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Spatial Analysis of Determinants of Hypertension Incidence in Kota Lama Subdistrict, Kupang, Indonesia

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ABSTRACT

Background: Cardiovascular diseases such as hypertension, heart attack, and stroke are chronic non-communicable diseases influenced by genetic, physiological, environmental, and behavioral factors. Geographic Information Systems (GIS) can be utilized for spatial analysis to identify risk factors, distribution patterns, and determinants of diseases, including hypertension. This study aims to examine the determinants of hypertension using a spatial analysis approach in Kota Lama Subdistrict, Kupang City.
Subjects and Method: This study employed an ecological study design using an observational analytic method with a cross-sectional approach. The population consisted of residents aged ≥18 years in Kota Lama Subdistrict. A total of 400 individuals diagnosed with hypertension were selected using simple random sampling. The variables examined were age, overweight, lack of physical activity, high-salt diet, alcohol consumption, medication adherence, economic level, and distance to health facilities. Instruments used included a sphygmomanometer, microtoise, weight scale, and questionnaire. Spatial analysis was conducted using the GeoDa application with Regression, Bivariate Local Moran's Index, Multivariate Local Geary, and Spatial Empirical Bayes tests.
Results: The results showed significant associations and clustered spatial autocorrelation with low-to-high relative risk (RR) observed in the subdistricts of LLBK, Bonipoi, Solor, Fatubesi, Oeba, Nefonaek, and Pasir Panjang for the variables: age (p=0.001, I=0.70), overweight (p<0.001, I=0.64), lack of physical activity (p=0.00, I=0.63), high-salt diet (p=0.00, I=0.63), and alcohol consumption (p<0.001, I=0.69). There were no significant associations for variables such as irregular medication intake, economic level, and distance to health facilities, with p-values of 1.000 > α (0.050).
Conclusion: Age, overweight, physical inactivity, high-salt diet, and alcohol consumption are significant determinants and show positive clustered spatial autocorrelation with hypertension. It is recommended that individuals over 40 years of age regularly monitor their blood pressure, maintain a healthy diet, engage in sufficient physical activity, and for those with hypertension, adhere to regular medication intake.

Keywords: Hypertension, determinants, spatial analysis, autocorrelation, cluster, Kota Lama

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BACKGROUND

Non-Communicable Diseases (NCDs) have become a strategic issue within the 2030 Sustainable Development Goals (SDGs) agenda. Cardiovascular diseases (such as hypertension, heart attacks, and stroke), cancer, chronic respiratory diseases, and diabetes are the major types of NCDs. One of the global targets for NCDs is to reduce the prevalence of hypertension by 33% between 2010 and 2030 (Kemenkes RI, 2019). Globally, 1.28 billion adults aged 30 to 79 years suffer from hypertension. Hypertension ranks 7th among the top 10 causes of death in upper-middle-income countries. According to the World Health Organization (WHO), factors that increase the risk of hypertension or high blood pressure include older age, genetic predisposition, being overweight or obese, physical inactivity, a high-salt diet, and excessive alcohol consumption (WHO, 2023).

The prevalence of hypertension in Indonesia has shown an upward trend, reaching 34.1% according to the 2018 Basic Health Research (Riskesdas), based on a total population of around 260 million people. This increase is associated with unhealthy lifestyles, such as lack of physical activity, smoking habits, and low consumption of fruits and vegetables. The proportion of the population with insufficient physical activity rose from 26.1% to 33.5%, while excessive alcohol consumption was recorded at 0.8%. The trend of obesity also showed a significant rise between 2007 and 2018, with the prevalence of overweight increasing from 8.6% to 13.6%, and obesity from 10.5% to 21.8% (Ministry of Health, Republic of Indonesia, 2019).

The prevalence of hypertension based on measurements in individuals aged ≥18 years in Indonesia is 34.11%, while in East Nusa Tenggara (NTT) it is 27.72%. In Kupang City, the number of hypertension cases in 2018 reached 28,701, followed by 6,935 cases in 2019, with the highest number recorded in Kota Lama Subdistrict, totaling 2,272 cases (Kupang, 2023). Geographic Information Systems (GIS) can be used for spatial analysis, which is valuable for identifying relationships between disease risk factors, patterns of disease spread, and disease autocorrelation—both for communicable and non-communicable diseases (Maziyya, 2023). Based on this background, the objective of this study is to determine the determinants of hypertension using a spatial analysis approach in Kota Lama Subdistrict, Kupang City.

SUBJECTS AND METHOD

1. Study Design

This was a cross-sectional study to examine the relationship between exposure and disease is examined at the same point in time within the population (Murti, 2013). The study was conducted at Pasir Panjang Public Health Center (Puskesmas) and Kupang Kota Health Center, both located in the Kota Lama Subdistrict. The study period was from February to March 2025.

2. Population and Sample

The population consisted of residents aged ≥18 years in Kota Lama Subdistrict, Kupang City. The sample size was 400 respondents selected using a Simple Random Sampling method. The subjects were male and female hypertension patients aged ≥18 years, residing in one of the 10 urban villages within Kota Lama Subdistrict. Inclusion criteria were those who visited the health center, integrated health post, and were either diagnosed with hypertension (≥190/140 mmHg) by a doctor or had a history of taking antihypertensive medication. The proportion of respondents from each urban village was determined using Proportionate Stratified Random Sampling.

3. Study Variables

The dependent Variable was Hypertension. The independent Variables were Age, Overweight, Physical Inactivity, High-Salt Diet, Alcohol Consumption, Irregular Medication Use, Economic Level, and Distance to Health Facilities.

4. Operational Definition of Variables

Hypertension: Measured blood pressure in adults aged ≥18 years, diagnosed with hypertension by a doctor/nurse or with a history of taking antihypertensive medication.

Age: Age determined based on date and year of birth.

Overweight: Nutritional status based on Body Mass Index (BMI) = Weight (kg) / Height (m^2), with a value ≥25.

Physical Inactivity: Lack of body movement or exercise activities (e.g., walking, running, aerobics) that expend energy and calories.

High-Salt Diet: Foods consumed by respondents that contain high levels of sodium or salt.

Alcohol Consumption: Respondents' habits of consuming alcoholic beverages.

Medication Behavior: Patients' adherence to taking antihypertensive medication.

Economic Level: Individual or household income per month.

Distance to Health Facility: Distance from the respondent's residence to the healthcare facility where blood pressure is monitored.

5. Study Instrument

Research instruments used included a sphygmomanometer (to measure blood pressure), weighing scale (to measure weight), microtoise (to measure height), and questionnaires and Excel-based forms for collecting data on other variables.

6. Data Analysis

Spatial analysis was conducted using Geographic Information System (GIS) software, specifically GeoDa, to generate visualizations, modeling, and autocorrelation of hypertension determinants. Analytical methods included Multiple Linear Regression to test significance, Local Moran's Index to assess spatial autocorrelation, Spatial Empirical Bayes to determine relative risk (RR), and Multivariate Local Geary for multivariate analysis.

7. Research Ethics

This study ensured the confidentiality of respondent data through prior informed consent. The research received ethical clearance from the Health Research Ethics Committee of the Faculty of Medicine and Veterinary Medicine, University of Nusa Cendana (Undana), with Decision Letter No. 04/UN15.21/KEPK-FKKH/2025 dated February 26, 2025, and Ethical Approval Recommendation No.04.1/UN15.21/KEPK-FKKH/2025 with Registration Number UN02250203 dated February 27, 2025.

RESULTS

1. Distribution of Hypertension Cases in Kota Lama Subdistrict

Figure 1 shows the quantile map of the number of hypertension cases in Kota Lama Subdistrict. It indicates that three urban villages (Kelurahan)—Air Mata, LLBK, and Bonipoi—had 23 to 45 cases. Four urban villages—Solor, Merdeka, Tode Kisar, and Fatubesi—had between 59 and 218 cases. Meanwhile, three urban villages—Oeba, Nefonaek, and Pasir Panjang—had between 241 and 450 cases of hypertension.

Figure 2 presents the percentile map of hypertension prevalence in Kota Lama Subdistrict. One urban village, LLBK, had a prevalence between 1% and 10%. Four urban villages—Air Mata, Bonipoi, Merdeka, and Tode Kisar—had a prevalence ranging from >10% to 50%. Another four—Solor, Fatubesi, Oeba, and Nefonaek—had a prevalence of >50% to 90%. The highest prevalence,

between >90% and 99%, was found in Pasir Panjang.

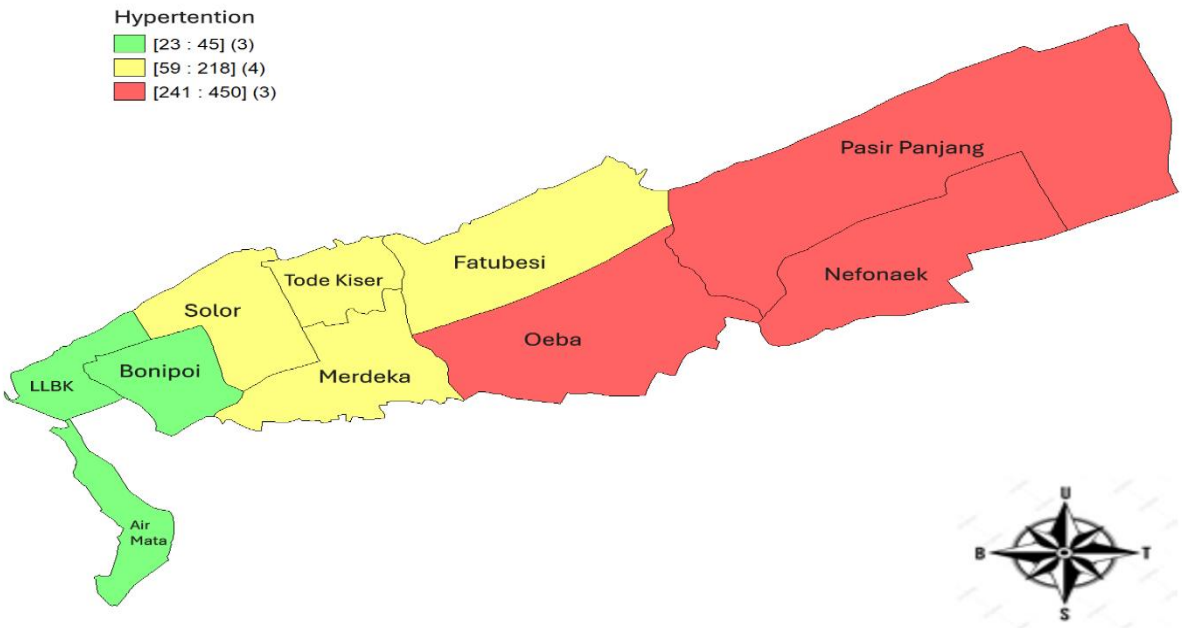


Figure 1. Quantile Map of Hypertension Case Distribution in Kota Lama Subdistrict

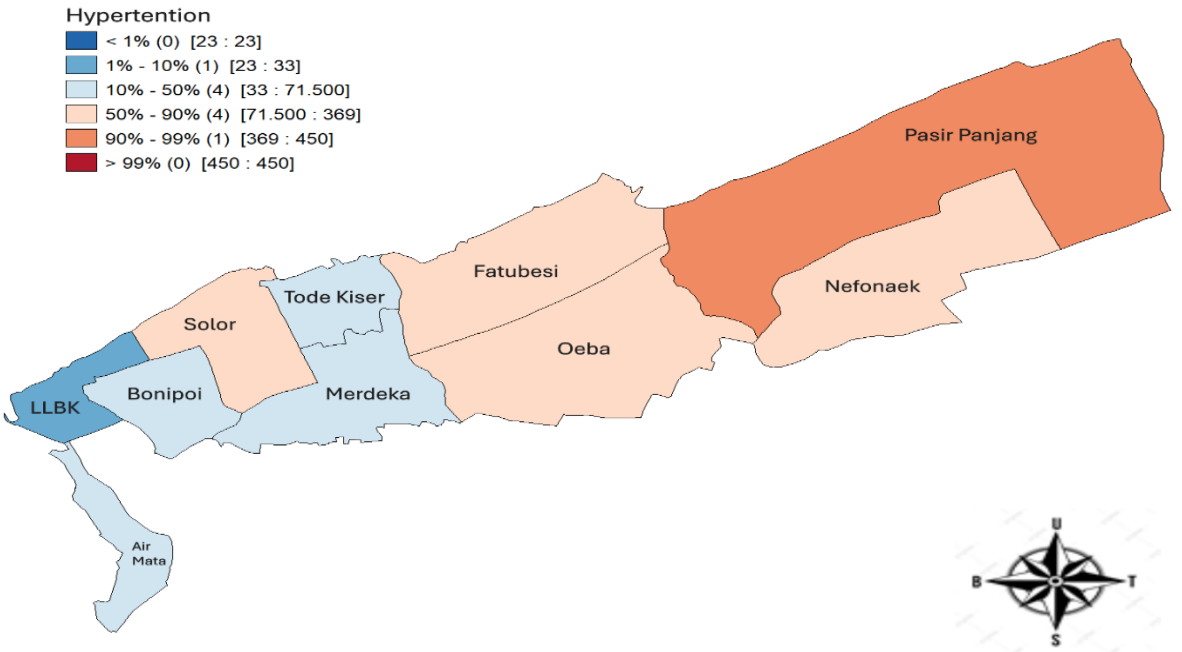


Figure 2. Percentile Map of Hypertension Distribution in Kota Lama Subdistrict

The characteristics of the study participants are presented in Table 1. This includes demographic and behavioral factors such as age group, body weight based on Body Mass Index (BMI), physical activity levels, high salt diet, and alcohol consumption. These

variables were selected due to their known associations with non-communicable disease risks, particularly hypertension. The distribution of participants across each category is shown in terms of both frequency and percentage

Table 1. Characteristic sample of the study in Kota Lama Subdistrict

Characteristics	Category	Frequency (n)	Percentage (%)
Age	Adult (18 – 59)	85	21.3
	Ederly >59	315	78.8
Weight	Normal (BMI <25)	37	93.3
	Overweight (BMI≥ 25)	363	90.8
Physical Activity	Routines	30	7.5
	Lack	370	92.5
High Salt Diet	No	32	8.0
	Yes	368	92.0
Consumption of alcohol	No	132	33.0
	Yes	268	76.0

2. Linear Regression Analysis

A multiple linear regression analysis using the spatial lag model revealed that the following variables had a statistically significant association with hypertension cases in Kota Lama Subdistrict (p-value < 0.050): adult age (18–59 years), elderly age (≥ 60 years), overweight (BMI > normal), physical inactivity, high-salt diet, and alcohol consumption (Table 2). These significant variables were subsequently analyzed using Bivariate Local Moran's I to assess spatial autocorrelation.

Meanwhile, the spatial error model analysis showed that the following variables had no significant association with hypertension (p>0.050): irregular medication adherence, high economic status, low economic status, short distance to health facilities, and long distance to health facilities. Therefore, these five variables were not further analyzed using Bivariate Local Moran's I.

Table 2. Results of Multiple Linear Regression Analysis

Idependent variables	b	SE	*p*
Adults (18–59 years)	0.41	0.10	0.001
Elderly (≥ 60 years)	0.17	0.01	0.011
Overweight (BMI > normal)	-2.33	0.46	0.001
Physical Inactivity	2.40	0.31	0.001
High-Salt Diet	0.45	0.13	0.001
Alcohol Consumption	0.72	0.14	0.001
Irregular Medication Intake	-2.00	8.47	1.000
High Economic Status	-4.50	1.74	1.000
Low Economic Status	-9.01	1.74	1.000
Short Distance to Facility	4.50	1.74	1.000
Long Distance to Facility	9.01	1.74	1.000

3. Local Moran's Index test

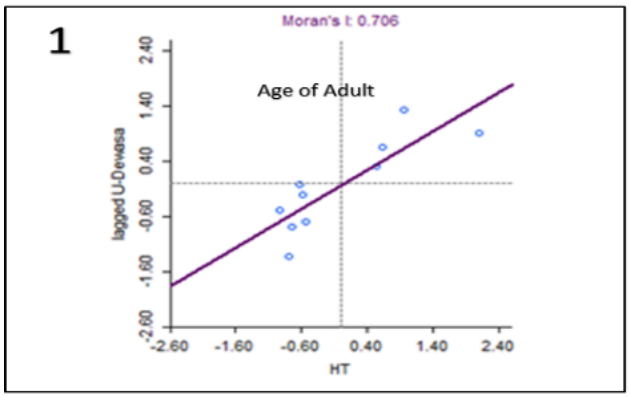
Local Moran's Index test used to determine autocorrelation based on Moran's I values, BiLISA Significant Map, and BiLISA Cluster Map. If Moran's value I = 1 means that there is a positive autocorrelation with a regular pattern, if Moran's value I = 0 means that there is no autocorrelation, if Moran's value I= -1 means that there is a negative autocorrelation with the pattern tends to spread (Sofia et al., 2023).

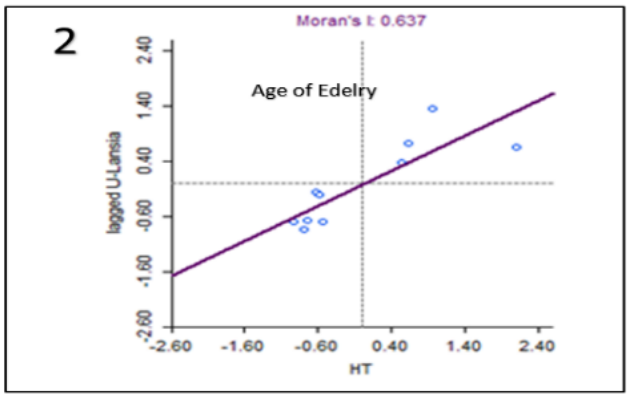
Significant levels will be displayed on the significance map, showing the p-value (0.050 to 0.010) and the magnitude of the significant level for each region. Clusters will be shown with a cluster map to show the observation values categorized into four clusters, namely, High-High (HH), Low-Low (LL) cluster, Low-High (LH) cluster, and High-Low (HL) cluster to show the observed value in a location with the area it surrounds. Furthermore, variables that have a positive autocorrelation are tested using Spatial Empirical Bayes to determine the Relative Risk (RR) and determine the level of risk of each area, consisting of high risk, medium risk, and low risk.

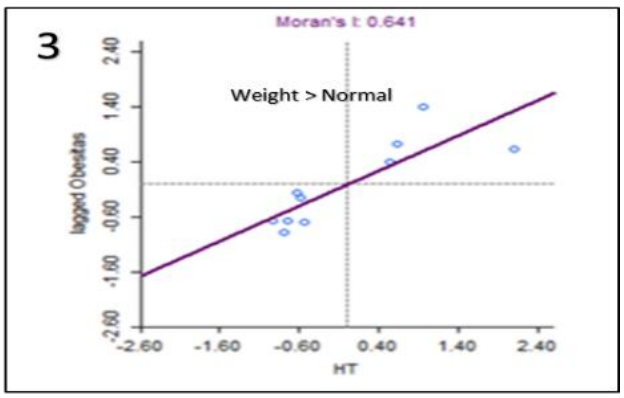
Based on the results of Moran's autocorrelation analysis I (Table 2), it was found that there was a spatial autocorrelation in the variables of adult age, elderly age, BB >Normal, lack of exercise, diet high in salt and alcohol consumption as evidenced by a p-value of 0.050 and a positive autocorrelation as shown by Moran's value I > E[1] (-0.11). The results of Moran's I scatter plot analysis in Figure 3 also show that the pattern of prevalence of hypertension is clustered (clustered).

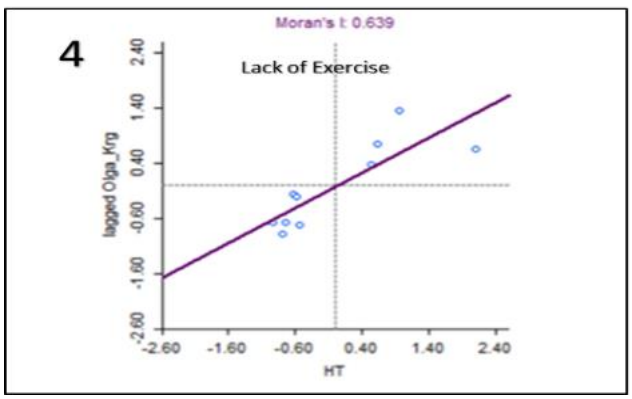
Table 1. Results of Moran's I Spatial Autocorrelation Analysis

Variabel	Moran's I (I)	E[I]	Mean	Z
Age of Adult (18 – 59 Thn)	0.71	-0.11	-0.10	3.79
Age of Ederly (> 60 Tahun)	0.64	-0.11	-0.11	3.64
Weight >Normal	0.64	-0.11	-0.11	3.68
Lack of Physical Activity	0.64	-0.11	-0.11	3.65
High Salt Diet	0.64	-0.11	-0.11	3.65
Consumtion of Alcohol	0.69	-0.11	-0.11	3.82









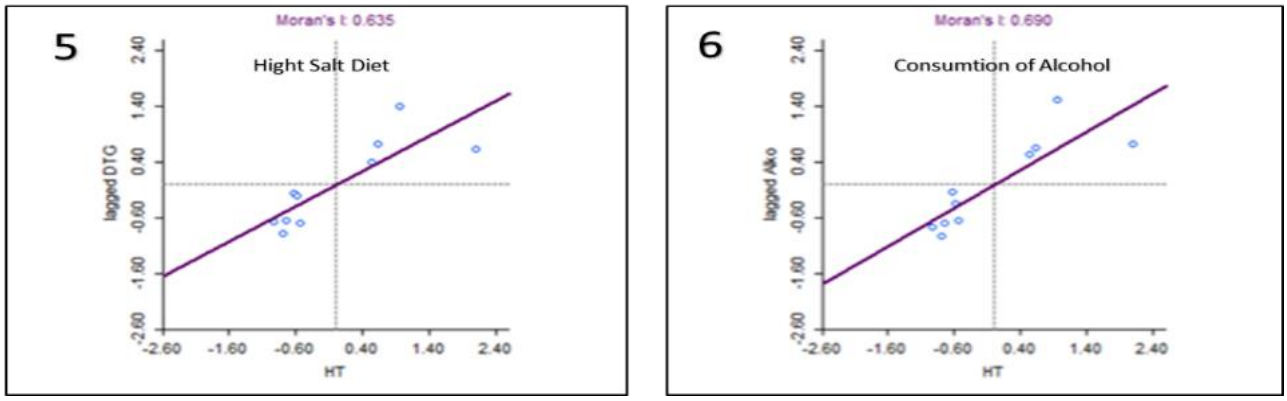


Figure 1. Moran's I, Scatterplot

Areas in the high-high cluster (hotspot area) of red shade mean that this area has a high observation value surrounded by areas with a high observation value, while the low-low cluster (cold spot) of blue shade means that areas with low observation values are surrounded by areas with low observation values. The observation values were dependent variables (hypertension) and independent variables (hypertension determinants). The p= 0.050 and p=0.010 of each region are shown with a significant map (shades of green and light green on the map) while the relative risk (RR) which shows the level of risk into high, medium risk, and low risk is shown by spatial analysis of empirical bayes maps (shades of red, yellow, and green on the map). The description of the results of the bivariate local Moran's index analysis, showing cluster maps, significant maps, and empirical bayes maps, is shown in Table 4 and Figure 4.

Table 2. Results of Moran's I and Spatial Empirical Bayes Bivariate Analysis

Variable	Cluster Type	Villages Involved	Moran's I p-value	SEB p-value	RR (CI)	Risk Level
Adult	High-high	Oeba, Pasir Panjang	0.010	0.05	<0.001 to 0.005	Medium
	Low-low	Solor	0.050	–	0.007 to 0.307	High
Elderly	High-high	Oeba, Nefonaek, Pasir Panjang	0.050	0.01	<0.001 to 0.012	Medium
	Low-low	LLBK, Bonipoi, Solor	0.050	–	0.087 to 0.111	High
Overweight (BMI > Normal)	High-high	Oeba, Nefonaek, Pasir Panjang	0.050	0.01	<0.001 to 0.004	Medium
	Low-low	LLBK, Bonipoi, Solor	0.050	–	0.014 to 0.107	High
Physical Inactivity	High-high	Oeba, Nefonaek, Pasir Panjang	0.050	0.01	<0.001 to 0.004	Medium
	Low-low	LLBK, Bonipoi, Solor	0.050	–	0.013 to 0.107	High
High-Salt Diet	High-high	Nefonaek, Oeba, Pasir Panjang	0.050	0.01	<0.001 to 0.004	Medium
	Low-low	LLBK, Solor	0.050	–	0.011 to 0.112	High
Alcohol Consumption	High-high	Fatubesi, Nefonaek, Oeba, Pasir Panjang	0.050 –	0.01 0.01	-0.079 to 0.000 0.001 to 0.021	Low Medium
	Low-low	Solor	0.050	–	0.001 to 0.021	Medium
		LLBK, Bonipoi	0.010	0.05	0.087 to 0.151	High

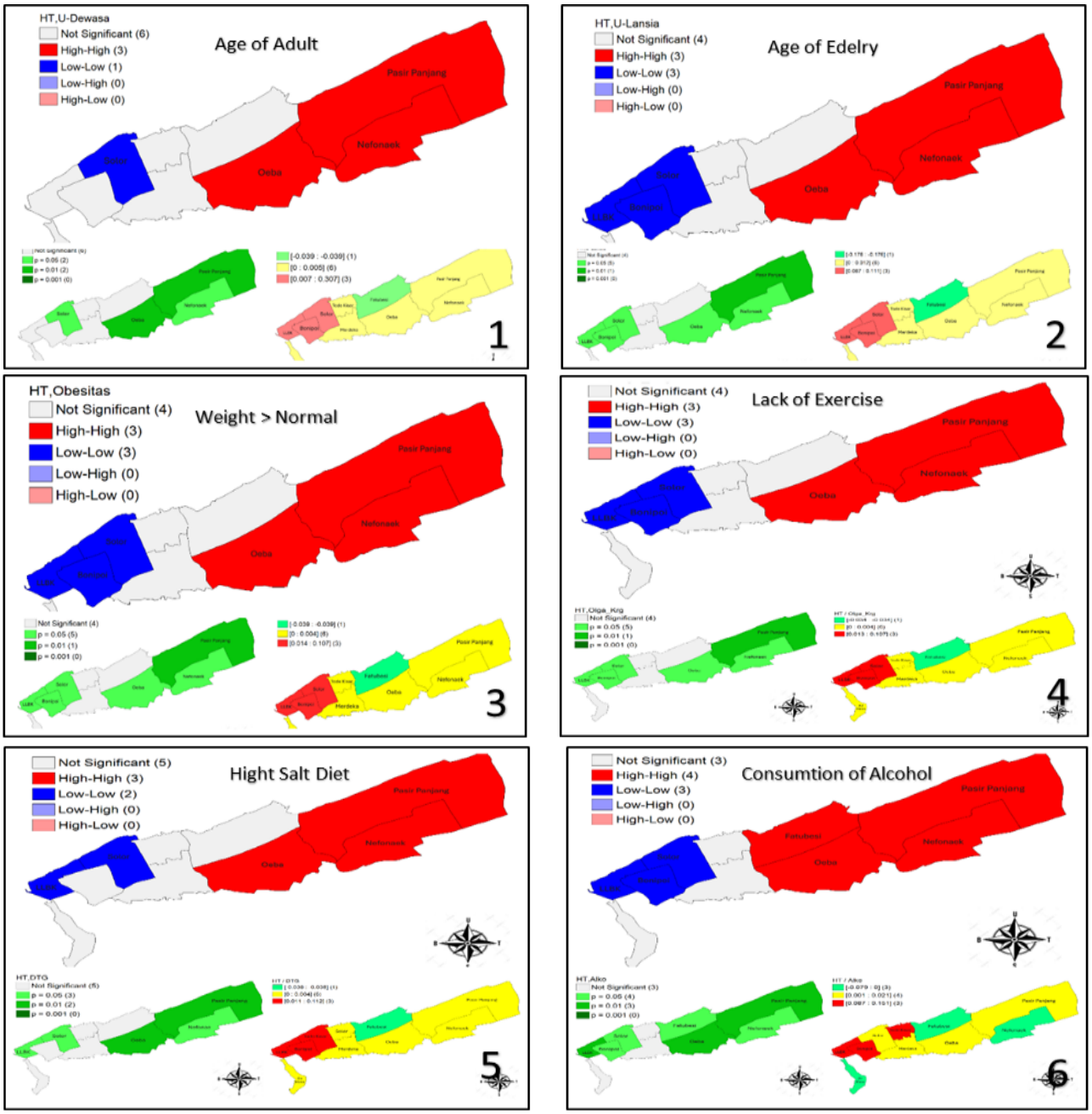


Figure 2. Cluster, Significant, and Spatial Empirical Bayes Map

4. Multivariate Spatial Analysis

Multivariate spatial analysis on the variables of Hypertension, Age, Weight, Physical Activity, Salt Diet, and Alcohol Consumption using the multivariate local geary test showed a positive spatial autocorrelation with p= 0.050 and p=0.010 in four villages (LLBK, Bonipoi, Solor, Pasir Panjang). Shown in Figure 5.

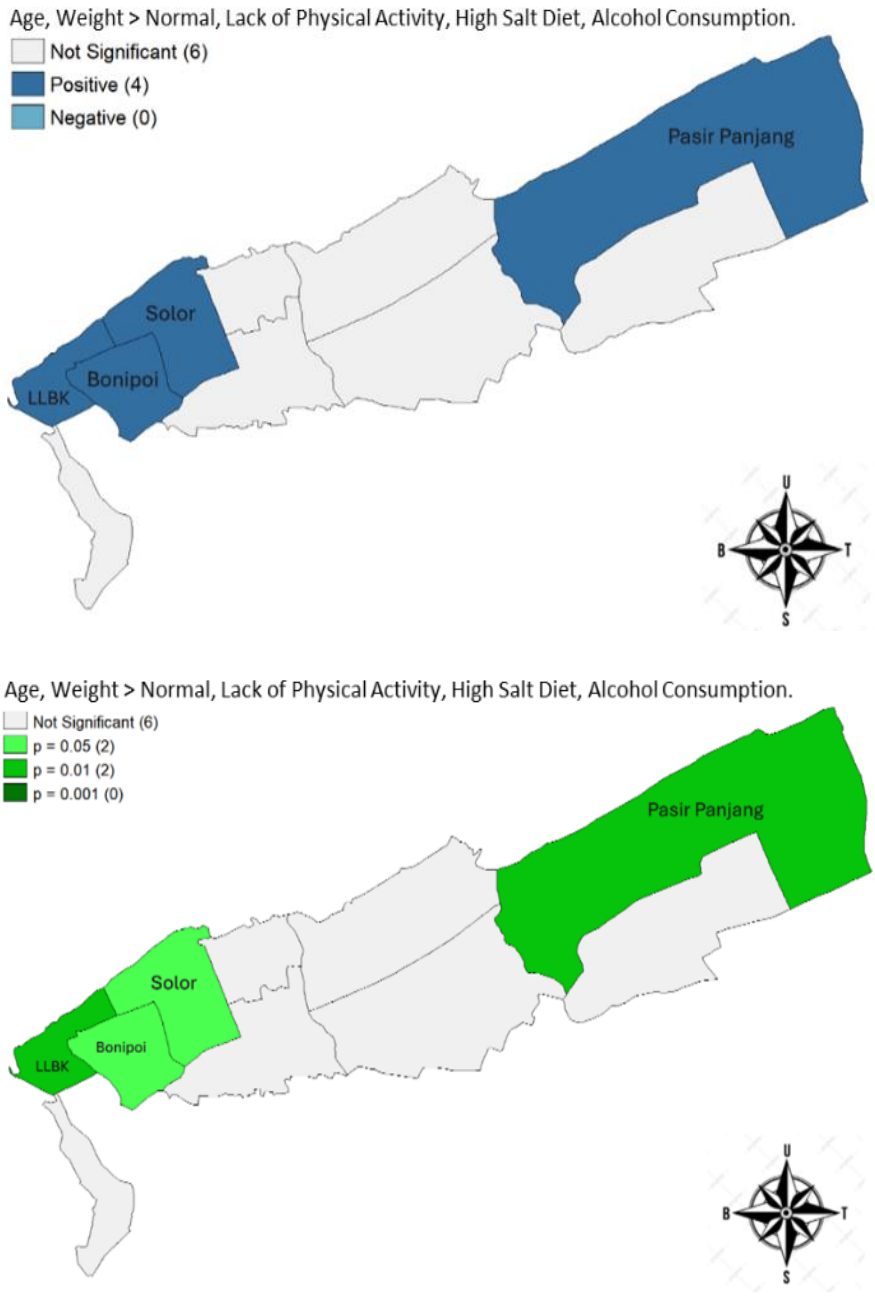


Figure 3. Multivariate Local Geary Map

DISCUSSION

The results of the multiple linear regression test in Table 3 showed significant p-values for adult age (p=0.001), elderly age (p=0.010), overweight (p=0.001), physical inactivity (p= 0.001), high-sodium diet (p = 0.001), and alcohol consumption (p= 0.001), all of which were below the alpha level (α = 0.050). Meanwhile, the bivariate Moran's I test results in Table 2 demonstrated strong spatial autocorrelation for the variables of age (adult= 0.71; elderly = 0.64), overweight = 0.64, physical inactivity= 0.64, high-sodium diet= 0.64, and alcohol consumption= 0.69; all Moran's I values exceeded the expected value E[I]= −0.11. These results indicate significant and positive spatial auto-

correlation with hypertension incidence, forming clustered patterns.

Increasing age is closely linked to hypertension, primarily due to physiological changes in the heart, vascular system, and hormonal balance. These changes are often exacerbated by other factors such as excessive body weight, unhealthy dietary patterns (high in cholesterol and sodium), alcohol consumption, and sedentary lifestyles. According to Pradono et al. (2020), such behavioral and physiological factors contribute significantly to the risk of hypertension. A study by Kusuma et al. (2024) also reported a significant spatial association between individuals aged >46 years and hypertension in the Burengan and Singonegaran sub-districts under the jurisdiction of Pesantren II Public Health Center, Kediri. However, that study found no significant relationship or spatial autocorrelation between BMI >25, physical activity, or salty food consumption with hypertension in the same region.

Hypertension is a chronic condition characterized by systolic blood pressure ≥140 mmHg and/or diastolic pressure ≥90 mmHg (Ministry of Health, 2021). It primarily affects individuals over the age of 40, as arterial aging results in lumen narrowing and arterial wall hardening, commonly referred to as atherosclerosis. According to Saragih and Karimah (2023), unhealthy lifestyle behaviors such as frequent consumption of fast food, insufficient physical activity, and poor sleep quality may trigger sympathetic nervous system activity and lead to physical and psychological stressors, thereby contributing to hypertension in younger adults. Singh et al. (2025) outlined that arterial stiffness, elastin degradation, collagen deposition, inflammatory mediators, and reduced left ventricular function are key pathophysiological factors contributing to hypertension with age. Similarly, Mohi et al. (2023) found a significant correlation (p= 0.001) between elderly age and hypertension.

Poor behavioral habits such as consuming high-fat foods (leading to obesity), excessive sodium intake, and alcohol consumption also contribute to hypertension. Obesity causes dysfunctions in the heart, kidneys, and vascular system, and is associated with hyperinsulinemia and abnormal lipid profiles, resulting in elevated blood pressure. Lukito et al. (2016) stated that both genetic and environmental factors contribute to obesity, which leads to insulin resistance, increased vasoconstriction, cardiac output, and blood pressure, ultimately raising cardiovascular risks. This is consistent with Hafni and Faridi (2024), who found a significant relationship (p= 0.001) between being overweight and hypertension.

Excessive sodium consumption (>5 grams/day, WHO standard) has been proven to significantly increase blood pressure and is closely associated with hypertension and cardiovascular complications. High sodium intake can trigger fluid retention, leading to increased arterial flow and pressure. It can also cause endothelial inflammation, anatomical remodeling, and functional impairments (Grillo et al., 2019). Mantuges et al. (2021) reported a significant association (p= 0.033) between high-sodium food intake and blood pressure, where individuals consuming high sodium were 5.70 times more likely to develop hypertension than those with adequate sodium intake.

Alcohol increases blood pressure because ethanol (C_2H_5OH) acts similarly to carbon dioxide by increasing blood acidity and cortisol levels, which in turn activates the renin–angiotensin–aldosterone system (RAAS), leading to elevated blood pressure. A case-control study by Nubatonis et al. (2024) found a significant association (p= 0.001) between alcohol consumption and

hypertension, with (OR= 3.80; 95% CI= 1.73 to 8.36), indicating that alcohol consumers are 3.8 times more likely to experience hypertension compared to non-drinkers.

Regular physical activity (30–45 minutes/day) is an important preventive measure against high blood pressure. It improves cardiovascular endurance and reduces vascular tension. The effectiveness of physical activity in lowering blood pressure depends on four factors: Frequency, Intensity, Time, and Type (FITT principle). A study by Qorina et al. (2023) at Tamansari Public Health Center in West Jakarta found a significant association (p= 0.003) between low physical activity and high blood pressure through a case-control observational analytic design.

Spatial analysis showed High–High clusters (hotspots) with low-to-moderate relative risk (RR) for these variables located in the sub-districts of Fatubesi, Oeba, Nefonaek, and Pasir Panjang. Conversely, Low–Low clusters (coldspots) with moderate-to-high RR were found in the sub-districts of LLBK, Bonipoi, and Solor. Multivariate analysis revealed a significant positive spatial autocorrelation (p=0.050) in LLBK, Bonipoi, Solor, and Pasir Panjang.

Hotspot areas are characterized by neighboring sub-districts that also show high hypertension incidence and similar elevated risk factor profiles. This may be attributed to effective case-finding and screening efforts, as well as lifestyle patterns such as frequent consumption of high-cholesterol, high-sodium foods, and alcohol (WHO, 2023). These regions are also located in coastal areas, which facilitates access to such foods (Isbandiyah et al., 2024). Therefore, strengthening hypertension control, treatment, and rehabilitation is crucial, requiring additional healthcare personnel, adequate diagnostic and pharmaceutical resources, and sustained screening efforts.

Coldspot areas are surrounded by sub-districts with similarly low hypertension incidence and low observed risk factors, which may reflect limited screening and case detection. Enhanced health promotion, regular blood pressure monitoring, and improved healthcare services are necessary in these areas, alongside continued medical treatment and rehabilitation efforts for existing patients.

Public health recommendations include routine health check-ups with regular blood pressure monitoring, adopting a healthy diet, engaging in regular physical activity, avoiding alcohol consumption, and adhering to prescribed medications and therapies, particularly for individuals with diagnosed hypertension.

AUTHOR CONTRIBUTION

The concept and research methodology were developed by Dominggus A. I. Lenda, Pius Weraman, and Yendris K. Syamruth. Data collection, analysis, interpretation, and manuscript drafting were conducted by Dominggus A. I. Lenda. The manuscript was reviewed and finalized by Dominggus A. I. Lenda, Pius Weraman, Yendris K. Syamruth, Apris A. Adu, and Anderias Umbu Roga. Final approval of the manuscript was given by Pius Weraman, Yendris K. Syamruth, Apris A. Adu, and Anderias Umbu Roga.

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CONFLICT OF INTEREST

I hereby declare that there is no conflict of of interest where this research is carried out without commercial and financial implications that can be a potential conflict of interest in the future.

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