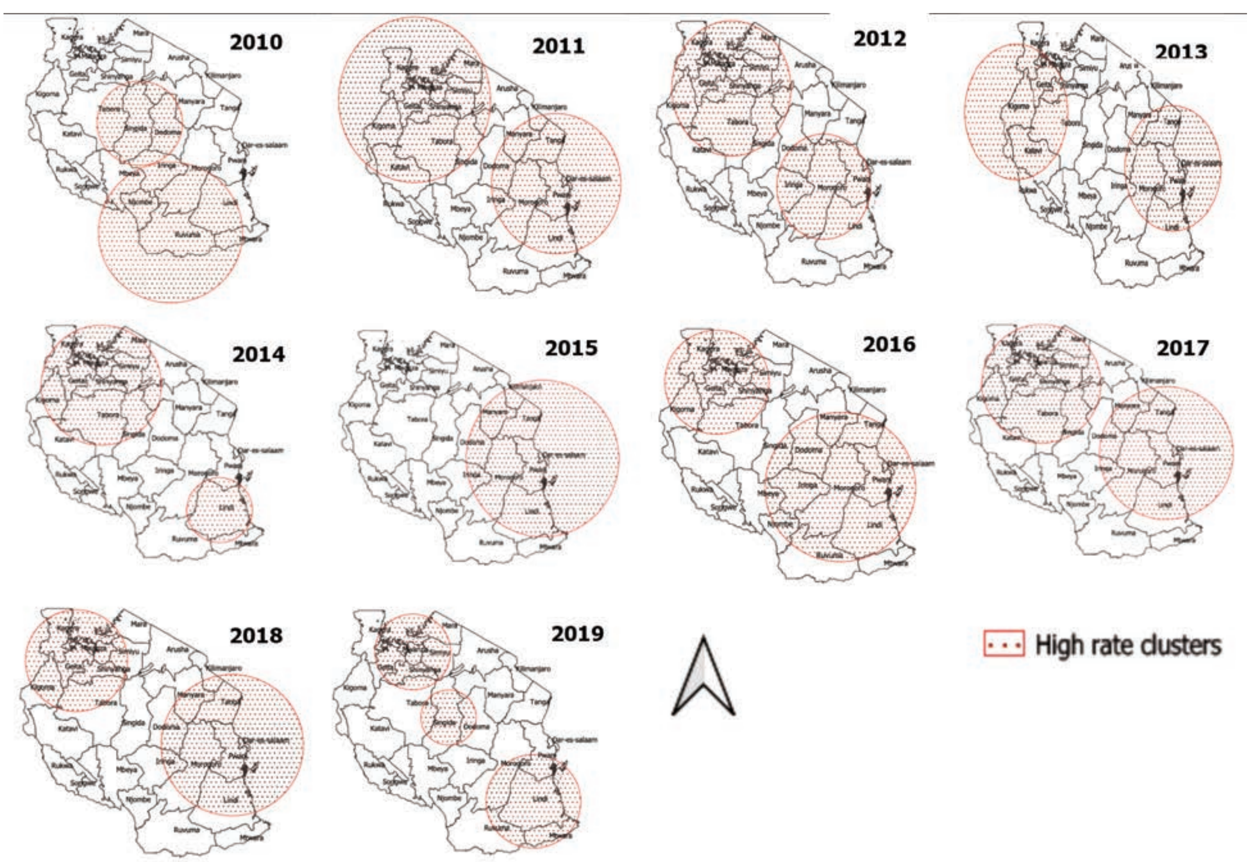

Figure 4. Location of the spatio-temporal high-risk CVD-incidence clusters.

Conclusions

This study revealed a decline in CVD incidence rate from 2015 to 2019. The high-risk CVD-incidence clusters were significant for the years 2012 to 2016 and located in Tanzania's Coastal and Lake zones. Furthermore, it was observed that sex, age, blood pressure level and lifestyle show various associations with CVD risk. To ensure people's health the Government should invest more in educating people about the risk factors associated with CVD since awareness of the risk should help individuals to take precautions and reduce disease incidence.

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