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Is socio-economic development of areas associate with hypertension prevalence, awareness and treatment? A multilevel approach

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ABSTRACT

Hypertension, which has been well recognized as a major independent risk factor for cardiovascular disease and stroke, is one of the most significant health problems now facing China. This study addresses how socio-economic development of areas affects hypertension prevalence, awareness and treatment by simultaneously examining individual-level socioeconomic status and community-level characteristics using a multi-level approach. The data are from China Nutrition and Health Survey: a representative sample of 7381 adults over 216 neighborhoods. A two-level Generalized Hierarchical Logit Model (GHLM) is used to combine community-level (level-2) characteristics (i.e., Comprehensive development index, CDI), and individual-level SES position and lifestyle habits (level-1) to examine the factors associated with hypertension in China. The results show the prevalence and awareness of hypertension is significantly higher in spatially clustered neighborhoods of low CDI after adjusting for individual-level characteristics. However, the treatment of hypertension is relatively lower in areas with low CDI. This suggests an association between neighborhood CDI level and blood pressure, regardless of well-known individual-level hypertension risk factors.

Keywords: Hypertension, Multi-level modeling, Social disparities, Blood pressure
JEL Classification: A11, B17, C63

1. Introduction

Hypertension, which is also called high blood pressure (HBP), is an important public-health challenge to China because it has been well documented as a major independent risk factor for cardiovascular disease, stroke and kidney disease (Hofelmann, Antunes, Santos Silva, & Peres, 2012). It is an important contributor to the burden of disease, disability, and death in the population (Morenoff et al., 2007). In whole world, hypertension is responsible for 7.6 million premature deaths and 92 million disability-adjusted life years (Lloyd-Jones et al., 2010). According to research, hypertension was a leading preventable risk factor for death among Chinese adults aged 40 years and older, claiming 11.7% of the total mortality (He et al., 2010).

In recent decades, China has experienced rapidly economic growth, which is followed by unprecedented increases in income and living standards. Meanwhile, people's lifestyle also has changed dramatically, many healthy lifestyles have been compromised with the increased use of motorized transportation; consumption of calorie-dense fast food, salt, and fat; and television viewing (Ahn, Zhao, Smith, Ory, & Phillips, 2011). In addition, with more and more stress from job, living and intensive competition, people are facing more health problems than before. The incidence of hypertension increases dramatically. The prevalence and absolute numbers of hypertension have increased dramatically during the past several decades. For example, the estimated number of hypertension cases among Chinese adults has increased from 30 million in 1960 to 59 million in 1980, to 94 million in 1990 (Gu et al., 2002) and to more than 160 million in 2010 (Griffiths, 2010). At present, the prevalence of hypertension has become the most significant health problem facing China, and it displays a fast developing trend and uneven distribution.

Understanding and reducing socioeconomic and regional disparities in prevalence of hypertension is the most significant challenge facing Chinese public health research and policy. Although there are abundant researches on these social disparities in health (Thorpe Jr, Brandon, & LaVeist, 2006) (Brunello & D'Hombres, 2007), important questions related to the reasons for observed differences, which do not appear to be fully "explained " by the traditional individual-level risk factors included in most analyses. Reasons for social disparities in the individual-level risk factors for hypertension are also not well understood.

The main objective of this study is to assess the association of the prevalence of HBP, the awareness of HBP, and the treatment of HBP with both individual-level factors and neighborhood-level factors. Understanding the influence of risk factors from both micro level and macro level for the prevalence, awareness and treatment of hypertension would allow national public-health policy-makers to assign sufficient priority and resources to its management and prevention.

This paper is organized as follows, in the second part, we briefly review related literatures on determinants of hypertension, and then we describe the dataset from CHNS 2009 in the following part. The empirical multilevel modeling approach is introduced in the fourth part, followed by the estimation results and brief discussion. Finally, some concluding remarks are given at the end of this paper.

2. Literature review

Risk factors for hypertension have been paid much attention from many scholars. Some researchers explored the reasons for suffering hypertension from the perspective of medicine. Cho (2009) and his colleagues examined the risk factor for hypertension through analyzing the structure of gene (Cho et al., 2009). And Siklar et.al (2011) examined the association between hypertension and ACE I/D polymorphism, as well as the contribution of clinical and metabolic parameters on blood pressure (Şıklar et al., 2011).

However, some scholars from the areas of social science found the incidence of hypertension also can be influenced by social and environmental factors. Some of them mainly focus on the impacts of risk factors at individual level on hypertension. They found individual socioeconomic status and lifestyle is strongly correlated with hypertension (Leigh & Du, 2012).

Most recently, some researchers from developed countries began to concern more about the influences of factors from both individual level and regional level on the prevalence of hypertension rather than just focus on individual factors. Mantheson (2009) analyzed Individual-level data from the Canadian Community Health Survey (2000–2005) which were combined with area-level data from the 2001 Canada Census to assess the relationship between gender, neighborhood deprivation and hypertension. The results showed that neighborhood deprivation appears to be a stronger predictor of hypertension among women, such that women living in areas of high deprivation were 10% more likely to report having hypertension in comparison with men living in the same neighborhoods and with women living in the least impoverished neighborhoods. Hamano (2011) investigated the association between social capital and systolic blood pressure, and found that lack of fairness had a strong effect on systolic blood pressure. Abeyta (2012) assessed the hypothesis that community affluence modifies the association between individual socioeconomic status (SES) and risk factors for hypertension. They stratified data from the Colorado Behavioral Risk Factor Surveillance System for 2007 and 2008 by individual SES and 3 categories of community affluence (median household income of county). And then they found that people who had a low SES seemed to benefit from residing in high-affluence communities. However, based on the literatures, we find that in China there are few studies investigated the risk factors of hypertension from both individual level and neighborhood level. We hope our study can fill this gap.

3. Methodology

Since the multistage random cluster process was used in CHNS to collect data, the dependence among observations often comes from several levels of the hierarchy (ie individual level and community level) (Kozlowski & Klein, 2000). In this situation, the use of single-level statistical models is no longer valid and reasonable (Lapointe & Rivard, 2005). Hence, in order to draw appropriate inferences and conclusions from multistage stratified clustered data we may require complicated modeling techniques like multilevel modeling.

Multilevel logistic regression models or multilevel logit models are an extension of fixed effect logistic regression, incorporating random effects into the model to deal with the intra-class correlation coefficient (ICC) that arises in hierarchy data. The multilevel logit model has mixed effects, i.e., both fixed-effects and random effects (Wang, Xie, & Fisher, 2011). The model is specified in matrix format as:

$$\log\left(\frac{p}{1-p}\right) = X\beta + ZU \qquad (1)$$

Where X is the design matrix, corresponding to fixed-effect parameter vector β , and Z is the design matrix, corresponding to the random effect parameter vector U. Multilevel logistic regression models can be represented in the 2-stage format. The level-1 equation of the model is described as:

$$\log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \beta_{0j} + \sum_{p=1}^{p} \alpha_p x_{pij} + \sum_{q=1}^{Q} \beta_{qj} z_{qij} \qquad (2)$$

Level-2 equations are:

$$\beta_{0j} = \gamma_{00} + \sum_{m=1}^{M} \gamma_{0m} w_{mj} + u_{0j} \qquad (3)$$

$$\beta_{1j} = \gamma_{10} + \sum_{m=1}^{M} \gamma_{1m} w_{mj} + u_{1j} \text{(Error! Bookmark not defined.)}$$

$$\vdots$$

$$\beta_{Qj} = \gamma_{Q0} + \sum_{m=1}^{M} \gamma_{Qm} w_{mj} + u_{Qj} \text{ (Error! Bookmark not defined.)}$$

Where y_{ij} represents level-1 outcome measure of the ith individual in the jth level-2 unit; i=1,2,3,…,N (N is the total sample size), and j=1,2,…,J(J is the number of level-units). x_{pij}, z_{qij} are level-1 explanatory variables and w_{mj} is level-2 explanatory variable. The level-1 intercept β_{0j} is random, a total of P level-1 explanatory variables x_{pij} have fixed-effects, and a total of Q level-1 explanatory variables z_{qij} have random effects on the dependent variable y_{ij}. Each of the level-1 random effects is specified as linear function of M level-2 explanatory variables w_{mj} in the Q+1 macro models. Substituting macro models into micro models, we have a combined model:

$$log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \gamma_{00} + \sum_{m=1}^{M} \gamma_{0m} w_{mj} + \sum_{p=1}^{p} \alpha_p x_{pij} + \sum_{q=1}^{Q} \gamma_{q0} z_{qij}$$

$$+ \sum_{q=1}^{Q} \sum_{m=1}^{M} \gamma_{qm} w_{mj} z_{qij} + \left(u_{0j} + \sum_{q=1}^{Q} z_{qij} u_{qj}\right) \text{ (Error! Bookmark not defined.)}$$

The combined model consists of two parts: the fixed-effects part and the random effects part which include the level-2 error terms u_{0j} and u_{qj}, and level-1 independent variable z_{qij}. We see that the level-2 error terms u_{0j} and u_{qj}, don't have subscript "ij", but "j" only, indicating that their value don't vary within group, but do vary across groups. The observations within each group share common unexplained level-2 random variations. As a result, the within group observations are not independent of each other. In addition, the composite error term depends on the values of u_{0j}, u_{qj} and z_{qij}. The term $z_{qij}u_{qj}$ is an interaction between the groups and variable z_{qij}.

In this study, we have nine variables at individual level, and one contextual variable. We begin with the empty model that has only a random intercept, and no covariates. The empty model allows us to examine intra-class correlation coefficient (ICC) which is an indicator of between-group heterogeneity or within-group homogeneity and it represents the proportion of group-level variance in the total variance. In addition, empty model often serve as a base for building more elaborated models. The levels 1 and 2 equations of the model follow:

$$log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \beta_{0j} \quad \text{(Error! Bookmark not defined.)}$$

$$\beta_{0j} = \gamma_{00} + u_{0j} \quad \text{(Error! Bookmark not defined.)}$$

The combined model is:

$$log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \gamma_{00} + u_{0j} \text{ (Error! Bookmark not defined.)}$$

In these equations p_{ij} is the probability of being hypertension, being awareness of hypertension, and receiving treatment of hypertension respectively; β_{0j} is the overall average logit of being hypertension, being awareness of hypertension, and receiving treatment of hypertension respectively; and u_{0j} is the random variation in the level-1 intercepts across groups (i.e., communities in this study), which represents the deviations of jth communities'' mean logit from the grand mean or overall mean logit. In subsequent steps, we expand the empty model by adding individual covariates and variables at community level, and then determining the appropriate fixed-effects component and the random-effects component of the model.

Dependent variable

In this paper, three dependent variables, which are high blood pressure, awareness of high blood pressure and treatment of high blood pressure, will be investigated.

Blood pressure is measured in millimeters of mercury (mm Hg). Both systolic blood pressure (SBP) and diastolic blood pressure (DBP) are used to measure hypertension. The normal ranges of systolic and diastolic blood pressure are less than 140mmHg and 90mmHg respectively. When either systolic value is greater than 140 mmHg or diastolic value is more than 90 mmHg, or both value beyond the critical value, the high blood pressure can be diagnosed.

TABLE 1. Diagnostic standard for High Blood Pressure

Category	**Systolic (top number)**		**Diastolic (bottom number)**
Normal	Less than 120	*And*	Less than 80
Pre-hypertension	120–139	*Or*	80–89
High blood pressure			
Stage 1	140–159	*Or*	90–99
Stage 2	160 or higher	*Or*	100 or higher

In our sample, the data of systolic blood pressure and diastolic pressure were collected from adult physical examination. Blood pressures were measured three times during the questionnaire application, with a 2-min interval and the average was considered. Most of respondents were required to seat at least 30 minutes before measuring blood pressure. Blood pressure measurements were taken with the interviewee in the sitting position, with feet planted on the floor, left arm relaxed and supported on a table at the level of the heart, and the palm facing upward. Electronic sphygmomanometers with a digital reading system, which had been previously and adequately calibrated, were used.

We analyze binary measures of being hypertensive, being aware of a hypertensive condition and receiving treatment for hypertension. We considered participants to be hypertensive if they had an average SBP of 140 mmHg or higher, or an average DBP of 90 mmHg or higher. Participants were considered to be aware of their hypertension if they were defined as hypertension and answered “yes” to the survey question “Has a doctor ever told you that you suffer from high blood pressure?” Participants were considered to be treated if they were defined as hypertension and reported “yes” to the survey question “Are you currently taking anti-hypertension drugs?”

Individual-level covariates

Individual-level variables cover four main aspects including demographic factors, social economic status factors, nutritional factors and life style factors.

In the aspect of socio-demographic, age, gender, and educational background are included. Age is continuous variable, and it is centralized to make it meaningful in multilevel model. Gender is binary variables (0=male, 1=female). Educational levels are classified into 4 categories: 0~6 years (Edu=0, reference group), 6~9 years (Edu=1), 9~12 years (Edu=2), and more than 12 years (Edu=3).

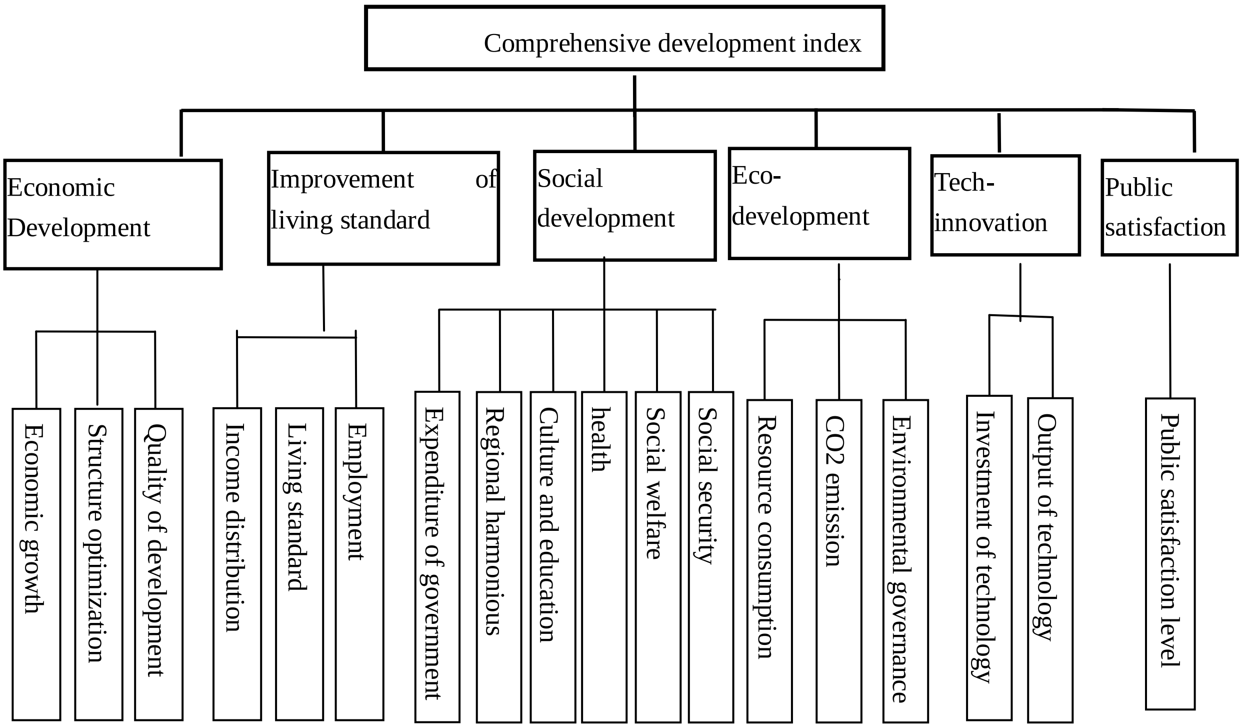
Social economic status factors include individual annual income, primary occupation types and health insurance. Individual income is adjusted by CPI and classified as three groups: low income group is defined as those earn less than 8942 RMB per year (code=0 reference group), those who earn between 8942 to 20915 RMB are defined as medium income group (code=1), and the high income group are those whose annual income are more than 20915 RMB (code=2). There are four main types of primary occupation. Type 1 is farmers and workers (code=0 referenced group); type 2 is professionals (code=1) which include both senior professionals (doctor, professor, lawyer, architect, engineer) and junior professionals (midwife, nurse, teacher, editor, photographer); type 3 is called office staffs (code=2), including working proprietor, government official, section chief, department or bureau director, administrative cadre, village leader, secretary, office helper; type 4 is service worker group (code=3) which consists of housekeeper, cook, waiter, doorkeeper, hairdresser, counter salesperson, launderer, child care worker, and drivers. Health insurance is binary variables.

Body mass index (BMI) is selected as nutritional factor. BMI is calculated by dividing weight in kilograms by the square of height in meters and rounding to the nearest tenth. Participants BMI scores are categorized using the Chinese criteria proposed by Chinese center for disease control and prevention: normal (BMI=18 to 24 kg/m2, reference group), overweight (BMI=24.1 to 28 kg/m2), and obese (BMI is greater than 28 kg/m2).

There are three factors covered in the aspect of lifestyle: smoking, drinking alcohol and participating activities, all of them are binary variables. Participants are defined as participating activities and coded as 1, if: 1) they answer "yes" to the question "do you travel to and from work or school on foot/ by bicycle?" and at the same time a round trip take at least 30 minutes; or 2) they admitted to take part in physical activities, such as martial arts, gymnastics, dancing, acrobatics, running, swimming, soccer, basketball, tennis, badminton, volleyball, pingpong, thai chi and etc., at least 40 minutes once a week. Participants who are defined as drinking alcohol based on the frequency and quantity of liquor consumption. If participants drink alcohol more than once a week or their liquor consumption is greater than 100ml per week, they are coded as 1, otherwise is 0.

Contextual-level variable

Comprehensive development index (CDI) is chosen as neighborhood-level variable, CDI is measured from five aspects: economic development, improvement of living standard, social development, eco-development, technological innovation and public satisfaction. The specific breakdown structure for CDI is shown as follows:



CDI is a good indicator which reflects the development of region. Total CDI is categorized into 4 levels: CDI>than 75 is coded as 0 (reference group), CDI between 60 and 75 is coded as 1, CDI ranged from 45 to 60 is coded as 2, and CDI lower than 45 is coded as 3.

4. Data

The data we used is drawn from China Health and Nutrition Survey (CHNS). CHNS was conducted by an international team of researchers whose backgrounds include nutrition, public health, economics, sociology, Chinese studies, and demography. In CHNS, all questions are designed to examine the effects of the health, nutrition, and family planning policies and programs implemented by national and local governments and to see how the social and economic transformation of Chinese society is affecting the health and nutritional status of its population.

CHNS is a longitudinal survey which includes nine provinces (Henan, Jiangsu, Hubei, Liaoning, Shandong, Guizhou, Hunan and Guangxi Zhuang Autonomous Region). All provinces vary substantially in geography, economic development, public resources, and health indicators. The first round of the CHNS, including household, community, and health/family planning facility data, was collected in 1989. Eight additional panels were collected in 1991, 1993, 1997, 2000, 2004, 2006, 2009 and 2011.

Figure 1. Locations of nine provinces chosen to conduct CHNS survey

A multistage, random cluster process was used to draw the samples surveyed in each of the provinces. Counties in these nine provinces were stratified by income (low, middle, and high), and a weighted sampling scheme was used to randomly select four counties in each province. Villages and townships within the counties and urban/suburban neighborhoods within the cities were selected randomly. From 1989 to 1993 there were 190 primary sampling units: 32 urban neighborhoods, 30 suburban neighborhoods, 32 towns (county capital city), and 96 rural villages. Since 2000, the primary sampling units have increased to 216: 36 urban neighborhoods, 36 suburban neighborhoods, 36 towns, and 108 villages. At present, this survey covers almost 4400 household and 26,000 individuals

5. Results

The total sample included 7381 adults. Table 1 shows the main characteristics of the studied population. This summary is classified into four aspects which include HBP outcomes, demographic factors, social economic status factors and lifestyle factors. From table 1, it can be seen that nearly 23.9% adults suffered from high blood pressure, but only half of them have been diagnosed and are aware of their condition, meanwhile among the HBP diagnosed patients, there are just 81.32% patient take anti-hypertension medicine. In our sample, female accounts for 50.96%, and the average age is around 45 years old. We see that 24% of adults received no more than 6-years education, 42% adults got middle school education, 25% received high school education, and only 8% people got more than 12-years education. SES factors cover two aspects (individual income per year and occupation type). The mean individual income per year is around 17355 RMB, nearly 34% earned less than 8950 RMB, 36% adults' income range from 8950 RMB to 20915 RMB, and 30% earn more than 20915 RMB per year. The primary occupation type is consists of 4 categories: farmers (32.82%), professionals including both senior and junior professionals (21.61%), administrators and office staffs (16.7%), and service workers (28.87%). From the part of lifestyle, we see approximately one third of sample admitted smoking and one fifth admitted drinking alcohol, almost 60% people take part in leisure physical activities more than once a week. In the sample, only 7% people do not have any kinds of medical insurance. The average BMI is 23, among them about 34% is classified as overweight and 11.21% participants are obesity.

TABLE 2. Individual-level summary statistics (n=7381)

Variable	Mean	Std. Dev.
High Blood Pressure outcomes		
HBP prevalence	23.93%	0.427
HBP Awareness	12.36%	0.329
HBP Treatment	10.01%	0.316
Demographic factors		
AGE	44.86	14.302
Gender		
Male	49.04%	0.500
Female	50.96%	0.491
Education Level		
0~6 years education	24.07%	0.323
6~9 years education	42.70%	0.495
9~12 years education	25.20%	0.434
More than 12 years education	8.03%	0.272
Residence		
Urban residence	41.81%	0.462
Rural residence	58.19%	0.429
Social Economic Status (SES) factors		
Individual income (cpi)		
<8942.86 RMB	33.92%	0.327
8942.86~20914.02 RMB	36.08%	0.480
>20914.02 RMB	30.00%	0.458
Primary occupation type		
Famers	32.82%	0.192
Professional	21.61%	0.211
Administrators and office staffs	16.70%	0.236
Service workers	28.87%	0.280
Life style factors		
Smoking		
No	70.64%	0.429
Yes	29.36%	0.455
Drinking alcohol		
No	78.12%	0.435
Yes	21.88%	0.413
Physical activity		
Inactive	39.11%	0.387
Active	60.89%	0.488

Other factors		
Medical insurance coverage		
No	6.79%	0.127
Yes	93.21%	0.252
Body Mass Index (BMI) (kg/m^2)	*23.37*	*3.393*
Body Mass Index Level (kg/m^2)		
<24	55.82%	0.421
24~28	32.97%	0.462
>28	11.21%	0.289

Between-community variation in the multilevel logistic model can be assessed by using the estimated ICC which represents the proportion of community–level variance in the total variance. For the logistic regression model, the residual variance is $\pi^2/3$, thus：

$$\text{ICC} = \frac{\hat{\sigma}_{u0}^2}{\hat{\sigma}_{u0}^2 + \pi^2/3} \quad (4)$$

The value of ICC for being hypertension, being awareness of hypertension, and receiving treatment of hypertension are 60.5%, 12.11%, and 15.89% respectively. All ICC values are significant at 1% level, and this suggests that the multilevel modeling should be considered for explaining the between-community heterogeneity in data analysis.

Following "caterpillar plots" (fig1-3) shows the estimated residuals for all 216 communities in the sample. For a substantial number of communities, the 95% confidence interval does not overlap the horizontal line at zero, indicating that the hypertension prevalence, hypertension awareness and hypertension treatment in these communities are significantly above average or below average. This also suggests there exist large heterogeneity among communities and multilevel approach should be applied.

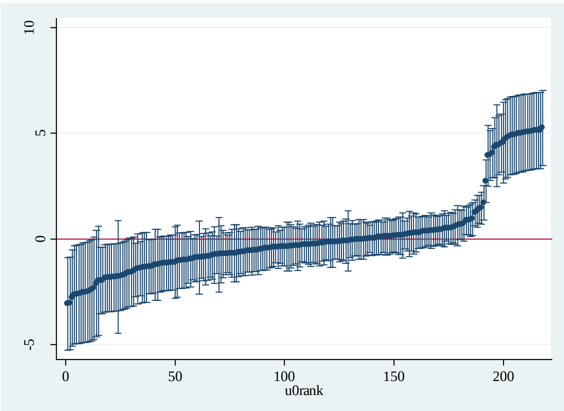


Figure 2 Caterpillar plot showing community residuals with 95% confidence intervals for log-odds of hypertension prevalence

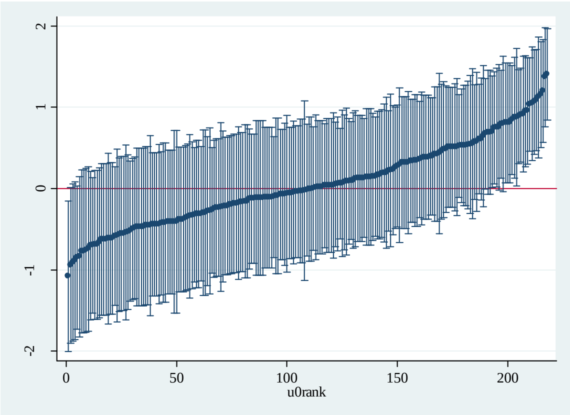


Figure 3 Caterpillar plot showing community residuals with 95% confidence intervals for log-odds of hypertension awareness

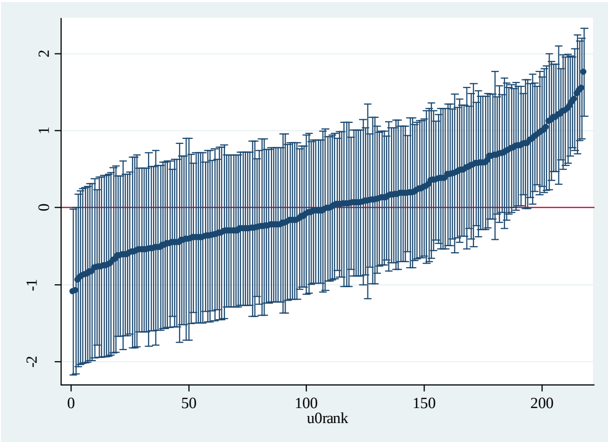


Figure 4 Caterpillar plot showing community residuals with 95% confidence intervals for log-odds of hypertension treatment

TABLE 3. Odds ratio (OR) and 95% confidence intervals (CI) for weighted logistic regression and hierarchical generalized linear models of hypertension prevalence: CHNS, 2009

	Empty Model		Model 1	
Variables	OR	CI	OR	CI
_cons	0.222***	[0.162,0.304]	0.0966***	[0.042,0.223]
Demographical factors				
Age (centered)			1.062***	[1.047,1.078]
GENDER			0.940	[0.707,1.249]
Education				
0~6 years			1	[1.000,1.000]
6~9 years			1.053	[0.741,1.495]
9~12 yeas			1.035	[0.644,1.664]
>12 years			1.084	[0.509,2.312]

	Empty Model		Model 1	
Variables	OR	CI	OR	CI
Social Economic Status factors				
Individual income (cpi)				
low			1	[1.000,1.000]
Medium			0.864	[0.603,1.238]
High			0.882	[0.589,1.322]
Primary occupation type				
Farmer			1	[1.000,1.000]
Professionals			1.127	[0.590,2.154]
Office staff			0.541*	[0.288,1.019]
Service worker			0.607**	[0.393,0.937]
Body Mass Index				
<24 (kg/m2)			1	[1.000,1.000]
24~28 (kg/m2)			1.883***	[1.394,2.543]
>28 (kg/m2)			4.732***	[3.087,7.255]
Lifestyle factors				
Smoke (ref=0)				
Liquor (ref=0)				
Physical activity (ref=0)				
Neighborhood factors				
Level_Dep0 (CDI>75)				
Level_Dep1 (CDI:60~75)				
Level_Dep2 (CDI:45~60)				
Level_Dep3 (CDI<45)				
Variance of				
_cons	10.52***		3.192***	
AIC	5555.599		2103.782	
BIC	5569.412		2198.911	

Exponentiated coefficients; 95% confidence intervals in brackets
* p<0.1, ** p<0.05, *** p<0.01

TABLE 3. (cont.)

	Model 2		Model3	
Variables	OR	CI	OR	CI
_cons	0.0838***	[0.022,0.325]	0.0364***	[0.007,0.191]
Demographical factors				
Age (centered)	1.056***	[1.033,1.079]	1.059***	[1.035,1.082]
GENDER	0.951	[0.433,2.092]	0.950	[0.432,2.089]
Education				
0~6 years	1	[1.000,1.000]	1	[1.000,1.000]
6~9 years	0.867	[0.498,1.509]	0.893	[0.514,1.550]
9~12 yeas	0.778	[0.383,1.581]	0.793	[0.391,1.609]
>12 years	0.830	[0.298,2.315]	0.895	[0.319,2.509]

	Model 2		Model3	
Variables	OR	CI	OR	CI
Social Economic Status factors				
Individual income (cpi)				
low	1	[1.000,1.000]	1	[1.000,1.000]
Medium	0.992	[0.564,1.744]	1.011	[0.576,1.776]
High	0.647	[0.346,1.211]	0.654	[0.350,1.223]
Primary occupation type				
Farmer	1	[1.000,1.000]	1	[1.000,1.000]
Professionals	1.659	[0.668,4.120]	1.663	[0.672,4.112]
Office staff	0.823	[0.339,2.000]	0.877	[0.361,2.129]
Service worker	0.584*	[0.313,1.092]	0.614	[0.330,1.140]
Body Mass Index				
<24 (kg/m2)	1	[1.000,1.000]	1	[1.000,1.000]
24~28 (kg/m2)	2.070***	[1.319,3.250]	2.041***	[1.303,3.199]
>28 (kg/m2)	5.381***	[2.782,10.409]	5.182***	[2.686,9.997]
Lifestyle factors				
Smoke (ref=0)	1.188	[0.750,1.881]	1.189	[0.752,1.882]
Liquor (ref=0)	1.313	[0.794,2.170]	1.293	[0.782,2.136]
Physical activity (ref=0)	0.477**	[0.271,0.841]	0.490**	[0.279,0.861]
Neighborhood factors				
Level_Dep0 (CDI>75)			1	[1.000,1.000]
Level_Dep1			0.853	[0.210,3.467]
Level_Dep2			2.329	[0.571,9.494]
Level_Dep3 (CDI<45)			4.94***	[2.160,7.297]
Variance of _cons	3.117***		2.911***	
AIC	1131.476		1115.000	
BIC	1230.315		1227.313	

Exponentiated coefficients; 95% confidence intervals in brackets
* p<0.1, ** p<0.05, *** p<0.01

For hypertension prevalence, hypertension awareness and hypertension treatment, the empty model shows there is strong evidence that the between communities variance is non-zero.

In Table 3, we examine social disparities in the prevalence of hypertension. It can be seen that the odds of being suffered from hypertension in an "average" community are estimated as 0.222. The intercept for community j is $1.504+u_{0j}$, where the variance of u_0 is estimated as 10.52. Model 1 which considers demographical factors, social economic status factors and body mass index shows that the odds of being hypertension slightly increase with age grow. We also see that the odds of being HBP are 40% lower for service workers compared to farmers. People with BMI range from 24 to 28 have 1.8 times chance suffering HBP than non-obese people, and for obese people whose BMI are greater than 28, their probability of suffering HBP dramatically increased to 4.7 times than normal people. After including lifestyle factors such as smoking, drinking, and participating physical activities, all of this disparity remain significant. The odds of hypertension prevalence are slightly low among those with high individual income and with more than 12-years education, but this association is only marginally significant statistically. In addition, we find that participating leisure physical activity can really help people to reduce the risk of being hypertension compared to those without any physical activities. When we control for neighborhood context in random effect models, some estimates changed, and there are no longer significant differences between service workers and farmers. We also find the lowest levels of comprehensive development index (CDI) are related to higher odds of hypertension prevalence.

TABLE 4. Odds ratio (OR) and 95% confidence intervals (CI) for weighted logistic regression and hierarchical generalized linear models of hypertension awareness: CHNS, 2009

	Empty Model		Model 1	
Variables	OR	CI	OR	CI
_cons	0.122***	[0.108,0.137]	0.0461***	[0.032,0.067]
Demographical factors				
Age (centered)			1.090***	[1.075,1.106]
GENDER			0.933	[0.709,1.228]
Education				
0~6 years			1	[1.000,1.000]
6~9 years			0.958	[0.692,1.325]
9~12 yeas			0.922	[0.603,1.410]
>12 years			1.411**	[0.979,2.849]
Social Economic Status factors				
Individual income (cpi)				
low			1	[1.000,1.000]
Medium			0.732*	[0.517,1.035]
High			1.078	[0.762,1.523]
Primary occupation type				
Farmer			1	[1.000,1.000]
Professionals			1.779**	[1.038,3.049]
Office staff			1.789**	[1.118,2.862]
Service worker			1.102	[0.788,1.541]
Health Insurance (ref=0)				
Body Mass Index			1	[1.000,1.000]
<24 (kg/m2)			2.675***	[2.015,3.550]
24~28 (kg/m2)			6.667***	[4.630,9.600]
>28 (kg/m2)				
Health Insurance (ref=0)			0.843	[0.471,1.509]
Lifestyle factors				
Smoke (ref=0)				
Liquor (ref=0)				
Physical activity (ref=0)				

	Empty Model		Model 1	
Variables	OR	CI	OR	CI
Neighborhood factors				
Level_Dep0 (CDI>75)				
Level_Dep1 (CDI:60~75)				
Level_Dep2 (CDI:45~60)				
Level_Dep3 (CDI<45)				
Variance of				
_cons	0.673***		0.539**	
AIC	5385.039		1852.214	
BIC	5398.853		1941.000	

Exponentiated coefficients; 95% confidence intervals in brackets

* p<0.1, ** p<0.05, *** p<0.01

TABLE 4. (cont.)

	Model 2		Model3	
Variables	OR	CI	OR	CI
_cons	0.0607***	[0.026,0.143]	0.0665***	[0.025,0.176]
Demographical factors				
Age (centered)	1.093***	[1.069,1.119]	1.094***	[1.069,1.119]
GENDER	0.575	[0.209,1.586]	0.564	[0.206,1.549]
Education				
0~6 years	1	[1.000,1.000]	1	[1.000,1.000]
6~9 years	1.093	[0.637,1.874]	1.111	[0.649,1.902]
9~12 yeas	0.829	[0.429,1.602]	0.804	[0.415,1.555]
>12 years	1.292**	[0.804,2.916]	1.282**	[0.801,2.797]
Social Economic Status factors				
Individual income (cpi)				
low	1	[1.000,1.000]	1	[1.000,1.000]
Medium	0.721*	[0.495,1.101]	0.674	[0.380,1.195]
High	1.056	[0.598,1.865]	1.051	[0.596,1.852]
Primary occupation type				
Farmer	1	[1.000,1.000]	1	[1.000,1.000]
Professionals	3.112***	[1.442,6.716]	2.978***	[1.384,6.406]
Office staff	3.035***	[1.527,6.029]	3.153***	[1.588,6.259]
Service worker	1.046	[0.606,1.806]	1.077	[0.624,1.859]
Health Insurance (ref=0)				
Body Mass Index	1	[1.000,1.000]	1	[1.000,1.000]
<24 (kg/m2)	2.813***	[1.823,4.341]	2.846***	[1.846,4.388]
24~28 (kg/m2)	4.715***	[2.502,8.886]	4.552***	[2.412,8.590]
>28 (kg/m2)				
Health Insurance (ref=0)	1.348	[0.556, 3.271]	1.274	[0.528,3.074]
Lifestyle factors				
Smoke (ref=0)	1.657**	[1.044,2.631]	1.678**	[1.058,2.664]
Liquor (ref=0)	0.551***	[0.350,0.866]	0.568**	[0.362,0.892]

	Model 2		Model3	
Variables	OR	CI	OR	CI
Physical activity (ref=0)	0.660	[0.390,1.118]	0.647	[0.383,1.093]
Neighborhood factors				
Level_Dep0 (CDI>75)			1	[1.000,1.000]
Level_Dep1 (CDI:60~75)			0.773	[0.423,1.413]
Level_Dep2 (CDI:45~60)			0.698	[0.375,1.298]
Level_Dep3 (CDI<45)			1.209**	[0.885,2.215]
Variance of				
_cons	0.522*		0.461**	
AIC	837.910		839.578	
BIC	931.258		949.400	

Exponentiated coefficients; 95% confidence intervals in brackets
* p<0.1, ** p<0.05, *** p<0.01

In Table 4, we analyze the odds ratio of ever being diagnosed with hypertension by doctor or health professional. Model 1 shows that the odds of being aware of hypertension are about 41% higher for those with more than 12 years of education compared to those with less than 6 years education. People who work as professionals, administers and office staffs are more likely than farmers to be aware of their hypertension, and this gap becomes more statistically significant after adjusting for neighborhoods. Compared to those with low income, the odds of hypertension awareness are marginally higher in high-income people, but lower among people with medium individual income and this association becomes insignificant after controlling for neighborhood context in model 3. The odds of being HBP awareness for overweight people is twice than normal people, and the odds for obese people is about 6 times than normal people, but this association decrease to 4.5 times after adjusting contextual factor CDI. In model 2, we see people with smoking are 60% higher in hypertension awareness than those without smoking, but the odds ratio for those with drinking alcohol are 40% lower than those without drinking. In model 4, when controlling for CDI in multilevel models, most of estimates remain significant, and we see people lived in deprived area are more likely (20% higher) to be aware of suffering high blood pressure.

TABLE 5. Odds ratio (OR) and 95% confidence intervals (CI) for weighted logistic regression and hierarchical generalized linear models of hypertension Treatment: CHNS, 2009

	Empty Model		Model 1	
Variables	OR	CI	OR	CI
_cons	0.0879***	[0.076,0.101]	0.0181***	[0.008,0.041]
Demographical factors				
Age (centered)			1.101***	[1.082,1.120]
GENDER			1.041	[0.752,1.440]
Education				

	Empty Model		Model 1	
Variables	OR	CI	OR	CI
0~6 years			1	[1.000,1.000]
6~9 years			0.947	[0.643,1.395]
9~12 yeas			0.935	[0.566,1.544]
>12 years			1.536	[0.537,3.212]
Social Economic Status factors				
Individual income (cpi)				
low			1	[1.000,1.000]
Medium			0.757	[0.496,1.157]
High			1.342	[0.891,2.021]
Primary occupation type				
Farmer			1	[1.000,1.000]
Professionals			1.670	[0.881,3.166]
Office staff			1.847**	[1.059,3.220]
Service worker			1.374	[0.919,2.054]
Health Insurance (ref=0)			1.263	[0.630,2.533]
Body Mass Index				
<24 (kg/m2)			1	[1.000,1.000]
24~28 (kg/m2)			2.580***	[1.836,3.624]
>28 (kg/m2)			7.431***	[4.870,11.340]
Lifestyle factors				
Smoke (ref=0)				
Liquor (ref=0)				
Leisure physical activity (ref=0)				
Neighborhood factors				
Level_Dep0 (CDI>75)				
Level_Dep1 (CDI:60~75)				
Level_Dep2 (CDI:45~60)				
Level_Dep3 (CDI<45)				
Variance of				
_cons	0.788***		0.480**	
AIC	4601.645		1427.638	
BIC	4615.458		1522.766	

Exponentiated coefficients; 95% confidence intervals in brackets
* p<0.1, ** p<0.05, *** p<0.01

TABLE 5. (cont.)

	Model 2		Model3	
Variables	OR	CI	OR	CI
_cons	0.0167***	[0.003,0.104]	0.0227***	[0.003,0.155]
Demographical factors				
Age (centered)	1.104***	[1.072,1.136]	1.100***	[1.068,1.133]
GENDER	0.337	[0.073,1.547]	0.325	[0.071,1.485]
Education				
0~6 years	1	[1.000,1.000]	1	[1.000,1.000]
6~9 years	1.068	[0.544,2.097]	1.045	[0.533,2.048]
9~12 yeas	0.699	[0.306,1.596]	0.637	[0.278,1.460]
>12 years	1.293**	[0.871,2.989]	1.251**	[0.732,2.861]
Social Economic Status factors				
Individual income (cpi)				
low	1	[1.000,1.000]	1	[1.000,1.000]
Medium	0.694	[0.325,1.482]	0.671	[0.314,1.437]
High	1.454	[0.762,3.169]	1.516**	[1.041,2.010]
Primary occupation type				
Farmer	1	[1.000,1.000]	1	[1.000,1.000]
Professionals	3.511***	[1.364,9.038]	3.463***	[1.348,8.897]
Office staff	3.179***	[1.349,7.493]	3.239***	[1.376,7.625]
Service worker	1.480	[0.748,2.929]	1.476	[0.747,2.917]
Health Insurance (ref=0)	2.450	[0.548,10.951]	2.579	[0.579,11.494]
Body Mass Index				
<24 (kg/m2)	1	[1.000,1.000]	1	[1.000,1.000]
24~28 (kg/m2)	2.810***	[1.617,4.882]	2.914***	[1.679,5.059]
>28 (kg/m2)	6.448***	[3.056,13.609]	6.402***	[3.037,13.497]
Lifestyle factors				
Smoke (ref=0)	1.288	[0.751,2.207]	1.316	[0.769,2.255]
Liquor (ref=0)	0.526**	[0.306,0.902]	0.551**	[0.322,0.944]
Leisure physical activity (ref=0)	0.470**	[0.258,0.858]	0.445***	[0.245,0.809]
Neighborhood factors				
Level_Dep0 (CDI>75)			1	[1.000,1.000]
Level_Dep1 (CDI:60~75)			0.864	[0.437,1.706]
Level_Dep2 (CDI:45~60)			0.395**	[0.178,0.879]
Level_Dep3 (CDI<45)			0.873	[0.445,1.714]
Variance of				
_cons	0.516**		0.398**	
AIC	673.074		669.435	
BIC	707.913		691.748	

Exponentiated coefficients; 95% confidence intervals in brackets
* p<0.1, ** p<0.05, *** p<0.01

In Table 5, we model the odds ratio of taking anti-hypertension medicine. Model 1 shows that, with age grow, more people tend to taking medicine to control the development of hypertension. Compared to farmers, office staffs are more likely to take anti-hypertension medicines than famers. However, after controlling life style habits and contextual factor, professionals also become more likely to take medicine than famers, and the odds ratio increase dramatically to 3.46 and significant at 1% level. It also can be seen that people with high individual income are more likely to take medicine than those with low income, and the odds ratio become significant after adjusting contextual variable in model 3. In this table, we see the similar trend in previous tables that overweight and obese people are most likely to take medicine than those with normal BMI value. From lifestyle factors, we find that people who drink alcohol are less likely to take medicine compared to those who do not drink. We still see an interesting phenomenon that people who like participating in leisure physical activities tend not to choose anti-hypertension medicine, among them only 45% of patients take medicine to control blood pressure. When controlling for the neighborhood factor in model 3, we see, among people who live in the area with the second lowest CDI, there are only 40% hypertensive patients take medicine. However, for the odds of taking anti-hypertension medicine in regions with the lowest CDI and the second highest CDI, there are only marginally 13% or 14% lower than people lived in area with the highest CDI.

6. Concluding remarks

The main objective of this study is to understand the potential contribution of residential neighborhoods to social disparities in hypertension prevalence, awareness and treatment. We found that service worker and people with high income have significantly lower odds of suffering hypertension than their respective comparison group, but after adjusting for neighborhood context these disparities diminished and become statistically insignificant. The risk of hypertension is also higher in communities with lower CDI value, even after adjusting for BMI, health insurance coverage, physical activity, smoking, and drinking. One hypothesis is that people lived in areas with low CDI, which means low GDP, high unemployment rate, bad living conditions, worse social security, and low-level public satisfaction, are more likely suffering from high blood pressure.

Among those with hypertension, the odds of being diagnosed by a doctor or health professional were higher for people with high education compared to people with less than 6 years education and for people who work as professional and office staffs. There two possible reasons for this. First, more education makes people have ability to obtain related health knowledge, thus if they have any uncomfortable symptoms, they will be cautious and go to see doctor. Second, for professionals and office staffs, usually the organization or companies they belong to may provide health check annually for them, so their hypertension awareness are higher than farmers and service workers. We also find that awareness is higher among people who live in more disadvantaged neighborhoods (lowest CDI value). This suggests that the public health system is effective at screening and diagnosing of high risk groups.

Among those with hypertension and have been diagnosed, the odds of taking anti-hypertension medicine are higher in people lived in areas with high CDI. However, the lowest proportion of taking medicine is in the area with the second lowest CDI rather than in areas with the lowest CDI, the main reason for these is that public health system and health care system is always target at the people who lived in the most deprived areas but overlooked those in the areas with the second lowest CDI.

In sum, we found that neighborhoods appear to play a role in explaining social disparities in hypertension prevalence, awareness and treatment. Our analysis also highlights the potentially protective effects of neighborhood with high CDI for reducing the risk of hypertension, and increasing the likelihood that people take anti-hypertension medicine. This study is part of a growing literature that has found neighborhood CDI to be associated with a variety of health outcomes, but it also makes some distinctive contributions. First, this is the only study of which we are aware that attempts to decompose social disparities in health into their within- and between-neighborhood components, thus focusing on the role of neighborhoods in explaining socioeconomic disparities. Second, in China, few prior studies have explored social disparities in awareness, and treatment of hypertension, and ours is the first to examine associations between these outcomes and socioeconomic development of areas.

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