Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Association Between Aggressive Urbanization and Dyslipidemia in Middle-Aged and Older Chinese Adults: Evidence From CHARLS

Zhiwen Wang
Guangxi University of Chinese Medicine
Xiao Jiang
2660920552@qq.com
Guangxi University of Chinese Medicine
Yujing Ye
Guangxi University of Chinese Medicine
Yu Lin
Guangxi University of Chinese Medicine
Jiayang Tang
Guangxi University of Chinese Medicine
Kongdi Liu
Guangxi University of Chinese Medicine

Research Article

Keywords: Aggressive urbanization, Dyslipidemia, All-cause mortality, CHARLS, China

Posted Date: June 24th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9912625/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background Rapid urbanization has profoundly reshaped the health landscape in China. However, the association between aggressive urbanization and dyslipidemia remains insufficiently understood. We aimed to investigate the association between aggressive urbanization and dyslipidemia in a nationally representative sample of middle-aged and older adults in China, and to further explore its nonlinear pattern, subgroup heterogeneity, spatial distribution, and association with all-cause mortality.

Methods Data were obtained from the 2011 baseline wave of the China Health and Retirement Longitudinal Study (CHARLS). Participants with available data on dyslipidemia status and the aggressive urbanization index were included. Weighted logistic regression models were used to estimate odds ratios (ORs) and 95% confidence intervals (CIs) for the association between aggressive urbanization and dyslipidemia. Restricted cubic spline models were applied to assess nonlinearity, and subgroup analyses were conducted to evaluate effect modification. Spatial distribution was visualized using heat maps. Logistic regression, Cox proportional hazards models, and Kaplan-Meier analysis were further used to examine the association between aggressive urbanization and all-cause mortality.

Results A total of 8,388 participants were included, of whom 862 (10.3%) had dyslipidemia. In the fully adjusted model, higher aggressive urbanization was independently associated with lower odds of dyslipidemia (OR = 0.86, 95% CI: 0.74-0.99, P = 0.040). Quartile-based analysis and restricted cubic spline modeling revealed a significant nonlinear association. Significant interactions were observed for age, hypertension, and diabetes. Spatial analysis showed marked geographic heterogeneity in aggressive urbanization across China. Higher aggressive urbanization was also associated with increased all-cause mortality risk in survival analyses.

Conclusions Aggressive urbanization was significantly associated with dyslipidemia in this nationally representative Chinese population, and the association was nonlinear and heterogeneous across subgroups. Higher aggressive urbanization was also associated with increased all-cause mortality, suggesting that rapid urban transformation may have complex health consequences.

Background

Urbanization is a major demographic and socioeconomic process that has substantially altered population health in China[1][2]. Although urbanization has improved infrastructure and healthcare access, it has also been accompanied by environmental and behavioral changes that may increase the burden of chronic non-communicable diseases[2][3].

Dyslipidemia is a major modifiable risk factor for cardiovascular disease and has become an important public health concern in China[4][5]. Previous studies have suggested that urban living is associated with cardiometabolic disorders, including obesity, diabetes, hypertension, and dyslipidemia[6]. However, conventional indicators such as urban or rural residence and urbanization rate may not adequately capture the complexity of urban development.

The aggressive urbanization index may provide a more nuanced measure of urban expansion beyond conventional urbanization indicators. Nevertheless, evidence linking aggressive urbanization to dyslipidemia remains limited, particularly in nationally representative Chinese populations[7]. In addition, the health effects of aggressive urbanization may vary across population subgroups and regions, and may also extend to broader outcomes such as all-cause mortality[8][9].

Therefore, using data from the China Health and Retirement Longitudinal Study (CHARLS), we investigated the association between aggressive urbanization and dyslipidemia in a nationally representative sample of middle-aged and older adults in China. We further examined the nonlinear pattern of this association, subgroup-specific heterogeneity, spatial distribution, and its relationship with all-cause mortality[10].

Methods

Study design and population

This study was based on data from the 2011 baseline wave of the China Health and Retirement Longitudinal Study (CHARLS), a nationally representative survey of middle-aged and older adults in China[10].

A total of 17,708 participants were initially identified. Participants with available data on dyslipidemia status and the aggressive urbanization index were eligible. Individuals with missing data on demographic characteristics, anthropometric measurements, behavioral factors, or metabolic covariates used in the multivariable models were excluded. Ultimately, 8,388 participants were included in the final cross-sectional analysis.

Assessment of aggressive urbanization

Urbanization exposure was assessed using the aggressive urbanization index at baseline. In subsequent analyses, the index was modeled both as a continuous variable and as a categorical variable based on quartiles. In the mortality analysis, tertiles were used.

Outcome definition

Outcome definition
The primary outcome was dyslipidemia at baseline. Participants were classified into dyslipidemia and non-dyslipidemia groups for descriptive and regression analyses.A secondary outcome was all-cause mortality during follow-up, which was used in time-to-event analyses.

Covariates

Covariates included age, sex, education level, marital status, body mass index (BMI), smoking status, alcohol consumption, diabetes, hypertension, triglyceride-glucose (TyG) index, and waist circumference.

Statistical analysis

Baseline characteristics were summarized according to dyslipidemia status. Continuous variables were presented as mean ± standard deviation (SD), and categorical variables as numbers and percentages. Group differences were assessed using the design-based Kruskal-Wallis test for continuous variables and Pearson's chi-square test with Rao-Scott adjustment for categorical variables.

Weighted logistic regression models were used to estimate ORs and 95% CIs for the association between aggressive urbanization and dyslipidemia. Model 1 was unadjusted. Model 2 was adjusted for age, education level, sex, marital status, and BMI. Model 3 was further adjusted for smoking status, alcohol consumption, diabetes, hypertension, TyG index, and waist circumference.

The aggressive urbanization index was also categorized into quartiles to assess dose-response patterns. Restricted cubic spline analysis was performed to evaluate potential nonlinearity. Subgroup analyses and interaction tests were conducted to assess effect modification.

A provincial-level heat map was generated to visualize the spatial distribution of aggressive urbanization in China.

For the all-cause mortality analysis, multivariable logistic regression and Cox proportional hazards models were used, and Kaplan-Meier curves were compared using the log-rank test. All analyses were conducted using R software, and a two-sided P value < 0.05 was considered statistically significant.

Results

Study population selection

A total of 17,708 participants were initially identified from the 2011 baseline survey of CHARLS. After excluding 2,392 individuals with missing data on dyslipidemia or the aggressive urbanization index, 15,316 participants remained. We then excluded 137 participants with incomplete demographic information and 8,791 participants with missing anthropometric, behavioral, or metabolic covariates. Ultimately, 8,388 participants were included in the final cross-sectional analysis (Fig. 1).

Baseline characteristics

Among the 8,388 participants included in the analysis, 862 (10.3%) had dyslipidemia. The mean age of the study population was 59.39 ± 10.06 years, and 3,839 (45.8%) were men. Compared with participants without dyslipidemia, those with dyslipidemia were more likely to be women (60% vs. 54%, P = 0.004), to reside in urban areas (rural residence: 47% vs. 59%, P < 0.001), and to have a higher educational level (P

= 0.002). Participants with dyslipidemia also had significantly greater height, body weight, waist circumference, body mass index (BMI), and TyG index than those without dyslipidemia (all $P < 0.05$). In addition, the prevalence of diabetes (32% vs. 13%, $P < 0.001$) and hypertension (70% vs. 46%, $P < 0.001$) was markedly higher in the dyslipidemia group. No significant differences were observed in age, marital status, alcohol consumption, or smoking status between the two groups (all $P > 0.05$) (Table 1).

Table 1
Baseline characteristics of the study population according to dyslipidemia status.

Characteristic	Overall N = 241,984,842	Without dyslipidemia N = 216,611,143	With dyslipidemia N = 25,373,699	P-value
Age, years	59.39 ± 10.06	59.39 ± 10.22	59.38 ± 8.49	0.289
Sex				0.004
Female	4,549 (55%)	4,030 (54%)	519 (60%)	
Male	3,839 (45%)	3,496 (46%)	343 (40%)	
Education level				0.002
Level 1	3,995 (46%)	3,639 (46%)	356 (39%)	
Level 2	1,856 (22%)	1,670 (22%)	186 (22%)	
Level 3	1,710 (21%)	1,523 (21%)	187 (24%)	
Level 4	827 (11%)	694 (10%)	133 (15%)	
Marriage				0.249
Other	995 (13%)	907 (14%)	88 (11%)	
Married	7,393 (87%)	6,619 (86%)	774 (89%)	
Rural residence	5,374 (58%)	4,919 (59%)	455 (47%)	< 0.001
Height, m	1.58 ± 0.08	1.58 ± 0.08	1.59 ± 0.08	0.032
Weight, kg	59.43 ± 12.43	58.54 ± 11.41	67.00 ± 17.27	< 0.001
Waist circumference, cm	84.52 ± 12.97	83.84 ± 12.79	90.32 ± 13.07	< 0.001
Body mass index, kg/m²	23.70 ± 4.22	23.38 ± 3.84	26.40 ± 5.99	< 0.001
TyG index	8.69 ± 0.67	8.64 ± 0.65	9.06 ± 0.74	< 0.001
Ever drank alcohol				0.090
No	5,160 (62%)	4,608 (62%)	552 (65%)	
Yes	3,228 (38%)	2,918 (38%)	310 (35%)	
Ever smoked				0.064
No	5,147 (62%)	4,571 (61%)	576 (65%)	
Yes	3,241 (38%)	2,955 (39%)	286 (35%)	
Diabetes				< 0.001

Characteristic	Overall N = 241,984,842	Without dyslipidemia N = 216,611,143	With dyslipidemia N = 25,373,699	P-value
No	7,102 (85%)	6,505 (87%)	597 (68%)	
Yes	1,286 (15%)	1,021 (13%)	265 (32%)	
Hypertension				< 0.001
No	4,430 (51%)	4,158 (54%)	272 (30%)	
Yes	3,958 (49%)	3,368 (46%)	590 (70%)	

Data are presented as mean ± SD or n (%). TyG, triglyceride-glucose. P-values were derived from the design-based Kruskal-Wallis test or Pearson's χ^2 test with Rao-Scott adjustment, as appropriate.

Association between aggressive urbanization and dyslipidemia

In the unadjusted model, the aggressive urbanization index was inversely associated with dyslipidemia, with a log(OR) of -0.24 (95% CI: -0.39 to -0.08, P = 0.002). After adjustment for age, education level, sex, marital status, and BMI, the association remained statistically significant, with a log(OR) of -0.17 (95% CI: -0.32 to -0.03, P = 0.018). In the fully adjusted model, aggressive urbanization remained independently associated with lower odds of dyslipidemia (OR = 0.86, 95% CI: 0.74–0.99, P = 0.040) (Table 2).

In the fully adjusted model, several covariates were also significantly associated with dyslipidemia. Higher education level was associated with increased odds of dyslipidemia, particularly for level 3 (OR = 1.52, 95% CI: 1.09–2.11, P = 0.013) and level 4 (OR = 1.99, 95% CI: 1.44–2.75, P < 0.001), compared with level 1. Male sex was associated with lower odds of dyslipidemia (OR = 0.69, 95% CI: 0.55–0.88, P = 0.003). BMI, diabetes, hypertension, TyG index, and waist circumference were all positively associated with dyslipidemia (all P < 0.01), whereas age, marital status, smoking status, and alcohol consumption were not significantly associated with the outcome.

Table 2
Association between aggressive urbanization index and dyslipidemia

Variable	Unadjusted model OR (95% CI)	P value	Partially adjusted model OR (95% CI)	P value	Fully adjusted model OR (95% CI)	P value
Aggressive urbanization index	0.79 (0.68–0.92)	0.002	0.84 (0.73–0.97)	0.018	0.86 (0.74–0.99)	0.040

Quartile-based analysis of aggressive urbanization

When the aggressive urbanization index was categorized into quartiles, a non-monotonic association was observed. In the unadjusted model, compared with participants in the lowest quartile (Q1), those in Q2 had significantly higher odds of dyslipidemia (OR = 1.62, 95% CI: 1.10–2.40, P = 0.015), whereas no significant associations were found for Q3 or Q4. Similar findings were observed after partial adjustment and full adjustment. In the fully adjusted model, the ORs for dyslipidemia were 1.49 (95% CI: 1.05–2.10, P = 0.025) for Q2, 1.01 (95% CI: 0.69–1.47, P > 0.900) for Q3, and 0.80 (95% CI: 0.55–1.17, P = 0.300) for Q4, relative to Q1 (Table 3). These findings suggested that the relationship between aggressive urbanization and dyslipidemia was not simply linear.

Table 3
Quartile-based analysis of aggressive urbanization and dyslipidemia

Variable	Unadjusted model OR (95% CI)	p-value	Partially adjusted model OR (95% CI)	p-value	Fully adjusted model OR (95% CI)	p-value
Aggressive urbanization index						
Q1	**1 (Ref)**		**1 (Ref)**		**1 (Ref)**	
Q2	1.62 (1.10–2.40)	0.015	1.57 (1.13–2.19)	0.008	1.49 (1.05–2.10)	0.025
Q3	0.90 (0.57–1.43)	0.700	0.99 (0.67–1.46)	> 0.900	1.01 (0.69–1.47)	> 0.900
Q4	0.65 (0.41–1.02)	0.059	0.80 (0.54–1.17)	0.200	0.80 (0.55–1.17)	0.300

Nonlinear association between aggressive urbanization and dyslipidemia

Restricted cubic spline analysis further demonstrated a significant nonlinear association between aggressive urbanization and dyslipidemia. As shown in Fig. 2, the predicted probability of dyslipidemia initially increased slightly at lower levels of the aggressive urbanization index and then gradually declined as the index increased. Both the overall association and the test for nonlinearity were statistically significant (P for overall < 0.001; P for nonlinearity < 0.001).

Subgroup analyses

Subgroup analyses were performed to assess whether the association between aggressive urbanization and dyslipidemia differed across clinically relevant strata (Fig. 3). Significant interactions were observed for age (P for interaction = 0.002), hypertension (P for interaction = 0.011), and diabetes (P for interaction = 0.003). Specifically, among participants aged < 40 years, aggressive urbanization was

positively associated with dyslipidemia (OR = 1.98, 95% CI: 1.08–3.66), whereas inverse associations were observed among those aged 40–64 years (OR = 0.88, 95% CI: 0.81–0.97) and those aged ≥ 65 years (OR = 0.78, 95% CI: 0.68–0.90).

Similarly, the inverse association was more evident among participants with hypertension (OR = 0.79, 95% CI: 0.71–0.87), whereas no significant association was observed among those without hypertension (OR = 0.98, 95% CI: 0.87–1.11). In participants without diabetes, the OR was 0.87 (95% CI: 0.79–0.95), while in those with diabetes it was 0.82 (95% CI: 0.69–0.96), with a significant interaction between strata.

No significant interactions were found for education level, marital status, alcohol use, smoking status, or BMI (all P for interaction > 0.05). A borderline interaction was observed for sex (P for interaction = 0.079), suggesting possible sex-specific heterogeneity, although this did not reach statistical significance.

Spatial Distribution of Aggressive Urbanization

To further elucidate the geographical distribution of aggressive urbanization in China, a provincial-level heat map was generated based on the aggressive urbanization index (Fig. 4). The map revealed pronounced spatial heterogeneity across the country. Contrary to the conventional expectation that eastern and coastal regions exhibit higher levels of aggressive urbanization, our findings indicated that provinces in central and southwestern China — including Hunan, Chongqing, Sichuan, Guangxi, and Jiangxi — tended to demonstrate relatively higher index values (ranging from − 3.15 to − 4.33). In contrast, several eastern and coastal provinces, such as Jiangsu, Zhejiang, Shanghai, Shandong, and Fujian, exhibited lower index values (below − 5.40). Additionally, northern and western provinces, including Inner Mongolia, Shaanxi, and Shanxi, also showed relatively low levels of aggressive urbanization.

Aggressive urbanization and all-cause mortality

Table 4 summarizes the associations between tertiles of the aggressive urbanization index and all-cause mortality in the multivariable logistic and Cox models. In the logistic regression trend analysis, no significant linear or quadratic trend was observed after adjustment for age, sex, marital status, education level, diabetes, hypertension, alcohol consumption, and smoking status (P for linear trend = 0.200; P for quadratic trend > 0.900).

By contrast, the Cox proportional hazards model showed a graded positive association between aggressive urbanization and mortality risk. Using the lowest tertile (Q1) as the reference, participants in Q2 had a 10% higher hazard of all-cause mortality (HR = 1.10, 95% CI: 1.04–1.17; P < 0.001), and those in Q3 had a 38% higher hazard (HR = 1.38, 95% CI: 1.30–1.46; P < 0.001). In the adjusted logistic model, male sex was associated with lower odds of death (OR = 0.57, 95% CI: 0.46–0.70), whereas married participants and those with higher education levels showed higher odds of death. In the Cox model,

most covariates were not significantly associated with survival time, although hypertension showed a borderline positive association with mortality risk (HR = 1.05, 95% CI: 1.00-1.10; P = 0.068).

Table 4
Logistic regression and Cox proportional hazards analyses of all-cause mortality according to tertiles of the aggressive urbanization index.

Characteristic	Logi			Cox		
	OR	95% CI	p-value	HR	95% CI	p-value
Ordered(A.quantile.var)						
Ordered(A.quantile.var).L	0.93	0.82, 1.05	0.2			
Ordered(A.quantile.var).Q	0.99	0.87, 1.13	> 0.9			
Sex						
Female	—	—		—	—	
Male	0.57	0.46, 0.70	< 0.001	1.00	0.93, 1.07	> 0.9
Marriage						
Other	—	—		—	—	
Married	1.72	1.43, 2.07	< 0.001	1.02	0.94, 1.11	0.6
Age	0.91	0.90, 0.91	< 0.001	1.00	1.00, 1.00	0.5
Education level						
Level1	—	—		—	—	
Level2	1.23	1.03, 1.48	0.025	0.98	0.92, 1.04	0.5
Level3	1.41	1.13, 1.78	0.003	0.99	0.93, 1.06	0.8
Level4	1.86	1.36, 2.60	< 0.001	1.01	0.93, 1.10	0.8
Diabetes						
No	—	—		—	—	
Yes	0.66	0.55, 0.80	< 0.001	1.03	0.97, 1.10	0.3
Hypertension						
No	—	—		—	—	
Yes	0.82	0.70, 0.95	0.008	1.05	1.00, 1.10	0.068
Ever drank alcohol						
No	—	—		—	—	
Yes	0.91	0.77, 1.07	0.2	0.96	0.91, 1.01	0.15
Abbreviations: CI = Confidence Interval, HR = Hazard Ratio, OR = Odds Ratio						

Characteristic	Logi			Cox		
	OR	95% CI	p-value	HR	95% CI	p-value
Ever smoked						
No	—	—		—	—	
Yes	0.67	0.56, 0.81	< 0.001	1.02	0.96, 1.09	0.5
A.quantile.var						
Q1				—	—	
Q2				1.10	1.04, 1.17	< 0.001
Q3				1.38	1.30, 1.46	< 0.001
Abbreviations: CI = Confidence Interval, HR = Hazard Ratio, OR = Odds Ratio						

Kaplan-Meier survival analysis

Kaplan-Meier survival curves were constructed to compare all-cause survival according to the aggressive urbanization index (Fig. 5). Participants in the high aggressive urbanization group (>= -4.916) showed consistently lower survival probabilities than those in the low aggressive urbanization group (<-4.916) throughout follow-up. The two survival curves gradually separated over time, and the difference between groups was statistically significant according to the log-rank test (P < 0.0001), indicating a worse survival profile among individuals with higher aggressive urbanization levels.

Discussion

In this nationally representative study of middle-aged and older adults in China, we found that aggressive urbanization was significantly associated with dyslipidemia, although the nature of this association was complex and clearly nonlinear. In the fully adjusted model, a higher aggressive urbanization index was independently associated with lower odds of dyslipidemia. However, quartile-based analysis and restricted cubic spline modeling showed that this relationship was not simply linear. Rather, the probability of dyslipidemia appeared to increase slightly at lower levels of aggressive urbanization and then gradually decline as the index increased. In addition, subgroup analyses revealed significant heterogeneity according to age, hypertension, and diabetes status. Beyond dyslipidemia, higher levels of aggressive urbanization were also associated with an increased risk of all-cause mortality in survival analyses, indicating that the health consequences of aggressive urbanization may differ depending on the outcome examined.

These findings suggest that aggressive urbanization may exert both protective and harmful influences on health through multiple pathways[1][3]. The inverse association observed between aggressive urbanization and dyslipidemia after full adjustment may reflect several features of more urbanized settings, including improved access to healthcare services, greater disease awareness, more frequent

health examinations, and better management of cardiometabolic risk factors[5][11]. Individuals living in more urbanized areas may also be more likely to receive earlier diagnosis and treatment for lipid abnormalities, which could contribute to a lower observed prevalence of dyslipidemia after accounting for major confounders[12]. At the same time, aggressive urbanization is often accompanied by profound changes in the physical and social environment, including shifts in diet, reduced occupational physical activity, psychosocial stress, environmental exposure, and widening health inequalities[13][14][15]. These competing influences may help explain why the relationship between aggressive urbanization and dyslipidemia did not follow a simple monotonic pattern.

The nonlinear association identified in the present study is particularly noteworthy. Compared with the lowest quartile, participants in the second quartile of aggressive urbanization had significantly higher odds of dyslipidemia, whereas those in higher quartiles did not show a similarly elevated risk. The spline analysis further supported this pattern by demonstrating an initial increase followed by a gradual decline in predicted dyslipidemia probability across the distribution of the aggressive urbanization index. One possible explanation is that populations exposed to early or intermediate stages of rapid urban transition may experience a period of metabolic vulnerability, during which adverse lifestyle changes occur more quickly than adaptive improvements in healthcare, infrastructure, or health behavior[3]. As urbanization progresses further, the potential benefits of better medical access, improved public services, and greater health awareness may begin to offset some of these metabolic risks. This interpretation highlights the importance of considering urbanization as a dynamic process rather than a static exposure.

The subgroup findings provide additional insight into the heterogeneous effects of aggressive urbanization. We observed a positive association between aggressive urbanization and dyslipidemia among participants younger than 40 years, whereas inverse associations were found among those aged 40–64 years and those aged 65 years or older. This pattern suggests that younger individuals may be more susceptible to the adverse behavioral and psychosocial consequences of rapid urban change, such as sedentary lifestyles, unhealthy dietary patterns, work-related stress, and sleep disruption. In contrast, older adults may derive greater benefit from improved healthcare access and chronic disease monitoring in more urbanized environments. We also found that the inverse association was more evident among participants with hypertension, and significant interaction was observed according to diabetes status. These results suggest that pre-existing cardiometabolic conditions may modify the way urbanization influences lipid metabolism, possibly through differences in healthcare utilization, risk awareness, or treatment intensity. Collectively, these findings emphasize that the health effects of aggressive urbanization are not uniform across population groups[16].

Our spatial analysis further demonstrated substantial geographic heterogeneity in aggressive urbanization across China. Interestingly, provinces in central and southwestern China showed relatively higher aggressive urbanization index values than several eastern and coastal provinces that are traditionally viewed as more developed. This finding suggests that the aggressive urbanization index may capture not only the level of urban development, but also the pace, imbalance, or disruptive features

of the urbanization process. In this context, regions undergoing rapid structural transformation may face distinct health challenges that are not fully reflected by conventional urban-rural classifications. Therefore, the relationship between urbanization and health should be interpreted within the broader context of regional development trajectories and local social environments.

An additional finding of this study is that higher aggressive urbanization was associated with increased all-cause mortality in the Cox proportional hazards model and with lower survival probability in Kaplan-Meier analysis. This result appears to differ from the inverse association observed for dyslipidemia and underscores the multidimensional nature of urbanization-related health effects. While more urbanized settings may offer advantages for the detection and management of dyslipidemia, they may simultaneously expose individuals to broader long-term risks that influence survival, including chronic stress, environmental pollution, social fragmentation, and unequal access to supportive resources[17][18]. Thus, the apparent protective association with dyslipidemia should not be interpreted as evidence that aggressive urbanization is uniformly beneficial for health. Instead, our findings indicate that aggressive urbanization may have divergent short- and long-term implications across different health outcomes.

Several strengths of this study should be acknowledged. First, we used a large, nationally representative sample of Chinese adults with detailed information on demographic, behavioral, anthropometric, and metabolic factors. Second, we applied multiple complementary analytic approaches, including multivariable regression, quartile analysis, restricted cubic spline modeling, subgroup analysis, spatial mapping, and survival analysis, which allowed us to characterize the association comprehensively. Third, the consistency of the nonlinear pattern across different modeling strategies strengthens confidence in the robustness of the main findings. Nevertheless, some limitations should also be considered. First, the analysis of dyslipidemia was cross-sectional, and therefore causal inference or temporal directionality cannot be established. Second, residual confounding remains possible despite adjustment for a wide range of covariates, particularly for factors such as diet, lipid-lowering medication use, healthcare utilization, environmental pollution, and area-level socioeconomic characteristics. Third, the exclusion of participants with missing data may have introduced selection bias. Finally, although the aggressive urbanization index provides a useful summary measure, it may not fully capture all dimensions of urban change relevant to cardiometabolic health and survival.

Conclusion

In conclusion, aggressive urbanization was significantly associated with dyslipidemia in this nationally representative Chinese population, and the association was distinctly nonlinear. Higher aggressive urbanization was associated with lower odds of dyslipidemia overall after multivariable adjustment, but an elevated risk was observed at intermediate levels of urbanization, and important heterogeneity was identified across age, hypertension, and diabetes subgroups. At the same time, higher aggressive urbanization was associated with increased all-cause mortality, suggesting that the health effects of rapid urban transformation may vary according to the specific outcome considered. These findings underscore the need to move beyond a simple rural-urban dichotomy and to understand aggressive

urbanization as a complex social and environmental process with both potentially protective and adverse health consequences. Future longitudinal studies are needed to clarify the causal mechanisms underlying these associations and to identify which aspects of rapid urban development may be most relevant for cardiometabolic prevention and healthy aging.

Abbreviations

CHARLS
China Health and Retirement Longitudinal Study
OR
odds ratio
CI
confidence interval
HR
hazard ratio
BMI
body mass index
TyG
triglyceride-glucose.

Declarations

Ethics approval and consent to participate

This study was based on data from the China Health and Retirement Longitudinal Study (CHARLS). CHARLS was approved by the Biomedical Ethics Review Committee of Peking University (approval number: IRB00001052-11015), and written informed consent was obtained from all participants prior to data collection. The present secondary analysis used de-identified publicly available data and was conducted in accordance with the Declaration of Helsinki.

Availability of data and materials

The data that support the findings of this study are available from the China Health and Retirement Longitudinal Study (CHARLS) database. These data are publicly accessible to qualified researchers upon reasonable application through the official CHARLS website: https://charls.charlsdata.com.

Competing interests

The authors declare that they have no competing interests.

Funding

This work was supported by the High-Level Key Discipline Construction Project of the State Administration of Traditional Chinese Medicine (No. zyyzdxk-2023167) and the Natural Science Research Project of Saiens New Medicine College, Guangxi University of Chinese Medicine (No. 2024ZZB009).

Authors' contributions

Zhiwen Wang and Xiao Jiang conceived and designed the study. Zhiwen Wang, Yujing Ye, Yu Lin, Jiayang Tang, and Kongdi Liu collected and organized the data. Zhiwen Wang performed the statistical analyses and drafted the manuscript. Xiao Jiang supervised the study and critically revised the manuscript. All authors reviewed the manuscript, approved the final version, and agree to be accountable for all aspects of the work.

Acknowledgments

The authors would like to thank the China Health and Retirement Longitudinal Study (CHARLS) research team for providing access to the data and all participants for their valuable contributions to this study.

References

1. Godfrey R, Julien M, London. England), 5(2), 137–41. https://doi.org/10.7861/clinmedicine.5-2-137.
2. Eckert S, Kohler S. Urbanization and health in developing countries: a systematic review. World Health Popul. 2014;15(1):7–20. https://doi.org/10.12927/whp.2014.23722.
3. Guan Q, Zhu C, Zhang G, Wang J, Xiang H, Chen Y, Cui H. (2023). Association of land urbanization and type 2 diabetes mellitus prevalence and mediation of greenness and physical activity in Chinese adults. Environmental pollution (Barking, Essex: 1987), 337, 122579. https://doi.org/10.1016/j.envpol.2023.122579
4. Li JJ, Zhao SP, Zhao D, Lu GP, Peng DQ, Liu J, Chen ZY, Guo YL, Wu NQ, Yan SK, Wang ZW. &Gao, R. L. (2023). 2023 Chinese guideline for lipid management. Frontiers in pharmacology, 14, 1190934. https://doi.org/10.3389/fphar.2023.1190934
5. Xia Q, Chen Y, Yu Z, Huang Z, Yang Y, Mao A, Qiu W. Prevalence, awareness, treatment, and control of dyslipidemia in Chinese adults: a systematic review and meta-analysis. Front Cardiovasc Med. 2023;10:1186330. https://doi.org/10.3389/fcvm.2023.1186330.
6. Wu J, Chen J, Li Z, Jiao B, Muennig P. Spatiotemporal Variation of the Association between Urbanicity and Incident Hypertension among Chinese Adults. Int J Environ Res Public Health. 2020;17(1):304. https://doi.org/10.3390/ijerph17010304.
7. Attard SM, Howard AG, Herring AH, Zhang B, Du S, Aiello AE, Popkin BM. &Gordon-Larsen, P. (2015). Differential associations of urbanicity and income with physical activity in adults in urbanizing China: findings from the population-based China Health and Nutrition Survey 1991–2009. The international journal of behavioral nutrition and physical activity, 12, 152. https://doi.org/10.1186/s12966-015-0321-2

8. Wang F, Liu S, Chen T, Zhang H, Zhang Y, Bai X. How urbanization affects residents' health risks: evidence from China. Environ Sci Pollut Res Int. 2023;30(13):35554–71. https://doi.org/10.1007/s11356-022-24767-y.
9. Ji JS, Zhu A, Lv Y, Shi X. Interaction between residential greenness and air pollution mortality: analysis of the Chinese Longitudinal Healthy Longevity Survey. Lancet Planet health. 2020;4(3):e107–15. https://doi.org/10.1016/S2542-5196(20)30027-9.
10. Zhao Y, Hu Y, Smith JP, Strauss J, Yang G. Cohort profile: the China Health and Retirement Longitudinal Study (CHARLS). Int J Epidemiol. 2014;43(1):61–8. https://doi.org/10.1093/ije/dys203.
11. Zhang X, Dupre ME, Qiu L, Zhou W, Zhao Y, Gu D. Urban-rural differences in the association between access to healthcare and health outcomes among older adults in China. BMC Geriatr. 2017;17(1):151. https://doi.org/10.1186/s12877-017-0538-9.
12. Zhang M, Deng Q, Wang L, Huang Z, Zhou M, Li Y, Zhao Z, Zhang Y, Wang L. Prevalence of dyslipidemia and achievement of low-density lipoprotein cholesterol targets in Chinese adults: A nationally representative survey of 163,641 adults. Int J Cardiol. 2018;260:196–203. https://doi.org/10.1016/j.ijcard.2017.12.069.
13. Day K. Built environmental correlates of physical activity in China: A review. Prev Med Rep. 2016;3:303–16. https://doi.org/10.1016/j.pmedr.2016.03.007.
14. Hong C, Xiong X, Li J, Ning X, Qi D, Yang Y, Liu Y, Luo Y. Urbanization and depressive symptoms among middle-aged and older adults in China. Front public health. 2022;10:1086248. https://doi.org/10.3389/fpubh.2022.1086248.
15. Wang L, Chen G, Pan Y, Xia J, Chen L, Zhang X, Silang Y, Chen J, Xu H, Zeng C, Wei J, Li S, Guo Y, Yang S, Hong F, Zhao X. ,&China Multi-Ethnic Cohort (CMEC) collaborative group (2021). Association of long-term exposure to ambient air pollutants with blood lipids in Chinese adults: The China Multi-Ethnic Cohort study. Environ Res, 197, 111174. https://doi.org/10.1016/j.envres.2021.111174
16. Mu L, Liu J, Zhou G, Wu C, Chen B, Lu Y, Lu J, Yan X, Zhu Z, Nasir K, Spatz ES, Krumholz HM. &Zheng, X. (2021). Obesity Prevalence and Risks Among Chinese Adults: Findings From the China PEACE Million Persons Project, 2014–2018. Circulation. Cardiovascular quality and outcomes, 14(6), e007292. https://doi.org/10.1161/CIRCOUTCOMES.120.007292
17. Hu M, Wei J, Hu Y, Guo X, Li Z, Liu Y, Li S, Xue Y, Li Y, Liu M, Wang L, Liu X. Long-term effect of submicronic particulate matter (PM1) and intermodal particulate matter (PM1-2.5) on incident dyslipidemia in China: A nationwide 5-year cohort study. Environ Res. 2023;217:114860. https://doi.org/10.1016/j.envres.2022.114860.
18. Li D, Ruan Y, Kang Q, Rong C. (2023). Association of urbanization with psychological well-being in Chinese adults aged 50 years and older: a population-based study. Revista brasileira de psiquiatria (Sao Paulo, Brazil: 1999), 45(3), 249–257. https://doi.org/10.47626/1516-4446-2022-3025

Figures

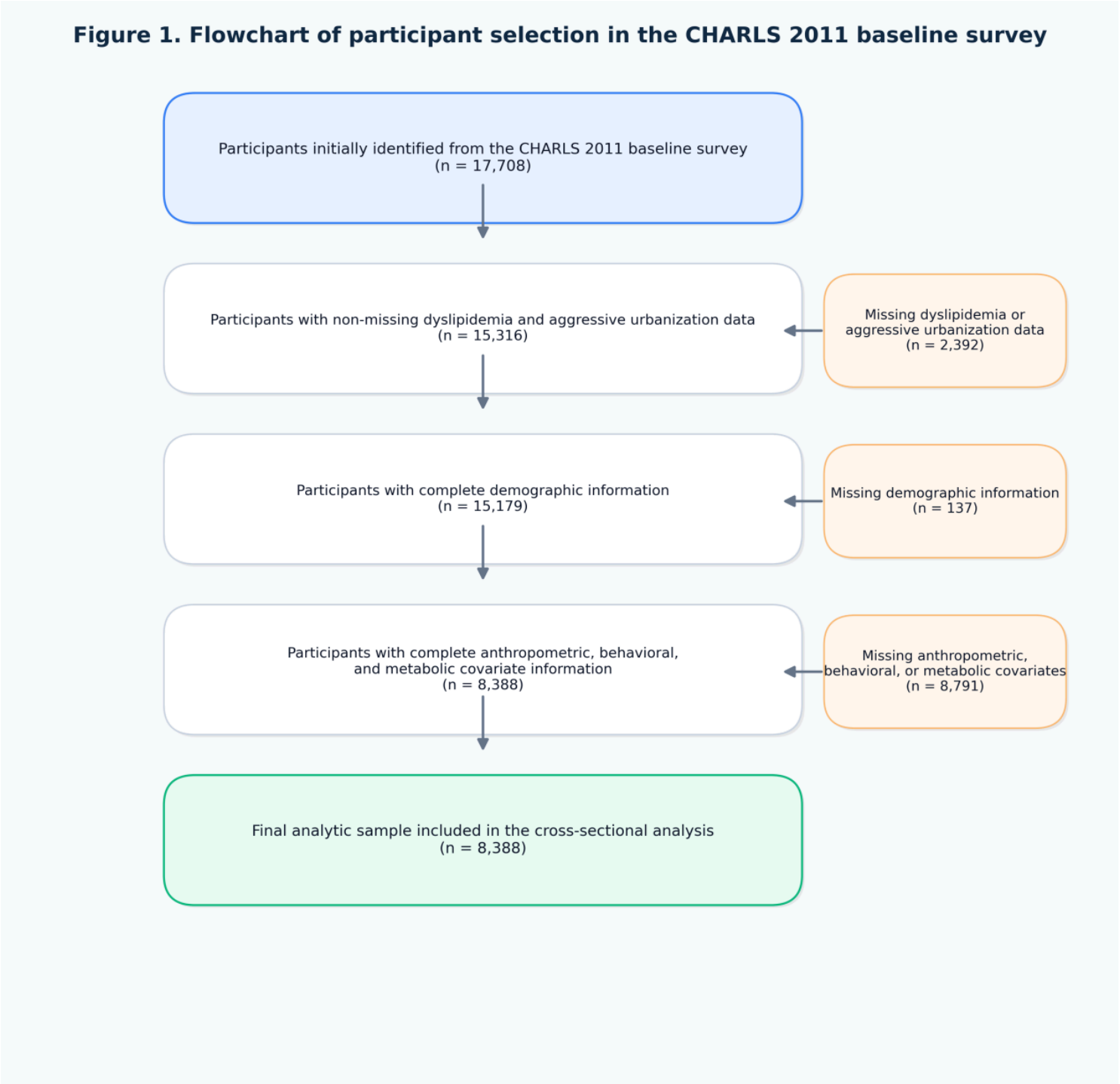


Figure 1

See image above for figure legend.

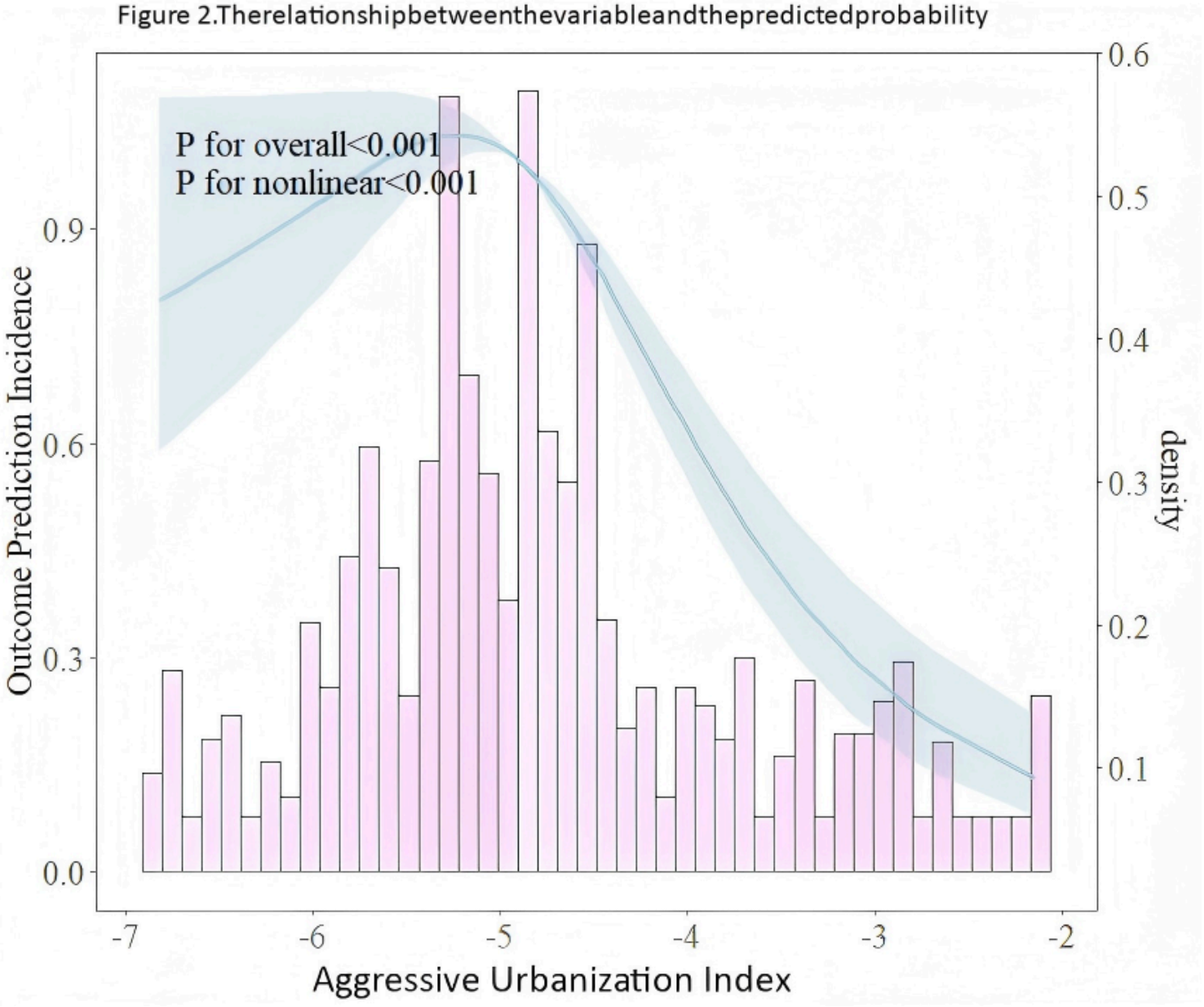


Figure 2

See image above for figure legend.

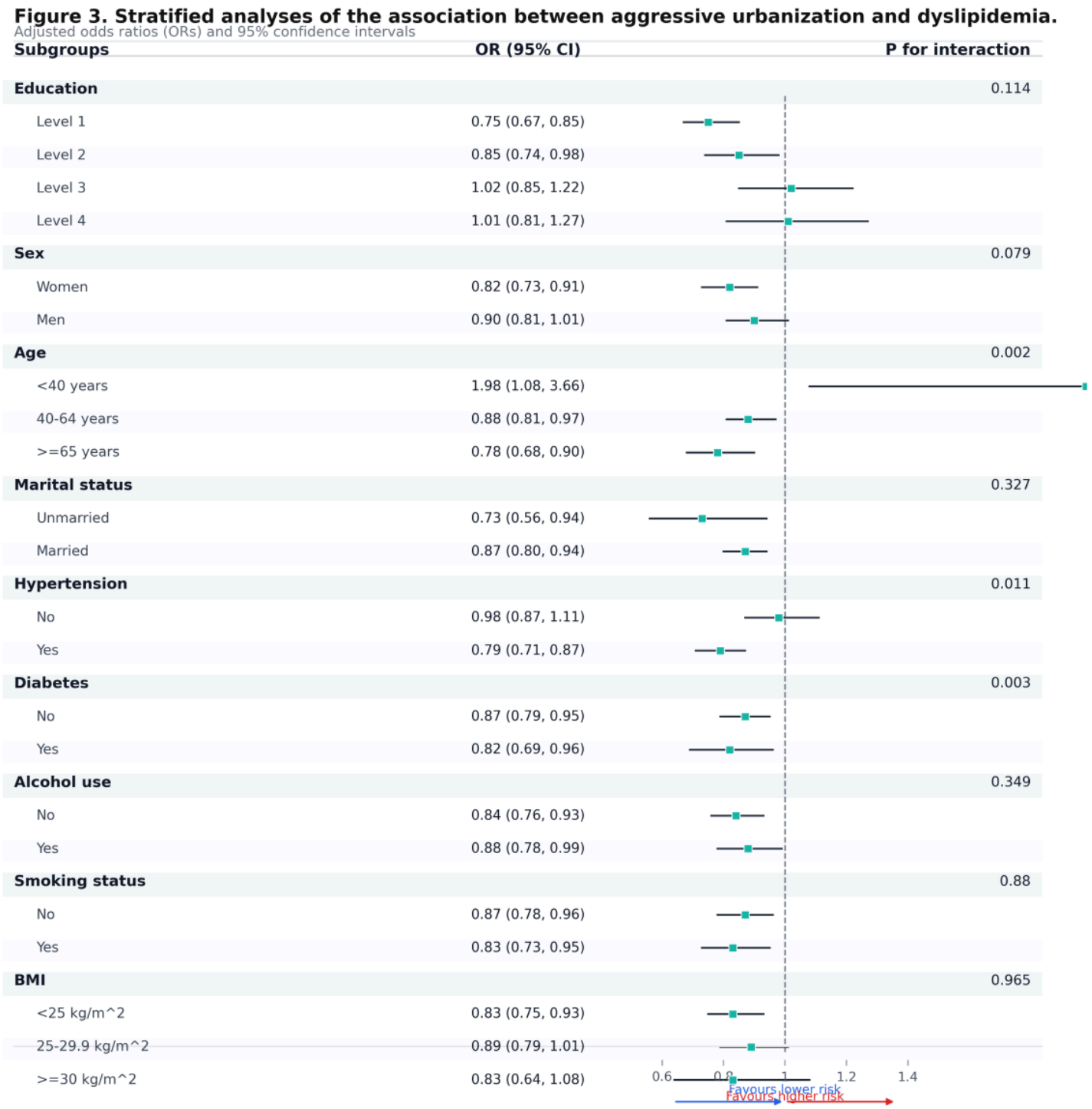


Figure 3

See image above for figure legend.

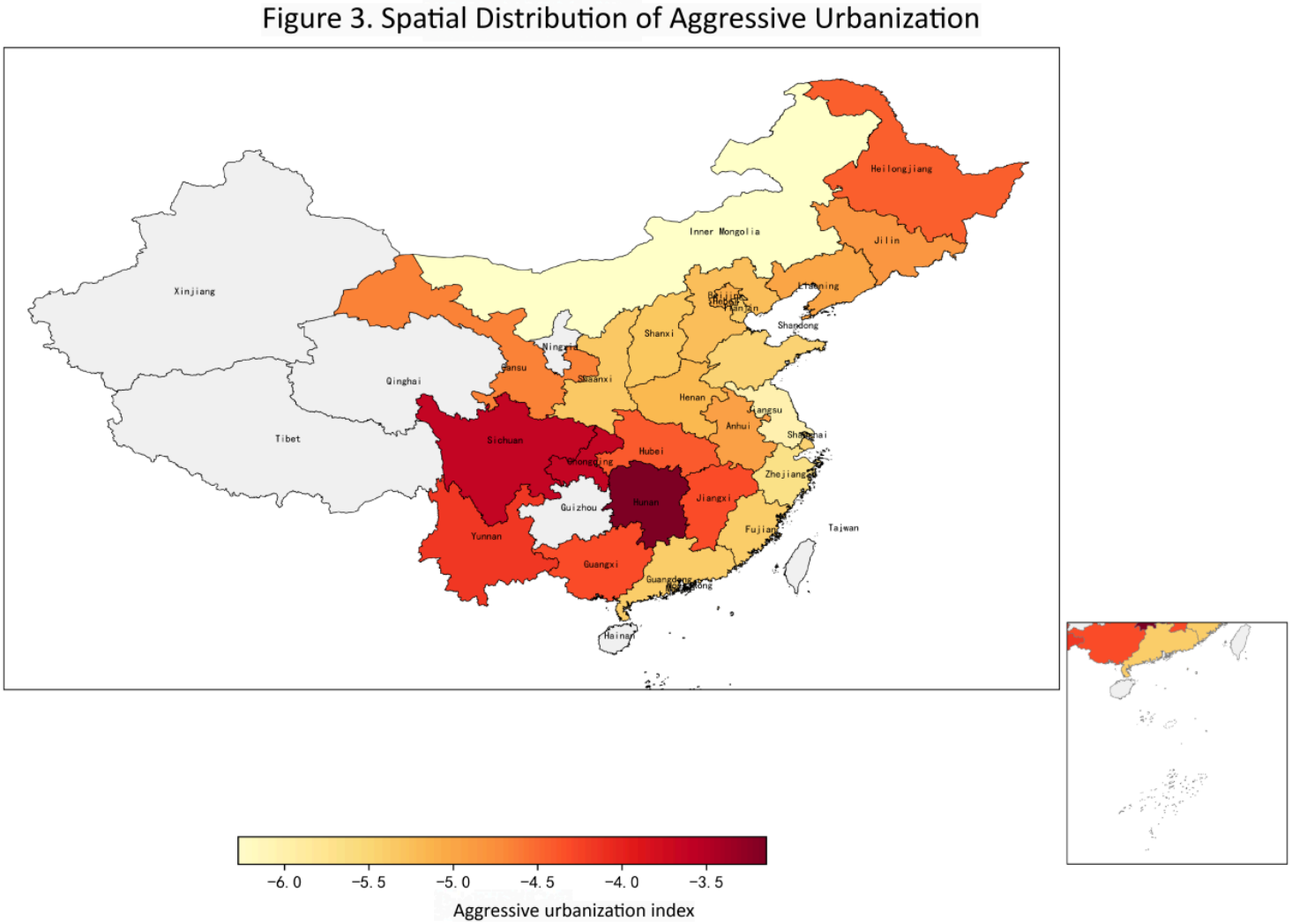


Figure 4

See image above for figure legend.

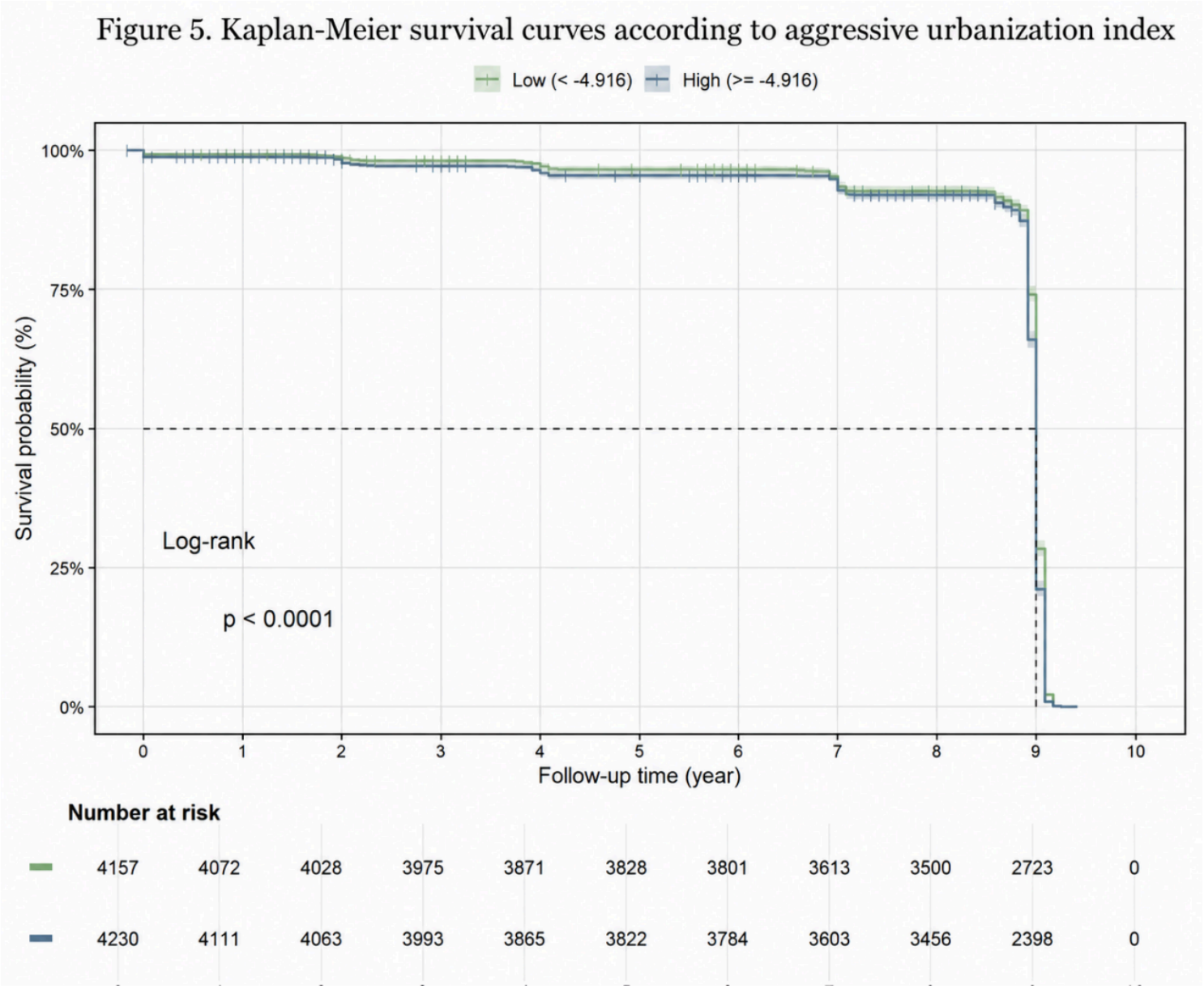


Figure 5

See image above for figure legend.