Urban index and lifestyle risk factors for cardiovascular diseases in China: A cross-sectional study

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Abstract

China is at a stage of rapid urbanization over the past decades, and the association of urbanization with cardiovascular disease has been confirmed by previous studies. However, few studies assessed the association of urbanization with cardiovascular risk factors, especially in Chinese population. We conducted a cross-sectional, populational-based study, using data from China Health and Nutrition Survey (CHNS) in 2009. The logistic regression was used to assess the association of urbanization measured by urban index with cardiovascular risk factors (diabetes mellitus, hypertension, dyslipidemia, obesity, smoking, physical activity and fruits and vegetables consumption), varied with sex. The current study included 18,887 participants enrolled (mean age 39.8 ± 19.8 years; 52.2% female) who live in China. In regression model, the urban index was

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significantly associated with the variations of cardiovascular risk factors for male, including diabetes (OR 1.34, 95% CI: 1.22–1.48), hypercholesterolemia (OR 1.15, 95% CI: 1.09–1.22), never smoking (OR 0.92, 95% CI: 0.89–0.96), higher fruits and vegetables consumptions (OR 0.93, 95% CI: 0.87–0.99), higher body mass index (BMI) (OR 1.16, 95% CI: 1.10–1.22), and higher physical activity (OR 0.69, 95% CI: 0.66–0.73). Compared with the male, the associations of urban index with cardiovascular risk factors for female were similar, but not for BMI (OR 1.00, 95% CI: 0.96–1.05). The present finding emphasizes the changes of cardiovascular risk factors associated with urbanization in China, and indicated that close attention should be paid to the risk of hypercholesterolemia, diabetes and men's obesity in the process of urbanization.

**Keywords**
Cardiovascular disease, China, urbanization, cardiovascular risk factors, China health and nutrition survey

**Introduction**
Cardiovascular diseases (CVDs) are the dominant cause of disease burden and death worldwide.¹ The higher risks of CVD death were closely associated with cardiovascular risk factors, such as obesity, abnormal blood pressure, dyslipidemia, diabetes and smoking.² Recently, national macroeconomic variable is conceptualized as a fundamental cause of disease.³,⁴ Prior studies have reported that urbanization was one of the major national macroeconomic variable associated with the increasing CVD events and cardiometabolic risk markers in rapidly developing countries.⁵,⁶ The underlying mechanisms that support observed associations between urbanization and CVD events are, however, incompletely understood. In this context, it is established that the produce of cardiovascular risk factors precedes the onset of CVD events.² Potential associations between urbanization and cardiovascular risk factors may therefore further elucidate reported associations with CVD outcomes. However, there are few studies to explore the association of urbanization with cardiovascular risk factors, especially in China that possessed the world's largest urban population.⁷

Therefore, we performed an analysis using data from the China Health and Nutrition Survey (CHNS) to assess the association of urbanization with cardiovascular risk factors in China. Additionally, documenting the consistency or variations in this association, both globally and by countries with rapid urbanization trend, will help the development of global and context-specific strategies for prevention.

**Methods**

**Study design**
The CHNS, an ongoing open cohort, international collaborative project between the Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Health (NINH, former National Institute of Nutrition and Food Safety) at the Chinese Center for Disease Control and Prevention (CCDC), was designed to examine the effects of the health,
nutrition, and family planning policies and programs implemented by national and local governments with ongoing data collection across nine provinces in China (south: Hunan, Guizhou, Guangxi, Hubei; central: Shandong, Jiangsu, Henan; north: Liaoning, Heilongjiang) during nine survey rounds from 1989 to 2011. A multistage, random cluster process was used to draw the sample surveyed in each of the provinces, 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. The primary sampling units have increased to 360: 60 urban neighborhoods, 60 suburban neighborhoods, 30 towns, and 180 villages. This cohort study mirrored national age-sex-education profiles initially, and the details about CHNS have been described previously.

A total of 18,887 adult participants from the 2009 CHNS were enrolled in current study. The inclusion criteria included the following. (a) All of the recruited individuals were \( \geq 18 \) years and \( \leq 80 \) years; (b) The participant included the data about age, gender, urban index; (c) The participant included the study endpoints about cardiovascular health metrics (hypertension, diabetes, obesity, hypercholesterolemia, physical activity, consumption of fruits and vegetables, or current smoking); (d) The participant gave the written informed consent. Those missed the information on covariates were excluded. In 18,887 included participants, 8277 provided the data on physical activity; 9454 provided the data on hypercholesterolemia; 10,597 provided the data on hypertension; 10,624 provided the data on diabetes; 11,100 provided the data on obesity; 10,643 provided the data on smoking; 11,542 provided the data on fruits and vegetable consumption. These participants were analysis for each risk factor, respectively.

The study was approved by the Institutional Review Board at the Ministry of Health, and the National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention, the University of North Carolina at Chapel Hill, and the China-Japan Friendship Hospital. All participants gave their written informed consent.

**Cardiovascular health metrics**

The data of seven cardiovascular risk factors (hypertension, diabetes, hypercholesterolemia, obesity, physical activity, consumption of fruits and vegetables, and current smoking) were collected from the CHNS (2009). We used the definition of American Heart Association (AHA) to record each cardiovascular risk factor using dichotomous variable (Supplemental data 1: Table S1).

Diabetes mellitus was defined by non-fasting glucose \( \geq 200 \text{mg/dl} \), fasting glucose \( \geq 126 \text{mg/dl} \), or self-reported or previously physician diagnosis. Hypertension was defined as systolic BP (SBP) above 140 mm Hg or diastolic BP (DBP) above 90 mm Hg, or self-reported or previously physician diagnosis. Hypercholesterolemia was defined as total cholesterol (TC) \( \geq 6.21 \text{mmol/L (240 mg/dl)} \) or self-reported physician diagnosis. Then obesity was defined as the body mass index (BMI) above 28 kg/m\(^2\). Respondents who reported they didn’t
smoke during their lifetime were coded as “Never smoke,” and those who currently smoked were coded as “Current smoke.” Sufficient physical activity was noted if individuals participated in activities of ≥150 total minutes of moderate or vigorous activity per week. Consumption of fruits and vegetables was defined based on the composite measure of daily fruits and vegetable consumption, and the consumption less than five servings of vegetables or fruits per day was defined as insufficient fruit and vegetable consumption. The relevant data in current study were collected using the validated questionnaires (Supplemental data 2–4).13

Urban index

The urban index was the sum of 12 components (Economic activity, Population density, Modern markets, Traditional markets, Infrastructure, Diversity, Education, Housing, Transportation, Communications, Sanitation, Social services, Health infrastructure), which was previously validated to measure the degree of urbanization for the study communities.

We identified 12 components to distinguish and define urbanicity that could be operationalized in the CHNS study, then allotted a maximum total of 10 points each to the each of the 12 components. Details on the scoring algorithm have been described elsewhere.14

Statistical analysis

The study focused on the association of the levels of urbanicity with the cardiovascular risk factors. All participants were categorized the urban index into tertiles based on the sample distribution, and further stratified by gender due to the sex differences in cardiovascular risk factors.15 The logistic regression models were used to assess the associations of individual cardiovascular health metric and urban index with adjustment for age based on different gender. To explore potential non-linear associations, restricted cubic splines were then introduced into the models. All statistical analyses were performed with Stata V.14.0 for Windows (Stata Corp, College Station, Texas, USA).

Results

The 18,887 participants were stratified into tertiles based on urban indexes (Tertile 1 [T1]: $N = 6224$, Age $37.6 \pm 19.4$ years; Tertile 2 [T2]: $N = 6441$, Age $38.6 \pm 19.2$ years; Tertile 3 [T3]: $N = 6222$, Age $43.3 \pm 20.3$ years), and further stratified by gender (9025 [47.8%] Men). Descriptive characteristics of the included participants are presented in Table 1. The participants with the highest tertile of urban index (T3), both males and females, were more diagnosed as obesity, hypertension, diabetes, hypercholesterolemia, and had more never smoker, sufficient physical activity, sufficient fruit and vegetable consumption.

Table 2 presents strong associations between urban indexes and life style risk factors for CDVs stratified by sex using logistic regression model. Compared with the lowest tertile of urban index (T1), males with the highest tertile of urban index
Table 1. The characteristics of the included participants.

| Tertile of urbanicity index* | Number of participants, No. (%) | Cardiovascular risk factors, n (%) or mean (SD) |
|-----------------------------|----------------------------------|-----------------------------------------------|
|                             | Age, y                           | Obesity, No. (%)                             | Hypercholesterolemia, No. (%) | Hypertension, No. (%) | Diabetes, No. (%) | Glucose, mmol/L | Never smoking, No. (%) | Physical activity, No. (%) | Consumption of fruits and vegetables, No. (%) |
| Total participants          |                                 |                                               |                             |                        |                  |               |                        |                                    |                                         |
| All                         | 18887 (100)                      | 39.8 (19.8)                                  | 11100 (100)                 | 9454 (100)             | 10597 (100)       | 10624 (100)    | 5.4 (1.4)                | 10643 (100)                        | 10610 (100)                        | 11542 (100)                          |
| T1 (30–53)                  | 6224 (33.0)                      | 37.6 (19.4)                                  | 3269 (29.5)                 | 2773 (29.3)            | 3089 (29.2)       | 3039 (28.6)    | 5.2 (1.3)                | 3048 (28.6)                        | 3037 (28.6)                        | 3408 (29.5)                          |
| T2 (53–76)                  | 6441 (34.1)                      | 38.6 (19.2)                                  | 3658 (33.0)                 | 3099 (32.8)            | 3476 (32.8)       | 3456 (32.5)    | 5.4 (1.4)                | 3456 (32.5)                        | 3428 (32.3)                        | 3776 (32.7)                          |
| T3 (76–107)                 | 6222 (32.9)                      | 43.3 (20.3)                                  | 4173 (37.6)                 | 3582 (37.9)            | 4032 (38.0)       | 4129 (38.9)    | 5.5 (1.5)                | 4139 (38.9)                        | 4145 (39.1)                        | 4358 (37.8)                          |
| Men                         | All 9025 (100)                   | 39.3 (20.1)                                  | 5381 (100)                  | 4494 (100)             | 5093 (100)        | 5114 (100)     | 5.4 (1.6)                | 5122 (100)                         | 5151 (100)                         | 5651 (100)                           |
| T1 (30–53)                  | 2999 (33.2)                      | 37.2 (19.7)                                  | 1625 (30.2)                 | 1372 (30.5)            | 1527 (30.0)       | 1492 (29.2)    | 5.2 (1.4)                | 1496 (29.2)                        | 1508 (29.3)                        | 1704 (30.2)                          |
| T2 (53–76)                  | 3045 (33.7)                      | 38.1 (19.5)                                  | 1768 (32.9)                 | 1447 (32.2)            | 1658 (32.6)       | 1654 (32.3)    | 5.5 (1.6)                | 1654 (32.3)                        | 1646 (32.0)                        | 1845 (32.7)                          |
| T3 (76–107)                 | 2981 (33.0)                      | 42.7 (20.6)                                  | 1988 (36.9)                 | 1675 (37.3)            | 1908 (37.5)       | 1968 (38.4)    | 5.6 (1.8)                | 1972 (38.5)                        | 1997 (38.8)                        | 2102 (37.2)                          |
| Women                       | All 9862 (100)                   | 40.2 (19.5)                                  | 5719 (100)                  | 4960 (100)             | 5504 (100)        | 5510 (100)     | 5.3 (1.3)                | 5521 (100)                         | 5459 (100)                         | 5891 (100)                           |
| T1 (30–53)                  | 3225 (32.7)                      | 38.0 (19.1)                                  | 1444 (28.8)                 | 1401 (28.3)            | 1562 (28.4)       | 1547 (28.1)    | 5.4 (1.3)                | 1552 (28.1)                        | 1529 (28.0)                        | 1704 (28.9)                          |
| T2 (53–76)                  | 3396 (34.4)                      | 39.0 (18.8)                                  | 1890 (33.1)                 | 1652 (33.3)            | 1818 (33.0)       | 1802 (32.7)    | 5.3 (1.3)                | 1802 (32.6)                        | 1782 (32.6)                        | 1931 (32.8)                          |
| T3 (76–107)                 | 3241 (32.9)                      | 43.8 (20.0)                                  | 2185 (38.2)                 | 1907 (38.5)            | 2124 (38.6)       | 2161 (39.2)    | 5.1 (1.1)                | 2167 (39.3)                        | 2148 (39.4)                        | 2256 (38.3)                          |

*Though the urban index was a consecutive value, we use tertile here just to show the tendency.
were associated with a higher risk of diabetes (OR 1.34, [95% CI: 1.22–1.48], \( p \leq 0.001 \)), hypercholesterolemia (odds ratio [OR] 1.15 [95% CI: 1.09–1.22], \( p \leq 0.001 \)), sufficient physical activity (OR 0.69 [95% CI: 0.66–0.73], \( p \leq 0.001 \)), obesity (OR 1.16 [95% CI: 1.10–1.22], \( p \leq 0.001 \)), sufficient fruit and vegetable consumption (OR 0.93 [95% CI: 0.87–0.99], \( p = 0.016 \)), and lower smoke exposure (OR 0.92 [95% CI: 0.89–0.96], \( p \leq 0.001 \)).

Simultaneously, the results indicated that there was not found the association between urban index and women’s obesity (OR 1.00 [95% CI: 0.96–1.05], \( p = 0.865 \)) (Table 2). Additionally, Compared with the lowest tertile of urban index (T1), females with the highest tertile of urban index (T3) showed the strong association with the higher risk of diabetes (OR 1.33 [95% CI: 1.21–1.47], \( p \leq 0.001 \)), lower smoke exposure (OR 0.79 [95% CI: 0.73–0.87], \( p \leq 0.001 \)), hypercholesterolemia (OR 1.08 [95% CI: 1.03–1.13], \( p = 0.003 \)), sufficient fruit and vegetable consumption (OR 0.87 [95% CI: 0.82–0.92], \( p \leq 0.001 \)), sufficient physical activity (OR 0.64 [95% CI: 0.60–0.68], \( p \leq 0.001 \)) (Table 2). However, the association between urban index and the risk of hypertension was not found in males (OR 0.99 [95% CI: 0.96–1.02], \( p = 0.482 \)) or females (OR 1.00 [95% CI: 0.97–1.04], \( p = 0.922 \)) (Table 2).

To explore the associations between urban index and cardiovascular risk factors as continuous variable, glucose and hemoglobin A1c as two continuous variables were used to evaluate diabetes while diastolic pressure and systolic pressure were used to evaluate hypertension. The association between associations between urban index and cardiovascular risk factors were further assessed by linear regression, and the results were similar as the primary results (Supplemental data 1: Table S2). Furthermore, the results of restrictive cubic spline revealed that there was no clear or consistent evidence for non-linearity of associations between urban index and cardiovascular risk factors as dichotomous variable (Figure 1) or as continuous variable (Supplemental data 1: Figure S1).
Figure 1. Restricted cubic spline modeling of the relationship between urban index and cardiovascular risk factors: (a) physical activity (female), (b) physical activity (male), (c) hypercholesterolemia (female), (d) hypercholesterolemia (male), (e) hypertension (female), (f) hypertension (male), (g) obesity (female), (h) obesity (male), (i) diabetes (female), (j) diabetes (male), (k) insufficient consumption of fruits and vegetables (female), (l) insufficient consumption of fruits and vegetables (male), (m) current smoking (female), and (n) current smoking (male).
Discussion

In the current cross-sectional study of Chinese population, we found urban index was associated with the higher risks of hypercholesterolemia and diabetes but not for hypertension, regardless of the gender. However, urban index was also associated with a lower smoke exposure and the increased negative risk factors (physical activity, consumption of vegetables and fruits), which might contribute to improve cardiovascular health. Of note, there were different trends of obesity in various urbanicity levels among men and women. Urban index was associated with the higher risk of obesity in males rather than in females. Our findings suggested the impact of urbanization on positive (obesity, hypercholesterolemia, diabetes, hypertension, smoking) and negative (physical activity, consumption of vegetables and fruits) cardiovascular risk factors in Chinese population, and underlined the sex differences in association between urbanization and obesity. Such information has contributed to generate the global and context-specific strategies for prevention of CVD in the country with rapid urbanization trend.

There was a similar study to analyze the relationship between urbanicity and lifestyle risk factors of CVD.\textsuperscript{16} It was also a cross-sectional study using Poisson regression models to assess associations of urbanicity with lifestyle risk factors by quartile of urbanicity. This study differed from the previous research in the following ways. We used the urban index, analogous to urbanicity score\textsuperscript{14} to investigate the association of urban index with cardiovascular risk factors in China, and used the restricted cubic spline to estimate the non-linearity. Moreover, we used prevalence rather than mortality to evaluate the diseases occurrences. To our knowledge, this study was the first one to analyze the associations of cardiovascular risk factors and urban index in China.

Our study indicated that urbanization contributed to increased positive risk factors (diabetes, hypercholesterolemia) but not for hypertension, and decreased smoke exposure. As we know, the urbanization could lead to the changes in lifestyle which might contribute to the development of diabetes.\textsuperscript{17} Similar to a previous study reported, we indicated that the urban index was associated with increased risk of diabetes in both sexes. In developing countries, diabetes was associated with higher urbanized status.\textsuperscript{18} It was likely that in developing countries, the higher urban index was associated with higher access to food and exposure to unhealthy lifestyles and environment. A prospective study of 512,869 adults in China found that diabetes was more common in urban areas.\textsuperscript{19} Another similar study in China reported that higher prevalence of diabetes among the urban residents than rural residents.\textsuperscript{20}

In the analysis stratified according to the level of urbanized development, the high prevalence of hypercholesterolemia was found in higher urbanized areas compared with lower urbanized areas. In the process of urbanization, the intake of lipid should increase with the development of economy. Previous studies have revealed that higher urban level had aroused in energy-rich diets and sedentary lifestyles,\textsuperscript{21,22} which might be associated with dyslipidemia in higher urbanized areas. Interestingly, the more senior urban index was associated with most cardiovascular
risk factors, but the association of urbanization with hypertension was not found in our study. The glucose or lipid of participants had a rapid increase in a transient time due to the energy-rich diets and sedentary lifestyles associated with urbanization, but the blood pressure can be confirmed only through a more prolonged period.\textsuperscript{21,22} Due to the exploratory results from the cross-sectional study, the association of urbanization with hypertension needs to be further clarified by future studies.

Smoking is probably the most complex and the least understood among the risk factors for CVDs.\textsuperscript{23} Results in research suggested that the rate of smoking might experience further decreases in areas with a heightened potential of urbanization.\textsuperscript{24} People in the urban area received a higher education about smoking cessation, and the healthy conception was also changing with the urbanization.

Several studies had previously explored urban-rural differences in hypertension, diabetes mellitus, and obesity in similar populations.\textsuperscript{25,26} Cross-Sectional analysis in Boston found such positive and independent association between urban residence and BMI.\textsuperscript{27} Interestingly, the tendency that we observed between obesity and the urban index was different by gender. There was a positive association between obesity and index among men but not among women. Obesity was a complicated issue arising from a myriad of environmental and individual factors. However, some studies about dietary intake and eating behaviors showed that the female had a healthier dietary profile and motivational variables than the male.\textsuperscript{28,29} Another study revealed that the female had healthier nutritional habits than the male and had more interested in change of lifestyle.\textsuperscript{30} Therefore, BMI in women had barely changed in the process of urbanization while obesity in men was related to the urban index.

Additionally, our study also indicated that urbanization contributed to increased negative risk factors (physical activity, consumption of fruits and vegetables), which might contribute to improve cardiovascular health. Recent research in Australia showed that higher green leafy vegetable intake was related to a lower CCA-IMT (Common Carotid Artery Intima-media Thickness) and a lower risk of an ischemic cerebrovascular disease event, independent of other risk factors.\textsuperscript{31} People who lived in areas with more urban characteristics was associated with an increase in healthy behaviors, including higher fruit and vegetable consumption,\textsuperscript{16} especially in the developed country. This previous result was consistent with what we found in our study that the more urban areas had higher fruit and vegetable consumption.

In current study, the higher physical activity was found in participants lived in the urban area compared with the rural area. However, previous studies reported sharp declines in physical activity for Chinese people from 1991 to 2009.\textsuperscript{32,33} Additionally, some cross-sectional studies found that the urbanization was associated with lower physical activity.\textsuperscript{34,35} The conflicting results might be caused by a reason that our study mainly focus on the leisure physical activity rather than occupational physical activity. The previous study from CHNS have reported that individuals living in higher urbanized areas increased the leisure physical activity,
although it did not have sufficient increase in leisure physical activity to counteract
the decrease of occupational physical activity in lower urbanized areas.36

There are several limitations in our study. First, the study is a cross-sectional
design, which reduces our ability to elucidate causal relationships. Hence, what we
discussed in this study was implications rather than confirmations. Second,
although the data came from China, the data may not be nationally representative.
Thus, it is needed to be of caution in extrapolating our findings to other popula-
tion. Third, there might be recall bias in this study due to the use of questionnaires
to collect the data even using the validated questionnaires.13 Fourth, the previous
disease and medication use history were not adjusted in the logistic regression due
to the lack of available data, although our analysis adjusted the age and the popu-
lation were stratified according to gender to get the robust results. Fifth, although
our study included its large sample size of almost 20,000 individuals, the sample
size calculation or power analysis was not performed. Last, the relations between
the risk factors and CVD are a dynamic process, while we just used past risk fac-
tors to assess, which will minimize the potential reverse causality. A prospective
study is needed in the future.

Conclusion

The present findings of this study underscore the change of cardiovascular risk fac-
tors associated with urbanization in China, and show that the never smoker, physi-
cal activity, consumption of vegetables and fruits were increased in the process of
urbanization. However, the risk of hypercholesterolemia and diabetes were also
increased in higher urbanized areas. Of note, in the process of urbanization, the
higher risk of obesity was just found in males rather than in females. Such informa-
tion has contributed to understand the impact of urbanization on cardiovascular
health in China, and generate the global and context-specific strategies for preven-
tion of CVD in the country with rapid urbanization trend.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research,
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Ethics approval

Ethical approval for this study was obtained from The China Health and Nutrition Survey
(CHNS) was approved by the Institutional Review Board at the Ministry of Health, and the
National Institute for Nutrition and Health, Chinese Center for Disease Control and
Prevention, the University of North Carolina at Chapel Hill, and the China-Japan
Friendship Hospital. The data in our study are obtained from the public data set of the China Health and Nutrition Survey (CHNS). However, the public data set did not provide the APPROVAL NUMBER/ID for us. The detailed information can be found on the website “https://www.cpc.unc.edu/projects/china.” Therefore, it is difficult for us to provide the detailed APPROVAL NUMBER/ID.

Informed consent
Written informed consent was obtained from all subjects before the study.

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Supplemental material
Supplemental material for this article is available online.

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