Associations between communities' urbanization levels and onset of hypertension in China

Jinjing Wu[1*], Jia Chen[2], Zhen Li[1]

1. Asian Demographic Research Institute, Shanghai University, China

2. Department of Social Work, Shanghai University, China

*E-mail address: jinjingwu1105@gmail.com

Abstract

Background: Although urbanization was considered as an underlying force of a nutrition transition towards "Western" diets and sedentary lifestyles and a subsequent increase in the burden of hypertension (HTN), empirical studies produced mixed results.

Methods: With data from the China Health and Nutrition Survey (1991-2015), we performed multilevel discrete-time event history analyses to examine the association between communities' urbanization levels and HTN onset by region (the Northeast, Coastal East, Central, and West) and period. We stratified analyses by sex.

Results: We found that 1) among women, the medium-to-high urbanization level was significantly positively associated with incident HTN in 1991 except that the positive association was insignificant in the Coastal East. From 1991 to 2015, the positive association became negative except for the West. 2) The high urbanization level was significantly negatively associated with incident HTN among the Coastal East's women in 1991. The negative association in the Northeast and Central became statistically significant across the period. In the West, the association was still positive and insignificant in 2015. 3) Among men, the urbanization levels were not significantly related to incident HTN except for the Coastal East in which we found that the negative association between the high urbanization level and HTN occurrence became significant across the period.

Conclusions: The regional differences in the association observed in the female, together with the changing association between 1991 and 2015, implied that a higher urbanization level might prevent HTN when a region becomes more economically developed.

Keywords: urbanization, hypertension, incidence, community, adults, China

Introduction

Cardiovascular diseases (CVDs) have become the leading cause of death in both China and the world (Zhou et al., 2016; Hay et al., 2017). Hypertension (HTN) is a major risk factor for CVDs (Lackland & Weber, 2015; Forouzanfar et al., 2017). Although the HTN prevalence has been decreasing in the high-income countries since 2000, it has been increasing in the low- and middle-income countries, including China (Mills et al., 2016).

China has become increasingly urbanized. On the one hand, the proportion of China's population living in urban areas has exceeded 50% since 2011 due to the rural-to-urban migration (Gong et al., 2012). On the other hand, rural and suburban areas have been gaining urban characteristics (Jones-Smith & Popkin, 2010). Although urbanization was considered as one of underlying forces of a nutrition transition towards "Western" diets and sedentary lifestyles and a subsequent increase in the burden of HTN and related CVDs in developing countries (Popkin 1999; Popkin, 2006; Gong et al., 2012; Yang et al., 2013), empirical studies about the association between the degree to which a place exhibits urban features and prevalent HTN in China provided mixed results (Van de Poel et al., 2012; Miao & Wu, 2016; Zhang, 2019).

The mixed findings may be due to the changing association between communities' urbanization levels and prevalent HTN over time, as has been found in a recent study (Zhang, 2019). Also, the inconsistent results may result from regional heterogeneity. A cross-country study showed that urban communities had lower HTN prevalence than rural communities in the middle- and high-income countries, but the reverse was true in the low-income countries (Chow et al., 2013), implying that a higher urbanization level may be associated with a decreased burden of HTN as a country becomes more developed. Within China, regional differences in socioeconomic development, geography, and population health are substantial (Zhou et al., 2016; Li et al., 2018). However, whether the association of communities' urbanization levels with the HTN burden varies by region remains to be investigated. Additionally, prevalent HTN is a less useful measure in etiological studies than incident HTN as the former is not only determined by the number of people affected but also their survival (Ward, 2013). A study on incident HTN is needed to increase our understanding of the effect of communities' urbanization levels on HTN onset.

With longitudinal data from the China Health and Nutrition Survey (1991-2015), we conducted multilevel discrete-time event history analyses to examine the association of communities' urbanization levels with incident HTN by region. Also, we examined whether the association changed during 1991-2015. We stratified our analyses by sex.

Data and method

Data

We analyzed data from the China Health and Nutrition Survey (CHNS) (1991-2015) that is a longitudinal study. It covers regions vary in socioeconomic development, geography, dietary culture, and population health. It was designed to examine the effect of social changes on population health among Chinese.

The first wave was conducted in 1989. Nine waves were conducted in 1991, 1993, 1997, 2000, 2004, 2006, 2009, 2011, and 2015. The CHNS applied a multistage, random cluster design to draw samples in eight provinces (Liaoning, Henan, Hubei, Hunan, Shangdong, Jiangsu, Guizhou, and Guangxi). Heilongjiang Province was added since 1991 and Beijing, Chongqing and Shanghai were added since 2011. Further details about the CHNS were reported in Zhang et al. (2014).

We excluded the 1989 wave from our analyses because only people aged 20-45 were sampled in 1989. As one of our objectives is to examine whether the association between communities' urbanization level and incident HTN changed between 1991 and 2015, we excluded samples of Beijing, Chongqing, and Shanghai as they were surveyed since 2011 and could not provide data in the 1990s.

Sample selection

In our study, eligible respondents were those 1) who were not pregnant during the physical examination, 2) 20-64 years old and 3) nonhypertensive when they were firstly surveyed, and 4) had at least one follow-up examination. 11,284 respondents, with 52,100 observations, were eligible for our analyses.

We performed complete-case analyses; therefore we excluded respondents who had missing values on hypertension status, educational attainment, household income, *Hukou* type, marital status, smoking, and alcohol drinking status, which resulted in an analytic sample of 10031 respondents, with 41265 observations. Figure 1 shows the sample selection process. Considering the potential bias caused by missing values, we conducted multiple imputations and rebuilt models based on the multiply imputed datasets in sensitivity analyses.

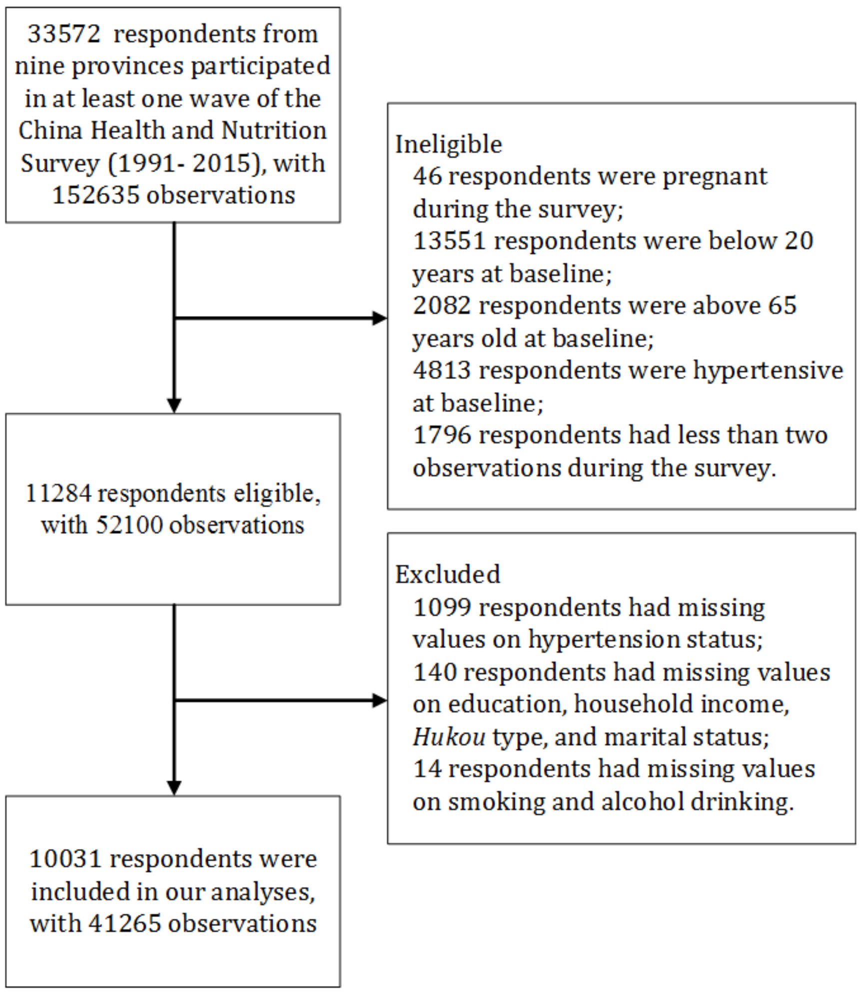

Figure 1 Sample selection process

Measurements

Incident hypertension

The dependent variable was incident HTN (i.e., becoming hypertensive in follow-up examinations or remain nonhypertensive). Trained physicians, using standardized mercury sphygmomanometers, measured seated systolic/diastolic blood pressure (SBP/DBP) of each respondent. SBP and DBP were measured three times after 5-minute rest, and three measurements were taken at 1 or 2 minutes intervals. We averaged the three readings of SBP and DBP, respectively. The HTN event occured if repondents had an average SBP higher than 140 mmHg, an average DBP higher than 90 mmHg, reporting a diagnosis of HTN, or having antihypertensive medicine in follow-up surveys.

Communities' urbanization levels

Jones-Smith and Popkin (2010) developed a composite scale, urbanicity, based on the community-level and individual-level data of CHNS. They identified 12 components that define features of urban places, including population density, economic activity, traditional markets, modern markets, transportation infrastructure, sanitation, communications, housing, education, diversity, health infrastructure, and social services. Each component was assigned 10 points and got equally weighted and was summed up to get a total score. The maximum of the total score is 120. A higher urbanicity score indicates that a community has a higher urbanization level.

We divided communities into three groups according to their urbanicity score. The low-urbanization-level communities were those with an urbanicity scores below the median estimated from the data pooled all waves. As the relationship between urbanization levels and burden of chronic diseases may be nonlinear (Liu et al., 2016), we included communities with the medium-to-high urbanization level (urbanicity scores in the third quartile) and communities with the high urbanization levels (urbanicity scores in the upper quartile) in our analyses.

We categorized communities with an urbanicity score in the third quartile and an urbanicity score in the upper quartile as the groups of medium-to-high urbanization level and high urbanization level, respectively.

Regions

Consistent with previous studies (Chen et al., 2010; Xu et al., 2015), we grouped our samples into four regions, including the Northeast, Coastal East, Central, and West. The West is the reference group.

Period

We centered the survey years at 1991 and included it as a continuous variable in our analyses. We also included interactions between the survey years and urbanization levels.

Control variables

We included the *Hukou* type in our model as Li et al. (2017) found that persons with non-agricultural *Hukou* type had significantly higher HTN prevalence than those with agricultural *Hukou* type. As the CHNS asked respondents about their *Hukou* status since 1993, we had no *Hukou* information in the 1991 wave. We, therefore, assumed that respondents' *Hukou* type in 1991 was the same as their *Hukou* type in their earliest follow-up surveys. Also, we included educational attainment, household income per capita, marital status, smoking, and alcohol drinking status. Table 1 reports definitions and distributions of independent and control variables included in our analyses.

Table 1 Definitions and distributions of the independent variable included in our analyses, China Health and Nutrition Survey (1991-2015)

Variables	Description	Mean (SD) / Proportion
Urbanization levels	The degree to which a community exhibited urban features, measured by urbanicity scores	58.11 (20.33)
The first or second quartile (Index<57.15)	Whether communities' urbanicity scores were below the median	51.05%
The third quartile (57.15≤Index<75.09)	Whether communities' urbanicity scores were in the third quartile	24.59%
The upper quartile (index≥75.09)	Whether communities' urbanicity scores were in the upper quartile	24.36%
Male	Whether a respondent was male	42.36%
Duration	Number of years after 20 years old	24.36 (12.18)
Period	Survey years centered at 1991	10.53 (7.53)
Married	Whether a respondent had a spouse	89.96%

Educational attainment		
≤Primary education	Whether a respondent's highest educational attainment was primary education or below	45.61%
Lower secondary education	Whether a respondent's highest educational attainment was lower-secondary education	31.78%
≥Upper secondary education or above	Whether a respondent's highest educational attainment was upper-secondary education	22.61%
Household income per capita	Household income in 10,000 yuan	0.86 (1.40)
Non-agricultural *Hukou*	Whether a respondent held a non-agricultural *Hukou*	38.02%
Smoking	Whether a respondent was a current smoker	30.42%
Alcohol drinking	Whether a respondent drank alcohol during the past year	33.28%
Number of respondents		10,031
Number of observations		41,265

Statistical analyses

To examine the association between communities' urbanization level and individual-level incident hypertension, we built multilevel discrete-time hazard models, using a logit link. We used the discrete-time hazard model rather than the Cox model because the latter requires the event data recorded in continuous time (Allison, 1982; Singer & Willett, 2003). However, our data was recorded in years, a discrete-time unit. We did not know the exact date of HTN occurrence, but we knew the interval for HTN onset. Additionally, the discrete-time hazard model can easily incorporate time-varying predictors (Allison, 1982; Singer & Willett, 2003).

The discrete-time hazard model can be written as:

Hazard function：

$$h_{tij}(t) = \Pr[y_{tij} = 1 | y_{t-1ij} = 0]$$

Logit model：

$$\text{logit}\left(h_{tij}\right) = \alpha_0 + \alpha_1((Time - c) + \alpha_2(Time - c)^2 + \alpha_3(Time - c)^3 + \beta X_{tij} + \mu_i + \mu_j$$

We conducted multilevel analyses, with random effects at the community level and individual level to account for the dependence of residents within communities and repeated observations of individuals.

To examine whether the association between urbanization levels and incident HTN varied by region, we added interactions between regions and urbanization levels. Furthermore, to examine whether the association changed during 1991-2015, we added interactions between period and urbanization levels. We stratified our analyses by sex as there might be sex differences in exposure and vulnerability to risk factors of HTN and other related CVDs (O'Neil et al., 2018).

We used the MELOGIT command in Stata 15.0 to perform multilevel discrete-time event history analyses, using the logit transformation. To facilitate the interpretation of the interactions between regions and urbanization levels as well as the interactions between period and urbanization levels, we used the LINCOM command to estimate odds ratios and 95% confidence intervals for different regions in different years.

Sensitivity analyses

To test the robustness of our findings, we examined whether our results changed when missingness data was accounted for, we performed multiple imputations with the MICE (multiple imputation by chained equation) package in R (version 3.6.0). Five multiply imputed datasets were generated. We then used the lme4 (linear mixed-effects models) package to build multilevel discrete-time hazard models on each dataset and pooled estimates of each model into a single set of coefficients and standard errors.

Results

Among 10031 respondents, about 40.37% got HTN from 1991 to 2015. Figure 1 shows the survival curve across age by sex. Table 2 reports estimates of multilevel discrete-time event history analyses among men and women, respectively. Model 1 shows an average effect of urbanization level on incident hypertension across region and period. Among women, people who lived in communities with a high level of urbanization had significantly lower odds of getting HTN than those living in communities with a low level of urbanization. But no significant difference in odds of getting HTN was found between residents of communities with a medium-to-high urbanization level and their counterparts of communities with a low urbanization level. Among men, both the positive coefficient of medium-to-high urbanization level and negative coefficient of high urbanization level were not significantly associated with incident HTN. According to Model 1 for both men and women, people of the Northeast, Coastal East, and Central had higher odds of becoming hypertensive than their counterparts in the West.

Table 2 Estimates of multilevel discrete-time event history analyses, complete case analyses, China Health and Nutrition Survey (1991-2015)

	Male			Female		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Intercept	-5.39***	-5.43***	-5.47***	-6.39***	-6.61***	-6.74***
	(0.19)	(0.20)	(0.21)	(0.24)	(0.25)	(0.26)
Duration	0.06***	0.06***	0.06***	0.11***	0.11***	0.11***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Duration^2	-0.00*	-0.00*	-0.00*	-0.00***	-0.00***	-0.001***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Coastal East	0.66***	0.83***	0.84***	0.53***	0.92***	0.93***
	(0.11)	(0.15)	(0.15)	(0.11)	(0.15)	(0.15)
Northeast	0.55***	0.59***	0.59***	0.73***	0.96***	0.95***
	(0.11)	(0.15)	(0.15)	(0.11)	(0.15)	(0.15)
Central	0.45***	0.44**	0.44***	0.47***	0.67***	0.68***
	(0.10)	(0.13)	(0.13)	(0.10)	(0.13)	(0.13)

Third quarile of urbanicity index	0.05	0.20	0.31	0.07	0.33*	0.76***
	(0.08)	(0.15)	(0.19)	(0.08)	(0.14)	(0.19)
Upper quarile of urbanicity index	-0.16	-0.18	-0.12	-0.37***	0.10	0.11
	(0.10)	(0.18)	(0.25)	(0.10)	(0.17)	(0.25)
Period	0.47***	0.47***	0.47***	0.43***	0.43***	0.45***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Period^2	-0.04***	-0.04***	-0.04***	-0.04***	-0.04***	-0.04***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Period^3	0.00***	0.00***	0.00***	0.00***	0.00***	0.001***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Third quartile × Northeast		-0.13	-0.11		-0.18	-0.14
		(0.22)	(0.22)		(0.21)	(0.21)
Upper quartile × Northeast		-0.01	-0.01		-0.63**	-0.62**
		(0.24)	(0.24)		(0.23)	(0.23)
Third quartile × Coastal East		-0.28	-0.29		-0.55**	-0.58**
		(0.20)	(0.20)		(0.19)	(0.19)

Upper quartile × Coastal East		-0.29	-0.30		-0.81***	-0.84***
		(0.22)	(0.22)		(0.22)	(0.22)
Third quartile × Central		-0.18	-0.18		-0.27	-0.28
		(0.19)	(0.19)		(0.18)	(0.18)
Upper quartile × Central		0.23	0.22		-0.47*	-0.51*
		(0.21)	(0.21)		(0.21)	(0.21)
Third quartile × Period			-0.01			-0.03***
			(0.01)			(0.01)
Upper quartile × Period			-0.00			0.002
			(0.01)			(0.01)
Household income per capita	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Lower secondary education	0.02	0.01	0.01	-0.09	-0.09	-0.09
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
Upper secondary education	0.01	0.00	0.00	-0.22*	-0.22*	-0.22*
	(0.08)	(0.08)	(0.08)	(0.09)	(0.09)	(0.09)

Non-agricultural *Hukou*	0.17*	0.19*	0.17*	0.03	0.05	-0.02
	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)
Married	-0.07	-0.07	-0.07	-0.09	-0.09	-0.09
	(0.09)	(0.09)	(0.09)	(0.08)	(0.08)	(0.08)
Current smoker	0.02	0.02	0.02	-0.21	-0.22	-0.22
	(0.05)	(0.05)	(0.05)	(0.12)	(0.12)	(0.12)
Drinking alcohol	0.14**	0.14**	0.14**	0.01	0.02	0.01
	(0.05)	(0.05)	(0.05)	(0.09)	(0.09)	(0.09)
Number of observations	17,478	17,478	17,478	23,787	23,787	23,787
AIC	11485.42	11487.49	11490.54	12237.97	12232.66	12222.98
-2 Log Likelihood	-5723.71	-5718.74	-5718.27	-6098.99	-6090.33	-6083.49

* p<0.05, ** p<0.01, *** p<0.001

In Model 2, we added the interactions between urbanization levels and regions based on Model 1. The coefficients of urbanization levels in Model 2 represented the association between urbanization levels and incident HTN in the West. Among women, the model fit improved after accounting for the regional variation in the effect of urbanization levels. Among women of the West, the medium-to-high urbanization level was significantly positively associated with incident HTN, while the positive association between the high urbanization level and incident HTN was not statistically significant. All the interactions between the high urbanization level and regions were statistically significant. And the coefficients were negative, and all their absolute values were larger than the high urbanization level's coefficient, indicating a negative association between the high urbanization level and incident HTN in the Northeast, Coastal East, and Central. The interactions between the medium-to-high urbanization level and regions were also negative, but only the interaction between the medium-to-high urbanization level and the Coastal Region was statistically significant. Among men, however, including the interactions between urbanization levels and regions did not improve the model fit significantly. And none of the interactions added was statistically significant.

In Model 3, we included the interactions between urbanization levels and Period on the basis of Model 2. The coefficients of urbanization levels in Model 3 indicate the association between urbanization levels and incident HTN in the West in 1991. Among women, the model fit further improved. After accounting for the interactions, the magnitude of the coefficient of medium-to-high urbanization level notably increased, while the coefficient of high urbanization level had no notable change. The coefficient of the interaction between the medium-to-high urbanization level and period was negative and statistically significant, suggesting that the magnitude of the positive association between the medium-to-high urbanization level and incident HTN among the female decreased from 1991 to 2015. However, the positive coefficient of the interaction between the high urbanization level and period was insignificant, suggesting that the association between high urbanization level and incident HTN among women had no notable change across the period. Among the male, however, the model fit did not improve after including the interactions between urbanization levels and Period, and none of the interactions added was statistically significant.

To illustrate the association between urbanization levels and incident HTN by region and period, based on the Model 3's estimates, Figure 1 shows odds ratio of getting HTN among women living in communities of higher urbanization level versus their counterparts in communities with the low urbanization level. In 1991, the medium-to-high urbanization level was significantly associated with higher odds of getting HTN except that the association was not statistically significant in the Coast East. The high urbanization level was negatively related to incident HTN in the Northeast, Coastal East, and Central in 1991. But only the negative association in the Coastal East was statistically significant. In the West, we found a positive but insignificant association between the high urbanization level and incident HTN.

In 2000, the magnitude of the positive association between medium-to-high urbanization level and incident HTN was lower than in 1991. Although the positive association was still significant in 2000 in the Northeast and West, the positive association between medium-to-high urbanization level and incident HTN became insignificant in 2000 in the Central. In the Coastal East in 2000, the association became negative but was still insignificant.

The negative association between high urbanization level and incident HTN in the Northeast and West became statistically significant in 2000. The high urbanization level remained to be significantly negatively associated with incident HTN in the Coastal East, and the association between high urbanization level and incident HTN was still positive and insignificant in 2000.

In 2015, the association between medium-to-high urbanization level and incident HTN turned out to be negative except the West, although only the negative association in the Coastal East was significant. In the West in 2015, the positive association between medium-to-high urbanization level and incident HTN became very weak and insignificant. The high urbanization level remained significantly negatively associated with incident HTN except for the West in which we still found a positive but insignificant association.

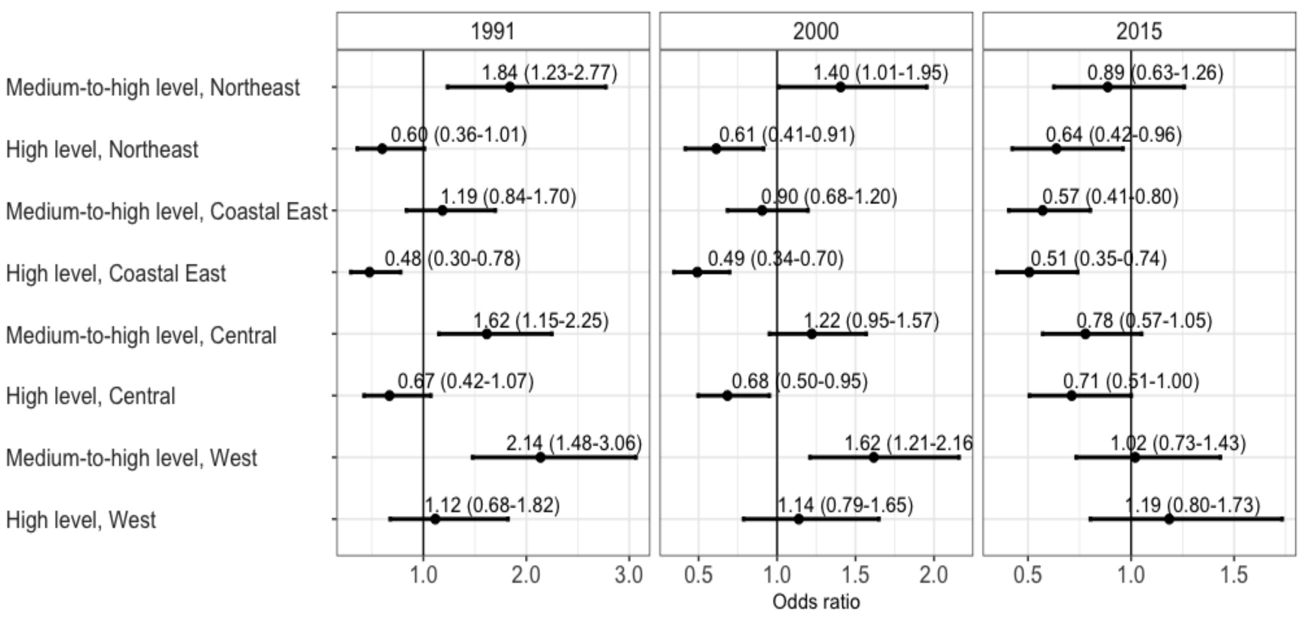

Figure 2 Odds ratio of getting hypertension (the medium-to-high urbanization level, or high urbanization level versus the low urbanization level) among women by region and period.

Figure 3 reported odds ratio of getting HTN among men. Consistent with the estimates of Model 3 in Table 2, the association between urbanization levels and incident HTN was not statistically significant in different regions and years except that a negative association between the high urbanization level and incident HTN became statistically significant across the period in the Coastal East.

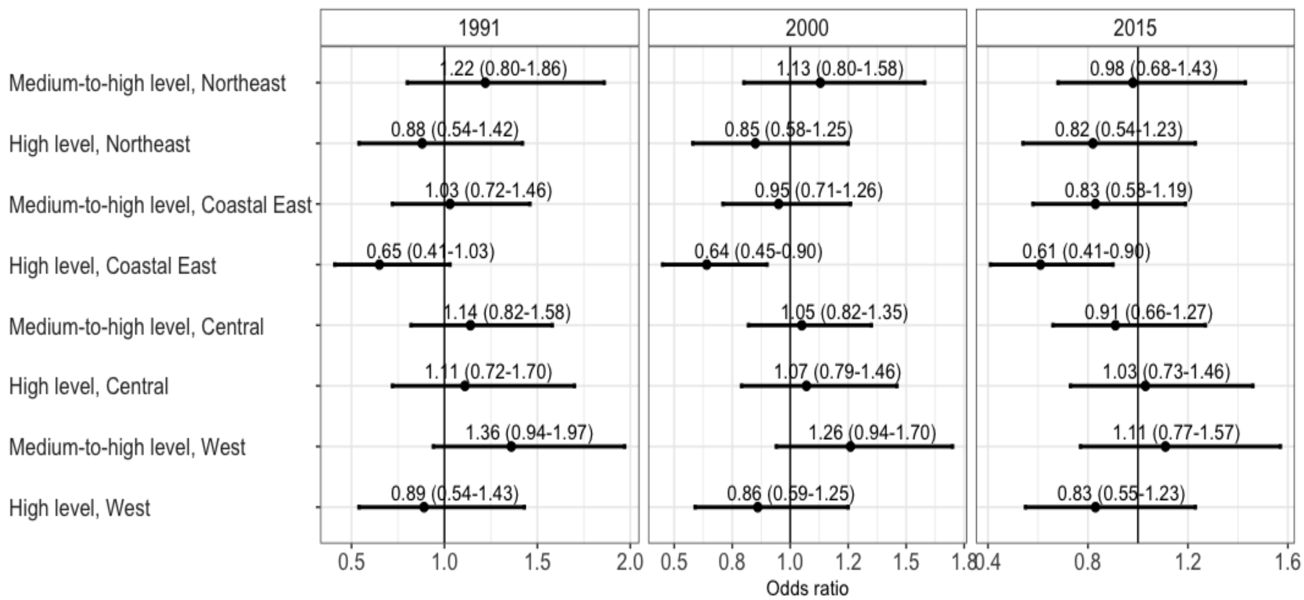

Figure 3 Odds ratio of developing hypertension (the medium-to-high urbanization level, or high urbanization level versus the low urbanization level) among men by region and period.

In terms of control variables, according to estimates of Model 3 for women, having at least upper-secondary education was associated with lower odds of getting HTN. However, household income, nonagricultural *Hukou*, married status, current smoking or alcohol drinking were not significantly associated with incident HTN. For men, nonagricultural *Hukou* and alcohol drinking were significantly associated with higher odds of getting HTN, while household income, educational attainment, married status, and current smoking were not significantly related to incident HTN.

In sensitivity analyses, we rebuilt models based on multiply imputed datasets. We presented estimates in Table A1 of Appendix A. After performing the multiple imputations, the findings that the association between urbanization levels and incident HTN varied by region and period in the female remained unchanged, and the effect of urbanization levels on incident HTN was still not statistically significant in the male, which indicated that our results were robust. However, the negative coefficient of married status became statistically significant among women, and the positive coefficient of nonagricultural *Hukou* type became insignificant among men after performing the multiply imputations.

Discussion

Zhang (2019) showed that the association between communities' urbanization levels and prevalent HTN shifted from positive to negative during 1991-2011. We filled a knowledge gap by studying the association of communities' urbanization with incident HTN. Consistently, we found that the association between communities' urbanization levels and incident HTN also changed during 1991-2015. Furthermore, we found that the association varied by region, and was statistically significant in women but not in men.

In the Coastal East, a more developed region of China, a higher urbanization level was associated with lower odds of getting HTN among women since 2000, while the association was still positive and insignificant among women in 2015 in the West, a less developed region of

China. Although communities' urbanization levels were generally not significantly associated with incident HTN among men, we found that a negative association between the high urbanization level and HTN occurrence became significant across the period in the Coastal East. The regional differences in the association between urbanization levels and incident HTN, together with the changing association from 1991 to 2015, suggested that a higher urbanization level of communities might contribute to HTN prevention when a region becomes more economically developed.

Our study was subject to several limitations. Firstly, although CHNS covers regions vary in socioeconomic development, geography, and population health, it is not nationally representative. Our findings, therefore, can only generalize to adults of the nine provinces included in our study. Secondly, we based our analyses on respondents' places of residence at the time of the survey and did not account for the selection effect of migration. Compared with persons with worse health status, healthier people are more likely to migrate from less developed regions to more developed regions. They are also more likely to move from communities with lower urbanization levels to those with higher urbanization levels. Thus, the association between communities' urbanization levels and incident HTN and the regional differences in the association may be partly due to the selection effect of movement rather than the impact of place of residence.

Our study revealed that the association between the urbanization levels and HTN burden among Chinese adults varied by region, and was different between men and women. Further studies are needed to examine which component of community-level urbanization was more closely related to HTN prevention. The sex difference in the association between communities' urbanization levels and HTN onset remains to be clarified.

References

Allison, P. D. (1982). Discrete-time methods for the analysis of event histories. *Sociological Methodology*, *13*, 61-98.

Chen, F., Yang, Y., & Liu, G. (2010). Social change and socioeconomic disparities in health over the life course in China: A cohort analysis. *American Sociological Review*, *75*(1), 126-150.

Chow, C. K., Teo, K. K., Rangarajan, S., Islam, S., Gupta, R., Avezum, A., ... & Kazmi, K. (2013). Prevalence, awareness, treatment, and control of hypertension in rural and urban communities in high-, middle-, and low-income countries. *JAMA*, *310*(9), 959-968.

Forouzanfar, M. H., Liu, P., Roth, G. A., Ng, M., Biryukov, S., Marczak, L., ... & Ali, R. (2017). Global burden of hypertension and systolic blood pressure of at least 110 to 115 mm Hg, 1990-2015. *JAMA*, *317*(2), 165-182.

Gong, P., Liang, S., Carlton, E. J., Jiang, Q., Wu, J., Wang, L., & Remais, J. V. (2012). Urbanisation and health in China. *The Lancet*, *379*(9818), 843-852.

Hay, S.I., A.A. Abajobir, K.H. Abate, C. Abbafati, K.M. Abbas, F. Abd-Allah, R.S. Abdulkader, A.M. Abdulle, T.A. Abebo, and S.F. Abera. (2017). Global, regional, and national disabilityadjusted life-years (DALYs) for 333 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *The Lancet*, 390(10100), 1260-1344.

Jones-Smith, J. C., & Popkin, B. M. (2010). Understanding community context and adult health changes in China: development of an urbanicity scale. *Social Science & Medicine*, *71*(8), 1436-1446.

Lackland, D. T., & Weber, M. A. (2015). Global burden of cardiovascular disease and stroke: hypertension at the core. *Canadian Journal of Cardiology*, *31*(5), 569-571.

Li, J., Shi, L., Li, S., Xu, L., Qin, W., & Wang, H. (2017). Urban-rural disparities in hypertension prevalence, detection, and medication use among Chinese Adults from 1993 to 2011. *International Journal for Equity in Health*, *16*(1), 50.

Li, Y., Wang, L., Feng, X., Zhang, M., Huang, Z., Deng, Q., ... & Wang, L. (2018). Geographical variations in hypertension prevalence, awareness, treatment and control in China: findings from a nationwide and provincially representative survey. *Journal of Hypertension*, *36*(1), 178-187.

Liang, Y., Liu, R., Du, S., & Qiu, C. (2014). Trends in incidence of hypertension in Chinese adults, 1991–2009: the China Health and Nutrition Survey. *International Journal of Cardiology*, *175*(1), 96-101.

Liu, G., Sun, M., Wang, Z., Jian, W. (2016). Association analysis between urbanization and non-communicable diseases and health-related behavior. *Journal of Peking University (Health Sciences)*, 48(3), 478-482.

Miao, J., & Wu, X. (2016). Urbanization, socioeconomic status and health disparity in China. *Health & Place*, *42*, 87-95.

Mills, K. T., Bundy, J. D., Kelly, T. N., Reed, J. E., Kearney, P. M., Reynolds, K., ... & He, J. (2016). Global disparities of hypertension prevalence and control: a systematic analysis of population-based studies from 90 countries. Circulation, 134(6), 441-450.

Popkin, B. M. (1999). Urbanization, lifestyle changes and the nutrition transition. *World Development*, *27*(11), 1905-1916.

Popkin, B. M. (2006). Global nutrition dynamics: the world is shifting rapidly toward a diet linked with noncommunicable diseases. *The American Journal of Clinical Nutrition*, *84*(2), 289-298.

Singer, J. D., & Willett, J. B. (2003). Applied longitudinal data analysis: Modeling change and event occurrence. Oxford University Press.

Van de Poel, E., O'Donnell, O., & Van Doorslaer, E. (2012). Is there a health penalty of China's rapid urbanization?. *Health Economics*, *21*(4), 367-385.

Ward, M. M. (2013). Estimating disease prevalence and incidence using administrative data: some assembly required. *The Journal of Rheumatology*, 40(8), 1241-1243.

Xu, X., Byles, J. E., Shi, Z., & Hall, J. J. (2015). Evaluation of older Chinese people's macronutrient intake status: results from the China Health and Nutrition Survey. *British Journal of Nutrition*, *113*(1), 159-171.

Yang, G., Wang, Y., Zeng, Y., Gao, G. F., Liang, X., Zhou, M., ... & Vos, T. (2013). Rapid health transition in China, 1990–2010: findings from the Global Burden of Disease Study 2010. *The Lancet*, *381*(9882), 1987-2015.

Zhang, B., Zhai, F. Y., Du, S. F., & Popkin, B. M. (2014). The China Health and Nutrition Survey, 1989–2011. *Obesity Reviews*, *15*, 2-7.

Zhang, N. (2019). Urban–rural disparities in cardiovascular disease risks among middle-aged and older Chinese: two decades of urbanisation. *Ageing & Society*, 1-23.

Zhou, M., H. Wang, J. Zhu, W. Chen, L. Wang, S. Liu, Y. Li, L. Wang, Y. Liu, and P. Yin. 2016. "Cause-specific mortality for 240 causes in China during 1990–2013: a systematic subnational analysis for the Global Burden of Disease Study 2013." *The Lancet* 387(10015), 251-272.

Appendix A

To examine whether our findings changed after accounting for the missing data, we performed multiple imputations and created five multiply imputed datasets. We conducted multilevel discrete-time event history analyses based on each imputed dataset. We then pooled results estimated based on each dataset and reported the coefficients and standard errors in Table A1.

Table A1 Estimates of multilevel discrete-time event history analyses, based on multiply imputed datasets, China Health and Nutrition Survey (1991-2015)

	Male	Female
	Model 3	Model 3
Intercept	-5.37***	-6.63***
	(0.18)	(0.20)
Duration	0.07***	0.11***
	(0.01)	(0.01)
Duration^2	-0.0004*	-0.001***
	(0.00)	(0.00)
Coastal East	0.86***	0.86***
	(0.14)	(0.14)
Northeast	0.62***	0.89***
	(0.15)	(0.15)
Central	0.46***	0.60***
	(0.13)	(0.14)

Third quartile of urbanicity index	0.32	0.69***
	(0.19)	(0.19)
Upper quartile of urbanicity index	-0.09	0.07
	(0.24)	(0.27)
Period	0.45***	0.42***
	(0.02)	(0.03)
Period^2	-0.04***	-0.03***
	(0.001)	(0.003)
Period^3	0.001***	0.001***
	(0.00)	(0.00)
Third quartile × Northeast	-0.07	-0.04
	(0.22)	(0.22)
Upper quartile × Northeast	-0.10	-0.54*
	(0.24)	(0.25)
Third quartile × Coastal East	-0.32	-0.43*
	(0.19)	(0.20)
Upper quartile × Coastal East	-0.34	-0.77***
	(0.24)	(0.21)
Third quartile × Central	-0.26	-0.16
	(0.17)	(0.19)
Upper quartile × Central	0.09	-0.43*
	(0.21)	(0.20)
Third quartile × Period	-0.01	-0.03**

	(0.01)	(0.01)
Upper quartile × Period	0.002	0.003
	(0.01)	(0.01)
Household income per capita	-0.02	-0.01
	(0.02)	(0.02)
Lower secondary education	0.005	-0.07
	(0.07)	(0.06)
Upper secondary education	-0.03	-0.23*
	(0.08)	(0.09)
Non-agricultural *Hukou*	0.13	-0.06
	(0.08)	(0.10)
Married	-0.09	-0.20
	(0.09)	(0.07)**
Current smoker	0.03	-0.20
	(0.05)	(0.12)
Drinking alcohol	0.11*	-0.01
	(0.06)	(0.10)
Number of observations	22096	30004

* p<0.05, ** p<0.01, *** p<0.001