RCPHN
Research in Community and Public Health Nursing

Original Article

pISSN 2983-0648 · eISSN 2288-4203
Res Community Public Health Nurs 2026;37(1):49-60
https://doi.org/10.12799/rcphn.2025.01340

Spatial Distribution and Determinants of Hypertension Prevalence at The Subdistrict Level: A Small-Area Ecological Cross-Sectional Study

Bongjeong Kim

Associate professor, Cheongju university, Cheongju, Korea

Purpose: This study aimed to analyze the spatial distribution of hypertension prevalence and identify the demographic, behavioral, and community environmental factors associated with regional variation across 153 eup-myeon-dong administrative units in Chungcheongbuk-do, South Korea.
Methods: Secondary data analysis was performed using Community Health Survey data from 62,411 adults aged ≥ 30 years (2017-2021). The prevalence of hypertension was defined as the proportion of individuals diagnosed with hypertension by a physician. Spatial statistical indicators were obtained from the Statistical Geographic Information Service (SGIS). Descriptive statistics, Pearson's correlation, choropleth mapping, global Moran's I, local indicators of spatial association (LISA), and ordinary least-squares (OLS) regression analyses were performed.
Results: The prevalence of hypertension showed statistically significant spatial clustering (global Moran's I=0.442, p<.001), with high-high clusters concentrated in rural eup-myeon areas and low-low clusters in urban dong areas. Despite confirmed clustering, the LM lag and error tests indicated no statistically significant spatial dependence in the regression residuals. The regression analysis showed that the prevalence of hypertension increased in areas with a higher proportion of older adults, greater obesity prevalence, and higher satisfaction with public transportation, whereas stronger trust among neighbors and greater satisfaction with healthcare access were associated with a lower prevalence.
Conclusion: These findings support a shift toward tailored nursing and public health interventions at the sub-district level, prioritizing rural high-risk areas and reflecting the distinct demographic, behavioral, and environmental contexts of each community.

Keywords: Hypertension; Spatial analysis; Rural population; Healthcare disparities

Introduction

Hypertension is one of the most significant cardiovascular risk factors worldwide and is a major cause of premature death because it contributes significantly to the development of coronary arteries and ischemic and hemorrhagic cerebrovascular diseases [1]. According to the World Health Organization and Global Burden of Diseases, Injuries, and Risk Factors Study 2021, hypertension is one of the most fatal risk factors and accounts for more than half of all cardiovascular diseases [1,2].

Although hypertension is a major global public health concern, its burden is unevenly distributed and varies substantially across populations and geographic areas [1,2]. Despite overall improvements in prevention and management, the prevalence of hypertension among adults nationwide remains high, and marked regional disparities persist across Korea [3]. According to the 2024 Community Health Survey (CHS), the prevalence of physician-diagnosed hypertension among adults aged ≥ 30 years increased from 19.3% in 2015 to 21.1% in 2024, whereas the gap between the si-gun-gu regions widened to 14.0 percentage

Received: October 17, 2025; **Revised:** January 7, 2026; **Accepted:** January 13, 2026
Corresponding author: Bongjeong Kim
Department of Nursing, Cheongju University, 298 Daesung-ro, Cheongwon-gu, Cheongju-si, Chungbuk 28503, Korea
Tel: +82-43-229-7983, Fax: +82-43-229-8969, E-mail: bjkim7853@cju.ac.kr

© 2026 Korean Academy of Community Health Nursing
This is an Open Access article distributed under the terms of the Creative Commons Attribution NoDerivs License (https://creativecommons.org/licenses/by-nd/4.0) which allows readers to disseminate and reuse the article, as well as share and reuse the scientific material. It does not permit the creation of derivative works without specific permission.

points. In addition, the prevalence in the eup and myeon areas was 1.4 percentage points higher than that in the dong area [4]. This indicates that the burden of hypertension is unevenly distributed across regional contexts, underscoring the need to reduce regional disparities in hypertension prevalence as a critical public health challenge in Korea.

Hypertension is a representative chronic disease whose risk increases due to modifiable health behaviors such as an unhealthy diet, physical inactivity, smoking, alcohol consumption, and being overweight or obese [5,6]. However, individual-level factors alone are insufficient to explain the observed regional disparities in prevalence. Recent studies have reported that community environmental factors—including access to healthcare services, living infrastructure, transportation conditions, and socioeconomic environment—strongly influence the spatial distribution of hypertension [7-11].

Individuals residing in spatially adjacent areas are exposed to similar social and environmental conditions; consequently, their health outcomes tend to cluster spatially. Disease prevalence reflects not only individual characteristics but also the contextual features of residential environments. Therefore, understanding geographic variation in hypertension prevalence requires spatial analytical approaches that explicitly account for place-based characteristics [12,13].

Previous studies have increasingly employed spatial statistical methods to investigate both the clustering patterns of hypertension prevalence and the contextual factors underlying such spatial disparities. Laohasiriwong et al. [14] identified spatial clusters of hypertension prevalence across 76 provinces and highlighted the role of local environmental and socioeconomic factors in cluster shaping. Similarly, Kauhl et al. [15] performed a spatial analysis and geographically weighted regression (GWR) on > 1,400 regions in northeastern Germany, demonstrating that regional characteristics, such as urban-rural status and levels of deprivation, affect the prevalence. Collectively, these findings indicate that hypertension prevalence is spatially structured and closely linked to area-level contexts, suggesting that analyses at finer geographic scales are necessary to capture localized health inequalities.

In Korea, multiple studies have investigated the spatial variation factors of hypertension using district-level (si-gun-gu) analyses [16-20]. These studies have consistently reported that a combination of sociodemographic characteristics, health behaviors, healthcare accessibility, population density, and community infrastructure contribute to regional differences in hypertension prevalence.

However, most previous studies have used si-gun-gu units as the unit of analysis, which limits their ability to capture heterogeneity among eup-myeon-dong areas and localize high-risk clusters within the same administrative boundary. Since si-gun-gu units encompass subareas that differ substantially in demographic structure, living environment, and access to healthcare resources, analyses at this level may mask intra-regional health inequalities through area-level aggregation. Consequently, significant spatial disparities within these regions may remain obscure. Accordingly, recent studies have emphasized that spatial analyses conducted at smaller administrative levels (eup-myeon-dong) are better suited for identifying localized high-risk clusters of chronic diseases, including hypertension, as they allow researchers to capture intra-regional heterogeneity and contextual factors that are often obscured in analyses based on larger units such as si-gun-gu [11,15,18].

Analyses at the eup-myeon-dong level enable a more precise interpretation of disease distribution by accounting for area-level demographic structure, living environments, and social context, which are often obscured in analyses based on higher administrative units such as si-gun-gu [13,15]. In particular, community environmental factors, including access to healthcare services and health infrastructure as well as social capital and trust among neighbors, have been reported to play a critical role in the formation of hypertension clusters [9,15,18,21].

Chungcheongbuk-do is a mixed urban-rural province characterized by marked disparities in population aging and access to healthcare across eup-myeon-dong units. Over the past decade, the prevalence of physician-diagnosed hypertension in this region has remained consistently higher than the national average, and substantial intra-regional variations have been observed [22]. In particular, rural areas are more likely to experience a concentrated burden of hypertension at the small-area level owing to rapid population aging and limited access to healthcare services. These regional characteristics make Chungcheongbuk-do a suitable study area for investigating spatial health inequalities in eup-myeon-dong.

Accordingly, this study aimed to examine the spatial distribution of hypertension prevalence across 153 eup-myeon-dong units in Chungcheongbuk-do and to identify demographic, behavioral, and community environmental factors associated with area-level hypertension prevalence. By focusing on subdistrict-level patterns, this study sought to capture intra-regional health disparities that may be obscured in si-gun-gu-level analyses and to provide evidence for developing tailored hypertension prevention and management strategies that reflect local characteristics.

Methods

Study design

This study employed a small-area ecological cross-sectional design using area-level data aggregated at the eup-myeon-dong administrative units. The analysis focused on the association between area-level hypertension prevalence and community characteristics. To improve the statistical stability of small-area estimates, data from five consecutive years (2017-2021) were pooled.

Study area and data sources

In South Korea, eup, myeon, and dong are submunicipal administrative units comparable to townships and neighborhoods. The unit of analysis consisted of 153 eup-myeon-dong administrative units (18 eup, 84 myeon, and 51 dong) within 14 cities and counties in Chungcheongbuk-do, based on administrative boundaries as of December 2021.

Data were obtained from the Community Health Survey (CHS) through the Chungcheongbuk-do Provincial Government. CHS is conducted annually by the Korea Disease Control and Prevention Agency (KDCA) under Article 4 of the Regional Health Act. Raw CHS data collected between 2017 and 2021 for Chungcheongbuk-do were used with official approval from the provincial government.

A total of 62,411 participants aged ≥ 19 years who participated in the CHS during the study period were included. Although the CHS targets adults aged ≥ 19 years, hypertension prevalence is officially defined and reported for adults aged ≥ 30 years according to the KDCA's standard criteria. Accordingly, hypertension prevalence in this study was calculated based on adults aged ≥ 30 years. To improve the stability of small-area estimates, annual eup-myeon-dong-level prevalence values from 2017 to 2021 were calculated and averaged.

Demographic structural variables, including the proportions of the population aged 15-64 years and ≥ 65 years, were not individual-level measures but area-level indicators reflecting the age composition of each eup-myeon-dong unit. These variables were derived from resident registration statistics. Resident registration data for December 2021 were obtained from the Chungcheongbuk-do provincial government website.

Although the CHS uses a complex sampling design with stratification, clustering, and weighting to ensure representativeness at the si-gun-gu level, pooled multi-year averages were used for eup-myeon-dong-level analysis to improve stability of small-area estimates.

For the spatial analysis, eup-myeon-dong-level shapefiles for 2021 were obtained from the Statistical Geographic Information Service of Statistics Korea. The spatial data were linked to the CHS dataset using unique administrative codes to construct a GIS-based dataset for analysis.

Measurement variables

1. Dependent variable: Hypertension prevalence

Hypertension prevalence was defined as the proportion of adults aged ≥ 30 years who had been diagnosed with hypertension by a physician based on self-reported data [22].

2. Independent variables: Health determinants of hypertension prevalence

The factors influencing hypertension prevalence were categorized according to prior studies on health determinants [23,24] into three domains: (a) demographic characteristics, (b) health behaviors, and (c) community environmental factors, including social and physical environments and the local healthcare system, such as access to medical services, transportation conditions, and community-level social resources. Table 1 presents the definitions and calculation methods for each variable.

Data analysis

All analyses were conducted at the eup-myeon-dong level. Descriptive statistics for the prevalence of hypertension and study variables were calculated using SPSS version 28.0. Pearson's correlation analysis was performed to examine the association between the prevalence of hypertension and related determinants.

To visualize the spatial distribution of hypertension prevalence and identify high-risk areas in Chungcheongbuk-do, a choropleth map was generated using QGIS version 3.34.4.

Spatial autocorrelation was assessed using global Moran's I and local indicators of spatial association (LISA) in GeoDa version 1.6.7 [25]. Moran's I was used to identify global spatial clustering, and LISA was used to detect local clusters.

An ordinary least-squares (OLS) regression model was used to analyze the factors influencing the prevalence of hypertension. Prior to model estimation, spatial dependence was tested using Lagrange multiplier (LM) and robust LM diagnostics. Because no statistically significant spatial dependence was detected in the regression residuals, geographically weighted regression (GWR) was not applied, and OLS regression was used as the final analytical approach.

Table 1. Definition of Variables Related to Hypertension Prevalence

Variables	Definition
Demographics	
Sex ratio	Ratio of the male population to 100 females
Age structure	Percentage of residents in each eup, myeon, and dong based on age group: 15-64 years and ≥ 65 years
Household monthly income (mean)	Average of the monthly household income amounts reported by survey participants, representing the mean across respondents who provided valid responses
Health behaviors	
Current smoking rate (%)	Percentage of current smokers among those who smoked five packs (100 cigarettes) or more in their lifetime
High-risk drinking rate (%)	Among those who drank in the past year, percentage of men who had seven or more drinks (or approximately five cans of beer) and women who drank more than five drinks (or approximately three cans of beer) at one drinking party twice a week
Walking practice rate (%)	Percentage of people who walked at least 30 min a day on ≥ 5 days in the past week
Obesity rate (%)	Percentage of people with a body mass index (kg/m^2) of ≥ 25 (%), age ≥ 19 years
Health literacy rate (%)	Percentage of people who reported having difficulty understanding spoken explanations or written health information (higher values indicate poorer health literacy)
Community environment	
Frequency of contact with neighbors (mean)	The frequency of contact with the most frequently encountered neighbor was measured on a 6-point scale (1 = less than once a month, 2 = once a month, 3 = 2-3 times a month, 4 = once a week, 5 = 2-3 times a week, 6 = >4 times a week), and the mean score was used as the variable
Trust among neighbors (%)	Percentage of people who reported that they can trust and rely on people in their neighborhood
Accessibility to exercise facilities (%)	Percentage of people who reported that they could easily find a place to exercise in their residential area during the past year
Satisfaction with natural environment (%)	Percentage of people who reported they are satisfied with local natural environment (air quality, water quality)
Satisfaction with living environment (%)	Percentage of people who reported they are satisfied with local living environment (electricity, water supply and sewage, waste collection, sports facilities)
Satisfaction with public transportation (%)	Percentage of people who reported they are satisfied with local public transportation
Satisfaction with healthcare accessibility (%)	Percentage of people who reported they are satisfied with local healthcare accessibility
Annual unmet medical need rate (%)	Percentage of people who reported being unable to visit a medical clinic (excluding dental) when needed during the past year

Ethical considerations

This study used de-identified secondary data from the CHS in Chungcheongbuk-do and was exempted from review by the Institutional Review Board of Cheongju University (IRB No.: 1041107-202302-HR-064-01).

Results

Descriptive statistics of the study variables and hypertension prevalence

Descriptive statistics for hypertension prevalence and study variables, including demographic characteristics, health behaviors, and community environmental factors, are presented in Table 2. The mean prevalence of hypertension was 34.77% (standard deviation [SD] = 9.53; range, 11.3-58.4%).

Spatial distribution of hypertension prevalence

A choropleth map was created to visualize the spatial distribution of hypertension prevalence across 153 eup-myeon-dong units in Chungcheongbuk-do. Previous study [26] classified prevalence using quintiles; in this study, quartile grouping was used to improve visual clarity and balance category sizes across regions. The spatial distribution based on quartiles is shown in Figure 1.

The 10 areas with the highest prevalence (41.2-58.4%) were primarily located in rural regions, including Chungju-si, Boeun-gun, Jecheon-si, and Cheongju-si (Sangdang-gu), while the 10 areas with the lowest prevalence (11.3-28.9%) were concentrated in urban areas, including Cheongju-si (Cheongwon-gu, Seowon-gu, and Heungdeok-gu), Chungju-si, and Jincheon-gun. Detailed rankings are listed in Table 3.

Correlations between hypertension prevalence and related determinants

Pearson's correlation analysis revealed that most demographic, behavioral, and community environmental factors were significantly associated with hypertension prevalence (Table 4). Among demographic characteristics, the proportion of adults aged 15-64 years ($r = -.78$, $p < .001$), the proportion of adults

Table 2. Descriptive Statistics of the Study Variables

Variable		Mean	SD	Min	Max
Demographics	Sex ratio	104.62	6.74	92.1	129.9
	Aged 15-64 years (%)	61.87	8.76	45.3	78.0
	Aged ≥ 65 years (%)	30.28	12.79	6.9	52.1
	Household monthly income(/10,000 KRW)	340.56	190.52	150.5	1880.6
Health behaviors	Current smoking rate (%)	35.03	7.58	13.2	50.5
	High-risk drinking rate (%)	18.59	5.84	4.1	35.3
	Walking practice rate (%)	34.02	10.27	11.0	63.3
	Obesity rate (%)	33.18	6.03	20.3	51.3
	Health literacy rate (%)	22.66	9.92	4.25	53.4
Community environment	Frequency of contact with neighbors (mean)	4.05	1.03	2.1	5.6
	Trust among neighbors (%)	64.73	26.35	15.35	97.92
	Accessibility to exercise facilities (%)	68.68	21.76	0.00	100.0
	Satisfaction with natural environment (%)	83.82	10.15	46.19	98.76
	Satisfaction with living environment (%)	83.81	8.80	39.21	100.0
	Satisfaction with public transportation (%)	66.29	16.20	25.05	95.83
	Satisfaction with healthcare accessibility (%)	66.43	18.23	23.61	97.21
	Annual unmet medical need rate (%)	6.73	4.85	0.0	21.5
Dependent variable	Hypertension prevalence (%)	34.77	9.53	11.3	58.4

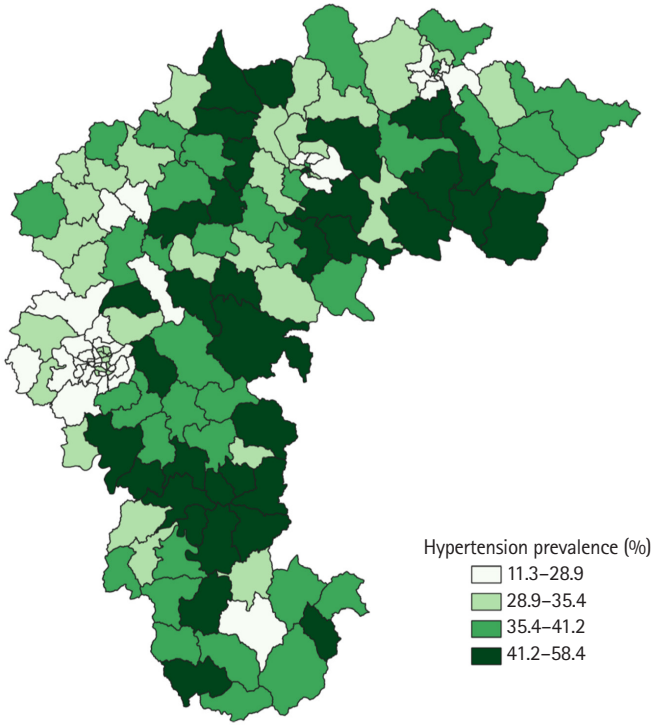

Figure 1. Spatial distribution of crude hypertension prevalence at the eup-myeon-dong level in Chungcheongbuk-do.

aged ≥ 65 years ($r = .82$, $p < .001$), and average monthly household income ($r = -.44$, $p < .001$) were significantly associated with hypertension prevalence.

Among health behaviors, current smoking rate ($r = -.24$, $p < .001$), high-risk drinking rate ($r = -.17$, $p = .032$), walking practice rate ($r = -.16$, $p = .045$), obesity rate ($r = .18$, $p = .075$), and health literacy ($r = .34$, $p < .001$) were associated with hypertension prevalence.

Regarding community environmental factors, frequency of neighbor contact ($r = .73$, $p < .05$), trust among neighbors ($r = .72$, $p < .001$), access to exercise facilities ($r = -.35$, $p < .001$), satisfaction with the natural environment ($r = .24$, $p = .003$), satisfaction with the living environment ($r = -.17$, $p = .039$), satisfaction with public transportation ($r = -.18$, $p = .025$), and satisfaction with medical services ($r = -.36$, $p < .001$) were significantly associated with hypertension prevalence.

Spatial autocorrelation of hypertension prevalence

Global Moran's I analysis revealed statistically significant spatial clustering of hypertension prevalence across eup-myeon-dong units in Chungcheongbuk-do ($I = 0.442$, $p < .001$).

LISA identified high-high (HH) clusters in several rural areas where high-prevalence regions were adjacent to other high-prevalence regions and low-low (LL) clusters in urban areas where low-prevalence regions were surrounded by low-prevalence areas. Because the local clustering patterns confirmed by LISA

Table 3. Spatial Distribution of Hypertension Prevalence Across Subdistricts (Eup, Myeon, and Dong)

Category	Rank	Si/gun/gu	Eup/myeon/dong	Hypertension prevalence (%)
Top 10 highest districts	1	Chungju-si	Noeun-myeon	58.4
	2	Chungju-si	Seongnae·Chungin-dong	56.6
	3	Boeun-gun	Hoenam-myeon	55.3
	4	Chungju-si	Sotae-myeon	51.9
	5	Chungju-si	Judeok-eup	51.7
	6	Jecheon-si	Susan-myeon	50.4
	7	Eumseong-gun	Soi-myeon	49.9
	8	Jecheon-si	Geumseong-myeon	48.5
	9	Boeun-gun	Songnisan-myeon	48.2
	10	Cheongju, Sangdang-gu	Nangseong-myeon	47.2
Top 10 lowest districts	144	Cheongju, Cheongwon-gu	Ogeunjang-dong	17.5
	145	Cheongju, Cheongwon-gu	Ochang-eup	17.2
	146	Cheongju, Seowon-gu	Bunpyeong-dong	17.1
	147	Jincheon-gun	Deoksan-eup	17.0
	148	Cheongju, Heungdeok-gu	Bongmyeong 2·Songjeong-dong	16.6
	149	Cheongju, Seowon-gu	Sannam-dong	14.5
	150	Cheongju, Heungdeok-gu	Gangseo 2-dong	14.1
	151	Cheongju, Sangdang-gu	Yongdam·Myeongam·Sanseong-dong	13.4
	152	Chungju-si	Hoam·Jik-dong	13.3
	153	Cheongju, Heungdeok-gu	Bokdae 1-dong	11.3

Table 4. Correlations Between Hypertension Prevalence and Related Determinants

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	R (*p*)																	
1. SR	1.00																	
2. Age15-64	.12	1.00																
3. Age65+	-.08	-.97**	1.00															
4. HMI	.05	.55**	-.56**	1.00														
5. CSM	.27**	.36**	-.32**	.21**	1.00													
6. HRD	.20*	.34**	-.31**	.24**	.24**	1.00												
7. WPR	-.19*	.10	-.09	-.00	-.00	-.05	1.00											
8. OBR	.28**	.05	-.02	-.03	.25**	.20*	-.30**	1.00										
9. HLR	-.02	-.35**	.36**	-.20*	-.07	-.19*	-.17*	.16*	1.00									
10. FCON	.02	-.87**	.85**	-.47**	-.20*	-.22**	-.09	.08	.32**	1.00								
11. TAN	.04	-.89**	.88**	-.46**	-.22**	-.20*	-.13	.05	.34**	.91**	1.00							
12. AEF	-.22**	.39**	-.42**	.26**	.17*	.11	-.04	-.17*	-.25**	-.36**	-.36**	1.00						
13. SNE	-.36**	-.35**	.32**	-.19*	-.25**	-.15	.01	-.12	.04	.29**	.29**	.04	1.00					
14. SLE	-.30**	.07	-.11	.04	.08	-.13	-.11	-.02	-.07	-.12	-.13	.28**	.34**	1.00				
15. SPT	-.47**	.18*	-.15	.09	.14	-.04	.14	-.18*	-.16*	-.28**	-.26**	.28**	.04	.47**	1.00			
16. SHA	-.47**	.27**	-.26**	.16	.14	-.03	.15	-.23**	-.22**	-.38**	-.35**	.30**	.01	.42**	.83**	1.00		
17. UMN	.05	-.13	.12	-.13	-.04	.02	-.21**	.08	.12	.18*	.11	-.08	.13	-.01	-.05	-.14	1.00	
18. HP	.02	-.78**	.82**	-.44**	-.24**	-.17*	-.16*	.14	.34**	.73**	.72**	-.35**	.24**	-.17*	-.18*	-.36**	.12	1.00

*p <.05, **p <.01; SR = sex ratio, Age 15-64 = aged 15-64 years, Age 65+ = aged ≥65 years, HMI = household monthly income, CSM = current smoking rate, HRD = high-risk drinking rate, WPR = walking practice rate, OBR = obesity rate, HLR = health literacy rate, FCON = frequency of contact with neighbors, TAN = trust among neighbors, AEF = accessibility to exercise facilities, SNE = satisfaction with natural environment, SLE = satisfaction with living environment, SPT = satisfaction with public transportation, SHA = satisfaction with healthcare accessibility, UMN = annual unmet medical needs, HP = hypertension prevalence.

https://doi.org/10.12799/rcphn.2025.01340

were consistent with a previous study [26], detailed LISA results are not presented; they were used as a reference framework for interpreting subsequent analyses of related determinants.

Factors influencing hypertension prevalence: multiple regression analysis

Multiple regression analysis was performed to identify the factors associated with hypertension prevalence across the 153 eup-myeon-dong units. Prior to model estimation, spatial dependence was assessed using LM and robust LM tests. Neither the spatial lag model (LMlag = 2.377, p = .123) nor the spatial error model (LMerror = 1.574, p = .210) was statistically significant, indicating that spatial regression was not required and that OLS regression was appropriate (Table 5).

Variables with high collinearity (e.g., the proportion of the 15-64-year-old population) were excluded, and all remaining predictors demonstrated acceptable variance inflation factor (VIF < 10). The final model showed high explanatory power (adjusted R^2 = .720) and was statistically significant (F = 27.06, p < .001). The Durbin-Watson statistics were 1.585, indicating no significant autocorrelation.

Among the factors, the proportion of adults aged ≥ 65 years (β = .95, p < .001), obesity rate (β = .13, p = .012), trust among neighbors (β = .13, p = .021), and satisfaction with public transportation (β = .14, p = .006) were positively associated with hypertension prevalence. In contrast, satisfaction with healthcare accessibility (β = -.14, p = .001) was negatively associated with hypertension prevalence.

Other factors, such as sex ratio, household income, current smoking, high-risk drinking, walking practice, health literacy, access to exercise facilities, satisfaction with the natural or living environment, and annual unmet medical needs, were not statistically significant (Table 6).

Table 5. Diagnostics for Spatial Dependence

Test	Value	p
Moran's I (error)	0.064	.056
Lagrange multiplier (lag)	2.377	.123
Robust LM (lag)	0.928	.335
Lagrange multiplier (error)	1.574	.210
Robust LM (error)	0.179	.673
Lagrange multiplier (SARMA)	2.503	.286

Discussion

This study was conducted as a follow-up to a previous study that analyzed the spatial distribution of hypertension and diabetes prevalence in Chungcheongbuk-do [26]. Although earlier studies mainly focused on identifying spatial clustering patterns, particularly HH clusters in rural areas and LL clusters in urban areas, this study aimed to explain the underlying causes of observed spatial patterns by examining demographic characteristics, health

Table 6. Multiple Regression Analysis of Factors Associated with Hypertension Prevalence

Variables	B	SE	β	t	p	VIF
Sex ratio	0.04	0.09	0.03	0.50	.619	2.20
AGE65+ (%)	0.67	0.08	0.90	7.99	< .001	7.02
Household monthly income	0.00	0.00	0.03	0.59	.556	1.51
Current smoking rate	-0.03	0.11	-0.02	-0.30	.767	1.66
High-risk drinking rate	0.08	0.08	0.05	0.98	.330	1.31
Walking practice rate	-0.05	0.05	-0.05	-1.02	.311	1.35
Obesity rate	0.23	0.09	0.13	2.56	.012	1.41
Health literacy rate	0.02	0.05	0.02	0.42	.676	1.26
Frequency of contact with neighbors	1.77	1.06	0.19	1.66	.099	7.22
Trust among neighbors	-0.10	0.04	-0.29	-2.33	.021	8.50
Accessibility to exercise facilities (%)	0.02	0.02	0.05	0.97	.336	1.60
Satisfaction of natural environment (%)	0.03	0.05	0.04	0.65	.516	1.69
Satisfaction of living environment (%)	(0.10)	0.06	(0.09)	(1.63)	.105	1.77
Satisfaction of public transportation (%)	0.14	0.05	0.24	2.82	.006	3.91
Satisfaction of healthcare accessibility (%)	-0.14	0.04	-0.27	-3.29	.001	3.78
Annual unmet medical need rate (%)	-0.08	0.09	-0.04	-0.85	.394	1.13
Model fit	R^2 = .753, Adjusted R^2 = .724, Durbin-Watson = 1.620 F = 25.87, p < .001					

behaviors, and community environmental factors at the eup-myeon-dong level. Rather than merely visualizing the distribution of prevalence, it interpreted regional disparities in hypertension prevalence by integrating the spatial context with local-level determinants.

In line with previous findings reported at both the si-gun-gu and eup-myeon-dong levels [18,19,26,27], hypertension prevalence was higher in rural eup and myeon areas and lower in urban dong areas. Clusters of adjacent areas with high prevalence (HH) were concentrated in rural regions such as Jecheon-si, Boeun-gun, and Okcheon-gun, and clusters of areas with low prevalence (LL) were observed in urban areas of Cheongju-si. Although eup-myeon-dong level spatial analyses have rarely been reported in Korea, similar patterns of high-risk clusters in rural regions and low-risk clusters in urban regions have been documented internationally. For example, Kauhl et al. identified HH clusters in rural areas of northeastern Germany characterized by population aging and high levels of deprivation [15]. Studies among Medicaid beneficiaries in South Carolina, the United States [28], and adults in Bangladesh [29] reported similar rural hotspots. These findings indicate that rural areas are more vulnerable to hypertension due to both demographic factors, such as a higher proportion of older adults, and contextual disadvantages, including limited living infrastructure and restricted healthcare access. Accurately identifying high-risk areas and developing tailored nursing and public health interventions at the eup-myeon-dong level are essential to reduce regional health disparities.

Spatial autocorrelation analysis showed a global Moran's I value was 0.442, indicating that hypertension prevalence was spatially clustered across eup-myeon-dong units. This finding is consistent with previous studies conducted at si-gun-gu or broader regional scales, which have reported spatial clustering and spatial dependence in hypertension and other chronic diseases [15,18,19,27,30]. Despite the confirmation of spatial clustering using Moran's I, diagnostic tests for the OLS regression model indicated that spatial dependence was not statistically significant. Although the *p*-value for Moran's I of the residuals was marginal, the results indicate that at the regression model level, hypertension prevalence was more strongly associated with area-specific characteristics than with spillover effects from neighboring regions. Thus, spatial clustering does not necessarily imply statistically significant spatial dependence in regression models, particularly at small-area levels like eup-myeon-dong. This is consistent with prior studies [11,15,19,27,30], showing that the spatial distribution of hypertension is shaped heterogeneously by regional socioeconomic and environmental conditions. Therefore, spatial analysis incorporating complex contextual factors at the local level is warranted. Clustering may be driven less by simple neighborhood effects and more by sociodemographic characteristics (e.g., aging and income), health behaviors, and region-specific environmental attributes [11,15,31].

Analysis of factors associated with hypertension prevalence showed that the proportion of adults aged ≥ 65 years, obesity rate, trust among neighbors, satisfaction with public transportation, and satisfaction with access to healthcare services were significant determinants. These findings are consistent with previous studies that repeatedly identified these variables as major contributors to the distribution of hypertension. In particular, the proportion of older adults was the most influential factor, aligning with earlier studies conducted at both the eup-myeon-dong and si-gun-gu levels, which demonstrated that population aging is a key determinant of the spatial distribution and clustering of hypertension [11,15,16]. Because age-standardized prevalence was not applied, the observed high-risk clusters—particularly in rural areas—may partially reflect differences in age structure. The identified clusters should therefore be interpreted as area-level prevalence patterns shaped by the spatial concentration of older populations, rather than as direct comparisons of individual-level risk. Nevertheless, analyzing crude prevalence at the eup-myeon-dong level provides practical insight into the actual burden faced by administrative units implementing public health programs.

The obesity rate was also identified as a positive predictor of hypertension prevalence, consistent with previous findings demonstrating that increasing community-level obesity is closely associated with higher prevalence [17,18,20,29,32]. Accordingly, in rural areas where obesity rates are high and hypertension hotspots are concentrated, intervention strategies should extend beyond individual-level approaches, such as medication and lifestyle modifications, to include community-based obesity prevention and management programs. Strengthening integrated public health center-led health promotion programs—including promoting physical activity, improving dietary environments, and supporting healthy lifestyle practices—is warranted.

Several independent variables included in this study—particularly the proportion of the population aged 65 years and older, frequency of contact with neighbors, and trust among neighbors—showed relatively high intercorrelations, suggesting the potential presence of multicollinearity among area-level variables. The observed changes in the direction of regression coefficients for neighbor trust and satisfaction with public transportation are therefore more plausibly interpreted as conditionally estimated

results within a regional context shaped by the combined effects of population aging and social environmental characteristics, rather than as independent effects of individual variables. As noted above, the regression findings of this study should be interpreted with caution, considering the potential instability of coefficient estimates due to multicollinearity.

Nevertheless, among the social environmental factors examined, trust among neighbors was negatively associated with hypertension prevalence, consistent with previous studies indicating that higher levels of interpersonal trust and social cohesion are associated with a lower risk of hypertension [21,33]. In this study, the CHS item on "frequency of contact with neighbors" was also analyzed; however, contact frequency itself was not significant; only trust among neighbors demonstrated a statistically meaningful association. These findings suggest that qualitative aspects of social relationships—such as trust and perceived support—may influence health outcomes more than strongly than the quantitative frequency of interactions.

These results are consistent with findings from spatial studies conducted in other settings. For example, a county-level spatial study in the United States [21] reported that regions with higher levels of social cohesion and neighbor trust showed reduced or absent clusters of chronic disease risks, including hypertension, whereas areas with lower trust levels exhibited high-risk hotspots. The association identified in this study also provides empirical support for community participation strategies that have already been incorporated into public health center-led integrated health promotion programs (e.g., health clubs, village health leader training, and self-help groups). In particular, Palafox et al [34], using multinational data from 61,229 individuals across 21 countries, demonstrated that social capital could play a critical role in hypertension management and improving health equity in environments with poor access to healthcare. Therefore, prioritizing interventions that strengthen social capital in rural high-risk clusters may be an effective strategy for hypertension prevention and management, with potential applicability to other chronic conditions.

The association between satisfaction with public transportation and satisfaction with access to medical services and hypertension prevalence aligns with previous spatial studies, indicating that regions with limited access to essential community resources, such as healthcare and transportation, tend to exhibit concentrated clusters of high hypertension prevalence. Community environmental factors related to healthcare accessibility directly contributed to the formation of high-risk hypertension clusters [15,16,18]. In particular, Lee and Lim [18], in their nationwide analysis of city-county-district units, emphasized that inadequate healthcare accessibility increased the likelihood of hypertension hotspots and that improving health resource availability was essential for reducing clustering and promoting health equity. The findings of this study support this perspective, suggesting that public health center-led health promotion programs should prioritize rural high-risk clusters and incorporate improvements in healthcare accessibility and transportation infrastructure into hypertension management strategies. However, the positive association between satisfaction with public transportation and hypertension prevalence is unlikely to indicate a direct causal relationship. Rather, it may reflect the demographic composition and living environments of rural areas—particularly the higher proportion of older adults— as well as limitations inherent in subjective satisfaction measures.

Overall, these findings suggest that regional disparities in hypertension are shaped not only by individual health behaviors but also by complex spatial and social environmental factors such as social trust and access to community resources. By identifying vulnerable areas at the eup-myeon-doing level, this study revealed intra-regional health inequalities that may have been overlooked in analyses conducted at broader spatial scales. The use of spatial autocorrelation indicators, such as global Moran's I and LISA, may also provide valuable tools for monitoring changes in high-risk areas and evaluating the effectiveness of public health interventions over time.

This study had several limitations. First, as an ecological study based on aggregated data at the eup-myeon-doing level, the observed associations should not be interpreted as individual-level causal relationships. The possibility of an ecological fallacy should be considered, because area-level characteristics may not directly reflect individual risk factors. Second, the prevalence of hypertension was assessed using crude rather than age-standardized rates. Age is a major determinant of hypertension prevalence, and given the higher proportion of older adults in rural areas, the spatial clustering and regression results observed in this study may partly reflect regional differences in age structure. Accordingly, high-risk clusters identified in rural areas should be interpreted as prevalence patterns combined with the spatial concentration of older populations. Future studies should apply age-standardized hypertension prevalence or more rigorously control for age effects to clarify regional inequalities in hypertension. Third, this study relied on self-reported survey data, which may have been subject to reporting bias.

Fourth, the analysis did not include objectively measured clinical indicators or a broad range of environmental variables, which

may have limited the scope of the interpretation. Future research should incorporate clinically measured data and expand environmental indicators to address these limitations. Finally, because this study was conducted in a single province (Chungcheongbuk-do), caution is required when generalizing the findings beyond the study area.

Conclusions

This study identified a distinct spatial pattern of hypertension prevalence at the eup-myeon-doing level in Chungcheongbuk-do, with high-risk clusters concentrated in rural areas and low-risk clusters in urban areas. Several area-level factors— including the proportion of adults aged ≥ 65 years, obesity rate, trust among neighbors, and access to public transportation and healthcare services — were significantly associated with hypertension prevalence. These findings indicate that hypertension is shaped not only by individual health behaviors but also by demographic composition and social and environmental contexts at the area level.

Although spatial clustering of hypertension prevalence was clearly identified, spatial dependence at the regression level was relatively low. This suggests that high-risk clusters identified in rural areas were more closely related to local community characteristics, such as population aging, social relationships, and healthcare infrastructure, than to spillover effects from adjacent regions. These results underscore the need to shift hypertension prevention and management strategies toward tailored nursing and public health approaches that reflect community environments rather than relying solely on individual-level interventions.

Despite the lack of age standardization, this study is meaningful because it analyzed the spatial distribution of the hypertension burden at the eup-myeon-dong level. This level corresponds to the actual administrative unit where public health center-led programs are implemented. By identifying high-risk areas at the operational level, our findings provide a practical basis for prioritizing and developing context-specific hypertension management strategies. In addition, spatial autocorrelation indicators may serve as useful tools for evaluating the effectiveness of public health interventions and monitoring changes in high-risk areas over time.

ORCID

Bongjeong Kim, https://orcid.org/0000-0002-8344-164X

Conflict of interest

The authors declared no conflict of interest.

Funding

None.

Authors' contributions

Bongjeoung Kim contributed to conceptualization, formal analysis, methodology, visualization, and writing-original draft, review & editing.

Data availability

Please contact the corresponding author for data availability.

Acknowledgements

The author would like to express sincere appreciation to the Chungcheongbuk-do Provincial Government for their cooperation in providing access to the Community Health Survey data used in this study. I acknowledge the use of ChatGPT (OpenAI, https://chat.openai.com/) for assistance with English translation during the manuscript preparation process. The final English editing was performed by Editage, and no AI-generated content has been presented as my own work.

References

1. World Health Organization. Global report on hypertension: the race against a silent killer. Geneva: World Health Organization; 2023. 276 p.
2. GBD 2021 Risk Factors Collaborators. Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990-2021: A systematic analysis for the Global Burden of Disease Study 2021. The Lancet. 2024;403(10440):2162–2203. https://doi.org/10.1016/S0140-6736(24)00619-4
3. Kim HC, Lee H, Lee HH, Son D, Cho M, Shin S, et al. Korea hypertension fact sheet 2023: Analysis of nationwide population-based data with a particular focus on hypertension in special populations. Clinical Hypertension. 2024;30(1):7. https://doi.org/10.1186/s40885-024-00262-z
4. Korea Disease Control and Prevention Agency. Korea com-

munity health at a glance 2024: Korea community health survey (full version). Research report. Cheongju: Korea Disease Control and Prevention Agency; 2025.
5. Liu F, Pan HW, Li YY, Zhao XJ, Hong XQ, Liu ZY, et al. Trends analysis of the global burden of hypertensive heart disease from 1990 to 2021: A population-based study. BMC Public Health. 2025;25(1):2233. https://doi.org/10.1186/s12889-025-23389-6
6. World Health Organization. Hypertension [Internet]. Geneva: World Health Organization; 2023 [cited 2023 Mar 16]. Available from:https://www.who.int/news-room/fact-sheets/detail/hypertension
7. Faka A, Chalkias C, Magriplis E, Georgousopoulou EN, Tripitsidis A, Pitsavos C, et al. The influence of socio-environmental determinants on hypertension: a spatial analysis in Athens metropolitan area, Greece. Journal of Preventive Medicine and Hygiene. 2020;61(1):E76–E84. https://doi.org/10.15167/2421-4248/jpmh2020.61.1.988
8. Guo J, Zhu YC, Chen YP, Hu Y, Tang XW, Zhang B. The dynamics of hypertension prevalence, awareness, treatment, control and associated factors in Chinese adults: results from CHNS 1991-2011. Journal of Hypertension. 2015;33(8):1688–1696. https://doi.org/10.1097/HJH.0000000000000594
9. Hossain A, Sultana SR, Sujan MJ, Ahsan GU, Hossain MZ, Hossain MA, et al. Coastal residency and its association with diagnosed hypertension based on findings from a cross-sectional study in rural Bangladesh. Scientific Reports. 2025;15(1):10278. https://doi.org/10.1038/s41598-025-94983-2
10. Tabashsum A, Mahdee CM, Ferdous MJ, Khan MAI, Rahman MA. Exploring socio-demographic and geographical variation of adult hypertension in Bangladesh: spatial hotspot analysis [preprint]. medRxiv. 2024;https://doi.org/10.1101/2024.07.02.24309855
11. Wei J, Miao Y, Zhang J, Wu J, Shen Z, Bai J, et al. Spatial heterogeneity of blood pressure control and its influencing factors in elderly patients with essential hypertension: a small-scale spatial analysis. Health & Place. 2025;92:103428. https://doi.org/10.1016/j.healthplace.2025.103428
12. Eberhard MS, Pamuk ER. The importance of place of residence: examining health in rural and nonrural areas. American Journal of Public Health. 2004;94(10):1682–1686. https://doi.org/10.2105/ajph.94.10.1682
13. Macintyre S, Ellaway A. Ecological approaches: rediscovering the role of the physical and social environment. Social Epidemiology. 2000;9:332–348.
14. Laohasiriwong W, Puttanapong N, Singsalasang A. Prevalence of hypertension in Thailand: Hotspot clustering detected by spatial analysis. Geospatial Health. 2018;13(1):608. https://doi.org/10.4081/gh.2018.608
15. Kauhl B, Maier W, Schweikart J, Keste A, Moskwyn M. Exploring the small-scale spatial distribution of hypertension and its association to area deprivation based on health insurance claims in Northeastern Germany. BMC Public Health. 2018;18(1):121. https://doi.org/10.1186/s12889-017-5017-x
16. Kim MJ, Park NH. Analysis of spatial distribution of hypertension prevalence and its related factors based on the model of social determinants of health. Journal of Korean Academy of Community Health Nursing. 2018;29(4):414–428. https://doi.org/10.12799/jkachn.2018.29.4.414
17. Kim YM, Cho DG, Hong SO, Kim EJ, Kang SH. Analysis on geographical variations of the prevalence of hypertension using multi-year data. Journal of the Korean Geographical Society. 2014;49(6):935–948.
18. Lee H, Lim J. Regional factors affecting the prevalence of hypertension using geographic information system. Scientific Reports. 2025;15(1):29087. https://doi.org/10.1038/s41598-025-14981-2
19. Park JH, Kim YE. Spatio-temporal patterns of hypertension prevalence and treatment in Korea using spatial statistical method. Korean Journal of Health Service Management. 2021;15(4):167–179. https://doi.org/10.12811/kshsm.2021.15.4.167
20. Seok HS, Kang SH. A study on the regional variation factor of hypertension prevalence. The Health and Social Welfare Review. 2013;33(3):210–236. https://doi.org/10.15709/hswr.2013.33.3.210
21. Peluso A, Tuccillo J, Sparks K, Kapadia A, Hanson HA. Spatial analysis of social capital and community heterogeneity at the United States county level. Applied Geography. 2024;162:103168. https://doi.org/10.1016/j.apgeog.2023.103168
22. Korea Disease Control and Prevention Agency. Status and issues of chronic diseases 2023: chronic disease fact book. Research report. Cheongju: Korea Disease Control and Prevention Agency; 2023.
23. Lee HE, Kim YG, Jeong JY, Kim DH. Data resource profile: the Korean Community Health Status Indicators (K-CHSI) database. Epidemiology and Health. 2023;45:e2023016. https://doi.org/10.4178/epih.e2023016
24. Schulz AJ, Zenk SN, Odoms-Young A, Hollis-Neely T, Nwankwo R, Lockett M, et al. Healthy eating and exercising to reduce diabetes: exploring the potential of social determi-

nants of health frameworks within the context of community-based participatory diabetes prevention. American Journal of Public Health. 2005;95(4):645–651. https://doi.org/10.2105/AJPH.2004.048256
25. Anselin L, Syabri I, Kho Y. GeoDa: an introduction to spatial data analysis. Geographical Analysis. 2006;38(1):5–22. https://doi.org/10.1111/j.0016-7363.2005.00671.x
26. Kim B, Kim H. Spatial clustering of hypertension and diabetes prevalence at the eup-myeon-dong level: A case study of Chungcheongbuk-do. Journal of Agricultural Medicine and Community Health. 2025;50(3):205–214. https://doi.org/10.5393/JAMCH.2025.50.3.205
27. Ju SH, Noh JW, Kim CS, Heo J. Local spatial autocorrelation analysis of 3 disease prevalence: a case study of Korea. Journal of Health Informatics and Statistics. 2017;42(4):301–308. https://doi.org/10.21032/jhis.2017.42.4.301
28. White K, Stewart JE, López-DeFede A, Wilkerson RC. Small-area variation in hypertension prevalence among Black and White Medicaid enrollees. Ethnicity & Disease. 2016;26(3):331–338. https://doi.org/10.18865/ed.26.3.331
29. Parvin S, Akter S, Hossain MI, Ali MS, Soni MSM. Residential variations in hypertension prevalence and trends among adults in Bangladesh. Research in Health Services & Regions. 2024;3(1):3. https://doi.org/10.1007/s43999-024-00040-2
30. Kim YM, Kang SH. Changes and factors of variability in community health behaviors and the prevalence of hypertension and diabetes. Journal of Digital Convergence. 2015;13(11):241–254. https://doi.org/10.14400/JDC.2015.13.11.241
31. Diez Roux AV, Mair C. Neighborhoods and health. Annals of the New York Academy of Sciences. 2010;1186(1):125–145. https://doi.org/10.1111/j.1749-6632.2009.05333.x
32. Kario K, Okura A, Hoshide S, Mogi M. The WHO Global report 2023 on hypertension warning the emerging hypertension burden in globe and its treatment strategy. Hypertension Research. 2024;47(5):1099–1102. https://doi.org/10.1038/s41440-024-01622-w
33. Kaiser P, Diez Roux AV, Mujahid M, Carnethon M, Bertoni A, Adar SD, et al. Neighborhood environments and incident hypertension in the Multi-Ethnic Study of Atherosclerosis. American Journal of Epidemiology. 2016;183(11):988–997. https://doi.org/10.1093/aje/kwv296
34. Palafox B, Goryakin Y, Stuckler D, Suhrcke M, Balabanova D, Alhabib KF, et al. Does greater individual social capital improve the management of hypertension? Cross-national analysis of 61,229 individuals in 21 countries. BMJ Global Health. 2017;2(4):e000443. https://doi.org/10.1136/bmjgh-2017-000443