

BMJ Open Exploring the association between urbanisation and self-rated health of older adults in China: evidence from a national population sample survey

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ABSTRACT

Objectives This study investigated the association between urbanisation and self-rated health of older adults in China, particularly how different dimensions, rate and level of urbanisation are related to older people's health. Additionally, it examined the moderating effect of education on the association between each of the four dimensions of urbanisation and older people's health.

Design The study uses a cross-sectional survey design.

Participants This study analysed 236 030 individuals (aged 60–79 years) nested within 267 prefecture-level cities from 2005 China's 1% population sample survey.

Outcome measures Self-rated health was the outcome variable. Four groups of predictors assessed prefectures' level and rate of urbanisation: land-use conversion, economic growth, population concentration and health services. Multilevel logistic regression was used to examine the association between self-rated health and the level and rate of urbanisation, after adjusting for individual-level covariates. Multiplicative interactions explored variations by education.

Results The odd of reporting fair or poor health was negatively associated with the level and rate of population concentration (OR 0.93, 95%CI 0.87 to 0.99 and 0.74, 95%CI 0.59 to 0.93, respectively) and positively associated with the level of health services (OR 1.12, 95%CI 1.06 to 1.19). Land-use conversion, economic growth and health service improvements (the forms of rate of urbanisation) were not significantly associated with self-rated health. Education had a moderating effect on the association between urbanisation and self-rated health.

Conclusions Older people living in more densely populated areas and areas undergoing rapid population concentration were less likely to report fair or poor health. This result supports healthy migration and 'salmon bias' hypotheses. No urban health penalty was observed for the older adults in China; therefore, the following pathways linking urbanisation to health are unclear: lifestyle changes, environmental pollution and cultivated land reduction.

INTRODUCTION

The 2018 revision of World Urbanisation Prospects reported that 55% of the world's population lived in urban settlements, and it is expected to increase to 68% by 2050.¹ A

Strengths and limitations of this study

- The study considers the different dimensions of urbanisation, thus capturing the complex association between urbanisation and self-reported health of older adults in China.
- It provides an in-depth understanding of the urbanisation–health relationship among older adults.
- The study used nationally representative survey data covering 267 prefectures across 31 provinces, thus providing a more comprehensive picture of urbanisation–health relationships across the country.
- We were unable to capture the causal effect of changes in urbanisation over time on older people's health outcomes due to the cross-sectional nature of the data.

lion's share of the future growth of the world's urban population is expected to happen in low/middle-income nations.¹ In advanced economies, city dwellers normally enjoy better living conditions, better healthcare access and more effective public-health interventions than their rural counterparts do. However, in low/middle-income countries, where urbanisation is rapid and unplanned, it is more likely to pose a threat to public health through environmental degradation, unhealthy lifestyles, increased stress and inadequate sanitation.^{2–5}

China, the largest low/middle-income country in the world, has been undergoing urbanisation at an unprecedented rate over the last three decades.¹ A small but growing body of literature has investigated the effect of urbanisation on the Chinese population's health.^{6–15} Most earlier studies used either a single indicator (eg, urbanisation rate) or a composite indicator derived from a set of neighbourhood characteristics (eg, urbanicity index) to assess the level of urbanisation and explore its relationship with individual health.^{6–11} However, these studies

have failed to recognise urbanisation as a multifaceted process involving population concentration, economic growth, land-use conversion, infrastructure upgrading, and lifestyle changes, and that different aspects of urbanisation may have complex effects on residents' health.^{5 16–18} For example, the healthy migrant hypothesis suggests that a massive inflow of migrants to cities may improve the overall level of residents' health.¹⁹ On the other hand, 'salmon bias' hypothesis implies that the unhealthy migrants who are retired or close to retirement age may return to their rural and small-town hometowns. A traditional Chinese aphorism is: 'Fallen leaves return to the roots' implying reverting to one's origin. Economic growth and land-use change in rapidly industrialising countries are normally accompanied by increased environmental pollution, which is detrimental to residents' health.^{2 3 12 20 21} On the other hand, economic growth may lead to better access to health knowledge and services, which could improve residents' health.⁵ Lifestyle changes associated with urbanisation, such as less physical activity and more high-calorie food intake, may also affect residents' health.^{8 22 23} Therefore, considering the effects of multiple dimensions of urbanisation on residents' health could provide a complete picture of how urbanisation affects individual health.

Another limitation of previous studies is that the extent to which the urbanisation rate influences residents' health has been rarely examined. For example, a previous study investigated the effect of living in more urbanised areas on health at a given time point (ie, urbanicity) in the Chinese context.^{6 8} However, highly urbanised areas do not necessarily experience rapid urbanisation.^{4 5 24} The rate of urbanisation also affects residents' health, as a rapid urban growth is usually accompanied by environmental and behavioural transitions, such as environmental deterioration, increased stress, lifestyle change, changing population composition and declining social cohesion.^{2 4 5 8 22 25} Only a few studies have considered both the level and rate of urbanisation simultaneously. For example, Chen *et al*¹⁶ investigated the effects of urbanisation on health using multiple measures of urbanisation dynamics including the level and rate of urbanisation; however, their conclusion was drawn from the analysis of a small-scale survey conducted in 27 prefectures, which had the limitations of poor generalisability and homogeneous environmental settings.^{26 27} Therefore, including the rate of urbanisation in the analytical framework of urbanisation–health relationships is essential.

Another research gap is the lack of investigation into the moderating effect of individual attributes on urbanisation–health relationships. It is hypothesised that these relationships vary by education, as higher and lower educated people are likely to have different health practices and different levels of access to health services in large cities, whereas this educational gap is less pronounced in small towns and rural areas.^{28 29} It is also hypothesised that higher and lower educated people have differing propensities to migrate, and the effect of health

selective migration varies by education level.³⁰ Furthermore, higher and lower educated people differ in their ability to adapt to stress arising from rapid urbanisation and consequent social life changes.^{5 22 31} Therefore, the moderating effect of education on urbanisation–health relationships among older people is worth exploring.

This study aimed to investigate the association between urbanisation and self-rated health of older adults using the 2005 China's 1% population sample survey and statistical data from statistical yearbooks. In particular, the study focused on how different dimensions of urbanisation (population growth, land-use change, economic growth and health service improvement) are related to older people's health and how both the level and rate of urbanisation are associated with their health. Further, it examined the moderating effect of education on the association between each of the four dimensions of urbanisation and health. The study is significant in several respects. First, it considers the different dimensions of urbanisation, thus capturing the complex association between urbanisation and self-reported health (SRH) of the older adults. Second, it provides an in-depth understanding of the urbanisation–health relationship among older adults. Moreover, this study used nationally representative survey data covering 267 prefectures across 31 provinces, thus providing a more comprehensive picture of urbanisation–health relationships across the country.

METHODS

Data

This study used individual microdata from the 2005 China's 1% population sample survey (hereinafter, the 2005 survey). The 2005 survey was conducted by the National Bureau of Statistics of China using a stratified, cluster, and probability proportional to size sampling. The survey team obtained written consents from each participant at the time of survey. We accessed the data with specific permission from the National Bureau of Statistics of China (<http://www.stats.gov.cn/>). The 2005 survey included 2.59 million individuals living in 340 prefectures (including prefecture-level cities, prefectures in a narrow sense, leagues and autonomous prefectures). Postsurvey enumeration has indicated an undercount rate of 1.72%. We excluded individuals aged less than 60 years and further restricted the sample to those aged 60–79 years, as those aged over 80 years had a higher risk of mortality. We excluded 3701 (1.54% of the total) individuals aged 60–79 years who had any missing value in the outcome variable and covariates. The final dataset included 236 030 individuals from 267 prefecture-level cities.

Patient and public involvement

Patients or the public were not involved in this study.

Measures

Outcome

The outcome variable in this study was SRH, which was the only question in the 2005 survey pertaining to health. SRH is a sensitive and reliable indicator of the current health status of older people, which has been widely used in previous studies.^{32–34} Respondents were asked to assess their overall health status over the past month based on a four-point scale (good, fair, poor, or not able to answer). To simplify the analysis, we removed respondents who were not able to answer and recoded the variable into a binary variable: 0 for good health and 1 for fair or poor health.

Predictors

The key predictors used to measure prefectures' urbanisation level and rate included four specific dimensions of urbanisation (land-use conversion, economic growth, population concentration and health services). The ratio of urban built-up areas to the entire area, the gross domestic product per capita, population density and the number of hospital beds per thousand population were used to assess the level of rural-urban land-use conversion, economic growth, population concentration and health services, respectively. Further, the rates of land-use conversion, economic growth, concentration of population and improvement in health services were considered using the changes in the corresponding indicators from 2000 to 2005.

Covariates

We adjusted for individual-level covariates: gender, age, ethnicity, marital status, urbanicity of current residence, hukou status (governmental household registration system), education, having primary endowment insurance, having basic medical insurance, housing area per capita, housing construction time and the provision of four types of housing facilities (water supply, kitchen, toilet and bathroom).

Analysis

Multilevel logistic regression was used to examine the association between SRH and the level and rate of urbanisation. The models were initially fitted with covariates only. We then added predictors related to both the level and rate of urbanisation. Thereafter, these models were sequentially adjusted for interaction terms between the level or the rate of urbanisation on one hand and education on the other. We performed a variance inflation factor test and found no multicollinearity among the variables. All analyses were conducted using STATA V.14.0.

RESULTS

The descriptive analysis of the variables is presented in [table 1](#). Of all the respondents, 66.19% reported good health, 22.73% reported fair health and 11.08% reported poor health. 62.13% of respondents were aged between 60

and 69, 96.5% of respondents were Han Chinese, 75.3% of individuals were not married, 63.8% of respondents were local agricultural hukou and about 90% of individuals with low education (junior high school or below). Only 25% had primary endowment insurance scheme, and about 40% had basic medical insurance scheme. About 50% of the respondents lived in rural areas. The average housing area per capita was 32.57 square metres. About 77% lived in houses constructed after 1978, and 45.64% in houses with less than two types of facilities.

[Table 2](#) presents the results of the multilevel logistic regression. Model 1 includes covariates only. Older people who were female, at advanced age, not married, and less-educated were more likely to report fair or poor health than were their male, younger, married and more-educated counterparts. Local and agricultural hukou holders were more likely to report fair or poor health than were their non-local and non-agricultural counterparts. Primary endowment insurance recipients and urban residents were less likely to report fair or poor health than were non-recipients and rural residents. Moreover, older people who lived in larger, more recently constructed and better-equipped houses were less likely to report fair or poor health than those living in smaller, older and less-equipped houses.

The results of model 2 show that the level and rate of population concentration were negatively associated with the odds of reporting fair or poor health (OR 0.93, 95% CI 0.87 to 0.99 and 0.74, 95% CI 0.59 to 0.93, respectively), while the level of health services was positively correlated with the odds of reporting fair or poor health (OR 1.12, 95% CI 1.06 to 1.19). There was no significant relationship between the odds of reporting fair or poor health and the level of land-use conversion, economic growth (land-use conversion: OR 0.99, 95% CI 0.97 to 1.01; economic growth: OR 0.91, 95% CI 0.81 to 1.01). Similarly, no significant relationship was observed between the odds of reporting fair or poor health and land-use conversion rate, economic growth rate and health service improvement (land-use conversion rate: OR 0.96, 95% CI 0.90 to 1.02; economic growth rate: OR 0.94, 95% CI 0.85 to 1.05; health service improvement: OR 0.91, 95% CI 0.67 to 1.25).

The results of the moderating effect of education on the association between the level of urbanisation and SRH are shown in [table 3](#). The level of land-use conversion was negatively associated with the SRH of the least educated (OR 0.98, 95% CI 0.96 to 1.00) and positively associated with the odds of those who had completed primary education reporting fair or poor health (OR 1.02, 95% CI 1.02 to 1.03; OR 1.04, 95% CI 1.03 to 1.05; and OR 1.03, 95% CI 1.02 to 1.05) (model 3). The level of economic growth was not significantly associated with the SRH of the least educated (OR 0.95, 95% CI 0.88 to 1.02) and was positively associated with that of other educational groups (OR 1.08, 95% CI 1.05 to 1.12; OR 1.19, 95% CI 1.11 to 1.26 and OR 1.14, 95% CI 1.05 to 1.24) (model 4). The level of population concentration was negatively correlated with the odds of reporting

Table 1 Summary statistics of variables

	Whole sample (n=236 030)	Reported good health (n=156 222)	Reported fair or poor health (n=79 808)
Self-reported health (%)			
Good	66.19		
Fair or poor	33.81		
Predictors (prefecture-level variables)			
Land-use conversion in 2005 (%)	1.95 (3.48)	2.06 (3.65)	1.76 (3.13)
GDP per capita in 2005 (¥10 000)	1.87 (1.49)	1.91 (1.53)	1.77 (1.40)
Population density in 2005 (population per km ²)	548.98 (443.51)	562.51 (449.37)	522.51 (430.58)
The no of hospital beds per 1000 population in 2005 (bed)	2.93 (1.53)	2.96 (1.55)	2.88 (1.49)
The change in land-use conversion from 2000 to 2005 (%)	59.10 (88.93)	60.70 (92.26)	55.98 (81.92)
The change in GDP per capita from 2000 to 2005 (%)	87.47 (41.19)	87.39 (41.90)	87.63 (39.77)
The change in population density from 2000 to 2005 (%)	3.40 (11.88)	3.59 (13.11)	3.02 (8.97)
The change in no of hospital beds per 1000 population from 2000 to 2005 (%)	5.21 (13.46)	5.42 (13.44)	4.80 (13.48)
Gender (%)			
Female	48.74	45.96	54.18
Male	51.26	54.04	45.82
Age (years) (%)			
60–64	33.64	41.11	19.02
65–69	28.49	29.86	25.80
70–74	23.09	19.18	30.76
75–79	14.78	9.85	24.42
Ethnicity (%)			
Han Chinese	96.49	96.70	96.08
Minority	3.51	3.30	3.92
Marital status (%)			
Single, divorced or widowed	75.34	79.77	66.67
Married	24.66	20.23	33.33
Hukou status (%)			
Local agricultural	63.77	60.35	70.48
Local non-agricultural	28.68	31.13	23.87
Non-local agricultural	2.37	2.59	1.93
Non-local non-agricultural	5.18	5.93	3.72
Education (%)			
No schooling	34.73	28.09	47.72
Elementary school or junior high school	55.04	59.58	46.14
Senior high school	6.12	7.32	3.78
College or above	4.11	5.01	2.36
Primary endowment insurance (%)			
Had	24.68	27.55	19.05
Did not have	75.32	72.45	80.95
Basic medical insurance (%)			
Had	41.44	43.67	37.07
Did not have	58.56	56.33	62.93
Urbanicity of current residence (%)			
Rural areas	52.20	48.92	58.61
Urban areas: towns	14.87	15.47	13.69
Urban areas: cities	32.93	35.61	27.70

Continued

Table 1 Continued

	Whole sample (n=236 030)	Reported good health (n=156 222)	Reported fair or poor health (n=79 808)
Housing area per capita (m ²)	32.57 (25.98)	32.76 (25.81)	32.21 (26.30)
Housing construction time (%)			
Before 1978	22.62	20.63	26.52
After 1978	77.38	79.37	73.48
Housing facilities (%)			
None, one or two types of facilities	45.64	42.92	50.97
Three types of facilities	24.84	24.04	26.41
Four types of facilities	29.52	33.04	22.62

Results are presented as proportion for categorical variables and as mean (SEs) for continuous variables.
GDP, gross domestic product.

fair or poor health across all educational groups, and the strength of the negative relationship decreased with higher level of education (OR 0.84, 95% CI 0.79 to 0.89; OR 1.08, 95% CI 1.05 to 1.10; OR 1.19, 95% CI 1.13 to 1.26 and OR 1.19, 95% CI 1.11 to 1.28) (model 5). The level of health services was positively correlated with the odds of reporting fair or poor health across all educational groups with the strongest positive relationship found in senior high school (OR 1.05, 95% CI 1.01 to 1.09; OR 1.04, 95% CI 1.02 to 1.05; OR 1.07, 95% CI 1.04 to 1.10 and OR 1.04, 95% CI 1.00 to 1.07) (model 6).

Table 4 presents the results of the moderating effect of education in the association between the rate of urbanisation and SRH. The rate of land-use conversion was negatively correlated with the SRH of the least educated (OR 0.92, 95% CI 0.86 to 0.98) and not significantly associated with the odds of those who had completed primary education reporting fair or poor health (OR 1.01, 95% CI 0.99 to 1.04; OR 1.04, 95% CI 0.99 to 1.10 and OR 1.06, 95% CI 1.00 to 1.13) (model 7). Economic growth rate was negatively correlated with the odds of those who had education of junior high school or below reporting fair or poor health (OR 0.95, 95% CI 0.91 to 1.00) and not significantly correlated with other educational groups' SRH (OR 1.00, 95% CI 0.90 to 1.12; OR 0.94, 95% CI 0.84 to 1.05 and OR 0.96, 95% CI 0.84 to 1.10) (model 8). The rate of population concentration was negatively associated with the odds of those without schooling reporting fair or poor health (OR 0.73, 95% CI 0.56 to 0.94) and not significantly associated with that of those who had completed primary education (OR 0.99, 95% CI 0.81 to 1.22; OR 1.48, 95% CI 0.97 to 2.24 and OR 0.89, 95% CI 0.52 to 1.51) (model 9). The rate of health service improvement was positively correlated with the SRH of the most educated (OR 1.88, 95% CI 1.21 to 2.94) (model 10).

DISCUSSION

This study is the first study to examine the association between the multiple dimensions of urbanisation and SRH among older adults using nationally-representative

survey data covering most of the prefectures in China. In contrast to previous studies examining urban health penalty in Chinese people across all ages,^{6-8 16} our findings show that living in more densely populated areas and areas undergoing rapid population concentration decreases older people's odds of reporting fair or poor health. Fast-growing and densely populated cities draw numerous healthy and working-aged migrants from rural and small-town areas,^{35 36} and most of these migrants still perceive themselves to be healthy when they cross the age of 60 years (healthy migration phenomenon).¹⁹ On the other hand, as per traditional Chinese culture, people revert to their origin when they are old; migrants who perceive themselves to be unhealthy are likely to return to their rural and small-town hometowns when they retire or are close to retirement age ('salmon bias' phenomenon).³⁰ Additionally, unhealthy older migrants would go back to their hometowns to avoid high healthcare expenditure in urban areas. The health selective migration partially accounts for the positive association between population concentration and SRH.

Earlier studies have attributed urban health penalty in China to changes in health behaviours associated with urbanisation.^{7 8 16} Specifically, people living in more urbanised areas are more likely to have unhealthy lifestyles, such as insufficient physical activity and high-fat and high-calorie intake.^{7 8 16} Nevertheless, our study found no evidence that economic growth and population concentration may have a detrimental effect on people's SRH. This suggests that the pathway of lifestyle is less pronounced for older people than for the working-age population in China, as many older people living in well developed and densely populated areas still maintain their existing healthy lifestyle (ie, more physical activities and less high-fat and high-calorie intake) that was established many years ago (when China was a less developed and isolated country). Another pathway of urban health penalty involves environmental pollution and decrease in cultivated land.^{2 8 12} However, our results show no relationship between land-use conversion and economic

Table 2 Multilevel logistic regression estimates of reporting fair or poor health

Effects and variables	Model 1	Model 2
	OR (95% CI)	OR (95% CI)
Fixed part		
Land-use conversion in 2005		0.99 (0.97 to 1.01)
The change in land-use conversion from 2000 to 2005		0.96 (0.90 to 1.02)
The logarithm GDP per capita in 2005		0.91 (0.81 to 1.01)
The change in GDP per capita from 2000 to 2005		0.94 (0.85 to 1.05)
The logarithm population density in 2005		0.93 (0.87 to 0.99) *
The change in population density from 2000 to 2005		0.74 (0.59 to 0.93) **
The no of hospital beds per 1000 population in 2005		1.12 (1.06 to 1.19) ***
The change in no of hospital beds per thousand population from 2000 to 2005		0.91 (0.67 to 1.25)
Females (ref: males)	1.16 (1.14 to 1.19) ***	1.16 (1.14 to 1.19) ***
Age (ref: 60–64)		
65–69	1.81 (1.77 to 1.86) ***	1.81 (1.77 to 1.86) ***
70–74	3.19 (3.10 to 3.27) ***	3.19 (3.11 to 3.27) ***
75–79	4.66 (4.53 to 4.80) ***	4.67 (4.53 to 4.81) ***
Minority (ref: Han Chinese)	1.05 (1.00 to 1.11)	1.05 (0.99 to 1.10)
Single, divorced or widowed (ref: married)	1.30 (1.28 to 1.33) ***	1.30 (1.28 to 1.33) ***
Hukou status (ref: local agricultural)		
Local non-agricultural	0.92 (0.89 to 0.95) ***	0.91 (0.88 to 0.94) ***
Non-local agricultural	0.73 (0.69 to 0.78) ***	0.73 (0.69 to 0.78) ***
Non-local non-agricultural	0.83 (0.78 to 0.87) ***	0.82 (0.78 to 0.87) ***
Education (ref: no schooling)		
Elementary school or junior high school	0.68 (0.67 to 0.70) ***	0.68 (0.67 to 0.70) ***
Senior high school	0.60 (0.57 to 0.63) ***	0.60 (0.57 to 0.63) ***
College or above	0.55 (0.52 to 0.58) ***	0.55 (0.52 to 0.58) ***
Had primary endowment insurance (ref: did not have)	0.88 (0.85 to 0.91) ***	0.88 (0.85 to 0.91) ***
Had basic medical insurance (ref: did not have)	0.98 (0.95 to 1.00)	0.98 (0.95 to 1.00)
Urbanicity of current residence (ref: rural areas)		
Urban areas: towns	0.87 (0.84 to 0.89) ***	0.87 (0.84 to 0.89) ***
Urban areas: cities	0.87 (0.84 to 0.90) ***	0.87 (0.84 to 0.89) ***
Housing area per capita (m ²)	0.998 (0.997 to 0.999) ***	0.998 (0.997 to 0.999) ***
Housing construction time after 1978 (ref: before 1978)	0.88 (0.86 to 0.90) ***	0.88 (0.86 to 0.90) ***
Housing facilities (ref: none, one and two)		
Three	0.99 (0.96 to 1.01)	0.99 (0.96 to 1.01)
Four	0.82 (0.80 to 0.85) ***	0.83 (0.80 to 0.85) ***
Var (city-level constant)	0.14***	0.11***
Log likelihood	–135659.94	–135632.03
AIC	271363.90	271324.10
ICC	0.04	0.03

*P<0.05, **P<0.01, ***P<0.001.

AIC, Akaike Information Criterion; GDP, gross domestic product; ICC, Intraclass Correlation Coefficient.

growth on the one hand and older people's SRH on the other, which suggests that environmental pollution and decrease in cultivated land might play little role in the association between urbanisation and older people's SRH.

Urbanisation may also positively affect people's health through improved healthcare services and quality of life.⁵ These pathways are associated with two dimensions of urbanisation, economic growth and health service improvements, which are found to be either

Table 3 The relationship between the level of urbanisation and the odds of reporting fair or poor health moderated by education

Variables	Model 3 (IV: land-use conversion)	Model 4 (IV: logarithm GDP per capita)	Model 5 (IV: logarithm population density)	Model 6 (IV: health institutional beds per 1000 population)
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
The level of urbanisation in 2005	0.98 (0.96 to 1.00)*	0.95 (0.88 to 1.02)	0.84 (0.79 to 0.89)***	1.05 (1.01 to 1.09)*
The rate of urbanisation from 2000 to 2005	0.92 (0.87 to 0.98)*	0.98 (0.88 to 1.08)	0.73 (0.58 to 0.92)**	0.79 (0.58 to 1.08)
Education (ref: no schooling)				
Elementary school or junior high school	0.69 (0.67 to 0.70)***	0.69 (0.67 to 0.70)***	0.69 (0.67 to 0.70)***	0.69 (0.67 to 0.70)***
Senior high school	0.59 (0.56 to 0.62)***	0.59 (0.56 to 0.62)***	0.59 (0.56 to 0.62)***	0.59 (0.55 to 0.62)***
College or above	0.53 (0.50 to 0.57)***	0.54 (0.50 to 0.58)***	0.53 (0.50 to 0.57)***	0.55 (0.51 to 0.59)***
The level of urbanisation * education (ref: level * no schooling)				
Level* elementary school or junior high school	1.02 (1.02 to 1.03)***	1.08 (1.05 to 1.12)***	1.08 (1.05 to 1.10)***	1.04 (1.02 to 1.05)***
Level* senior high school	1.04 (1.03 to 1.05)***	1.19 (1.11 to 1.26)***	1.19 (1.13 to 1.26)***	1.07 (1.04 to 1.10)***
Level* college or above	1.03 (1.02 to 1.05)***	1.14 (1.05 to 1.24)**	1.19 (1.11 to 1.28)***	1.04 (1.00 to 1.07)*

All models have been adjusted for individual covariates shown in [table 2](#).

*P<0.05, **P<0.01, ***P<0.001.

GDP, gross domestic product.

non-significantly or counterintuitively positively related to older people's odds of reporting fair or poor health. Economic growth was not accompanied by an increase in older people's odds of reporting fair or poor health, probably because health benefits as a result of economic growth might be offset by associated detrimental effects such as environmental deterioration, increased stress and weakened social bonds. Surprisingly, the level of

health services was positively associated with the odds of older people reporting fair or poor health, and health service improvement was not linked to an increase in older people's odds of reporting fair or poor health. One possible explanation for this finding is that older people living in areas with better health services are more likely to receive health knowledge and be aware of their trivial illnesses, and thus, may report themselves as unhealthy.

Table 4 The relationship between the rate of urbanisation and the odds of reporting fair or poor health moderated by education

Variables	Model 7 (IV: land-use conversion)	Model 8 (IV: logarithm GDP per capita)	Model 9 (IV: logarithm population density)	Model 10 (IV: health institutional beds per 1000 population)
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
The level of urbanisation in 2005	1.00 (0.98 to 1.02)	1.00 (0.93 to 1.07)	0.88 (0.83 to 0.93)***	1.07 (1.04 to 1.11)***
The rate of urbanisation from 2000 to 2005	0.92 (0.86 to 0.98)**	1.00 (0.90 to 1.12)	0.73 (0.56 to 0.94)*	0.79 (0.57 to 1.09)
Education (ref: no schooling)				
Elementary school or junior high school	0.68 (0.67 to 0.70)***	0.68 (0.67 to 0.70)***	0.68 (0.67 to 0.70)***	0.68 (0.67 to 0.70)***
Senior high school	0.60 (0.57 to 0.63)***	0.60 (0.57 to 0.63)***	0.60 (0.57 to 0.63)***	0.60 (0.57 to 0.63)***
College or above	0.55 (0.52 to 0.58)***	0.55 (0.52 to 0.58)***	0.55 (0.52 to 0.58)***	0.55 (0.52 to 0.58)***
The speed of urbanisation * education (ref: speed * no schooling)				
Rate * elementary school or junior high school	1.01 (0.99 to 1.04)	0.95 (0.91 to 1.00)*	0.99 (0.81 to 1.22)	0.98 (0.85 to 1.13)
Rate * senior high school	1.04 (0.99 to 1.10)	0.94 (0.84 to 1.05)	1.48 (0.97 to 2.24)	1.03 (0.72 to 1.46)
Rate * college or above	1.06 (1.00 to 1.13)	0.96 (0.84 to 1.10)	0.89 (0.52 to 1.51)	1.88 (1.21 to 2.94)**

All models have been adjusted for individual covariates shown in [table 2](#).

*P<0.05, **P<0.01, ***P<0.001.

GDP, gross domestic product.

Education had a moderating effect on the association between each of the four dimensions of urbanisation and older people's SRH. Land-use conversion was negatively associated with the odds of the least educated individuals reporting fair or poor health. One explanation is that older people without education are indigenous peasants living in their home villages. Those living in areas with a high proportion of urban land and areas that undergo rapid land-use conversion usually have a better economic well-being and quality of life than do their less-urbanised counterparts, and thus report a better health status. The effects of land-use conversion and economic growth on older people's SRH are more detrimental to those who are more educated, probably because health behaviours differ greatly between those who are more educated and those who are less educated in economically developed areas.^{7,37} People with a higher level of education are more likely to consume more food than needed and adopt a new lifestyle than do less-educated people. Moreover, high-fat and high-calorie diets and sedentary behaviour are more prevalent in economically developed areas. By contrast, the educational gap in health behaviours is less pronounced in less-developed areas, as educated people in these areas do not have an unhealthy diet and sedentary behaviour.⁷ The negative effect of population concentration on older people's likelihood of reporting fair or poor health was stronger for the less educated than for the more educated, probably because in the Chinese context, the effect of health-selective migration is stronger for less-educated people who are often manual labourers and whose employment opportunities rely on their physical health conditions. The relationship between the level of health service and fair or poor SRH was positive; the rate of health service improvement was positively correlated with fair or poor SRH for the most educated individuals. This suggests that they tend to have stronger health awareness and higher expectations regarding their health when already living in areas with a high level of health services.

This study has some limitations. First, we were unable to capture the causal effect of changes in urbanisation over time on older people's health outcomes due to the cross-sectional nature of the data. Second, our estimates of the effect of urbanisation on health might be subject to self-selection bias, as older people with certain observed or unobserved characteristics (eg, having well-educated parents) are more likely to live in more urbanised areas and report better health than are those who do not have those characteristics. Given that the middle-aged and older people in China have a low migration rate, we can assume that self-selection bias is not a severe issue for the present study. Third, we did not explore the pathways (eg, health behaviours, the use of healthcare facilities and services, and social capital) through which urbanisation affects SRH due to the lack of relevant information in our dataset.

In conclusion, the results show that the odd of older people reporting fair or poor health is negatively

correlated with the level and rate of population concentration and is positively correlated with the level of health services. These findings support the healthy migration and 'salmon bias' hypotheses. Education had a moderating effect on the association between each of the four dimensions of urbanisation and older people's SRH. The possible explanations for the difference between more educated and less educated older people in terms of urbanisation–health relationships include health-selective migration, differing quality of life, differing health behaviours and varying health expectations. Public efforts such as the equitable distribution of health services and the elimination of social exclusion of migrants should be made to decrease health inequalities among older people in China.

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Contributors YL, BH, ZF and ZL conceived the research question and designed the study. BH and RW performed statistical analysis. YL and BH drafted the manuscript, all authors contributed to the subsequent revisions of the manuscript, and approved the final version of the submitted manuscript.

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Competing interests None declared.

Patient consent for publication Not required.

Ethics approval This study is exempt from ethical approval for the following reasons: first, the microdata from the 2005 survey did not contain any sensitive information; second, individuals who were involved in the survey were anonymous; third, access to the data was administered by a governmental organisation that complied with various legal requirements about data protection.

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REFERENCES

1. United Nations, Department of Economic and Social Affairs, Population Division. The 2018 revision of the world urbanization prospects. 2018 <https://population.un.org/wup/Publications/Files/WUP2018-PressRelease.pdf> (accessed 15 Oct 2018).
2. Gong P, Liang S, Carlton EJ, *et al*. Urbanisation and health in China. *The Lancet* 2012;379:843–52.
3. Moore M, Gould P, Keary BS. Global urbanization and impact on health. *Int J Hyg Environ Health* 2003;206(4-5):269–78.
4. Vlahov D, Freudenberg N, Proietti F, *et al*. Urban as a Determinant of Health. *Journal of Urban Health* 2007;84:16–26.
5. Vlahov D, Urbanization GS. urbanicity, and health. *J Urban Health* 2002;79(Suppl 1):S1–S12.
6. Chen H, Liu Y, Li Z, *et al*. Urbanization, economic development and health: evidence from China's labor-force dynamic survey. *Int J Equity Health* 2017;16:207–14.
7. Miao J, Wu X, Urbanization WX. Urbanization, socioeconomic status and health disparity in China. *Health Place* 2016;42:87–95.
8. Poel EV, O'Donnell O, Doorslaer EV. Is there a health penalty of China's rapid urbanization? *Health Econ* 2012;21:367–85.

9. Van de Poel E, O'Donnell O, Van Doorslaer E. Urbanization and the spread of diseases of affluence in China. *Econ Hum Biol* 2009;7:200–16.
10. Jones-Smith JC, Popkin BM. Understanding community context and adult health changes in China: development of an urbanicity scale. *Soc Sci Med* 2010;71:1436–46.
11. Thompson AL, Houck KM, Adair L, et al. Multilevel examination of the association of urbanization with inflammation in Chinese adults. *Health Place* 2014;28:177–86.
12. Li X, Song J, Lin T, et al. Urbanization and health in China, thinking at the national, local and individual levels. *Environ Health* 2016;15 Suppl 1:113–23.
13. Li X, Wang C, Zhang G, et al. Urbanisation and human health in China: spatial features and a systemic perspective. *Environmental Science and Pollution Research* 2012;19:1375–84.
14. Wang R, Xue D, Liu Y, et al. The relationship between urbanization and depression in China: the mediating role of neighborhood social capital. *Int J Equity Health* 2018;17:105–14.
15. Sun R, Gu D. Air pollution, economic development of communities, and health status among the elderly in urban China. *Am J Epidemiol* 2008;168:1311–8.
16. Chen J, Chen S, Landry PF, et al. How Dynamics of Urbanization Affect Physical and Mental Health in Urban China. *China Q* 2014;220:988–1011.
17. Chen H, Liu Y, Zhu Z, et al. Does where you live matter to your health? Investigating factors that influence the self-rated health of urban and rural Chinese residents: evidence drawn from Chinese General Social Survey data. *Health Qual Life Outcomes* 2017;15:78–88.
18. Villanueva K, Pereira G, Knuiman M, et al. The impact of the built environment on health across the life course: design of a cross-sectional data linkage study. *BMJ Open* 2013;3:e002482.
19. Abraído-Lanza AF, Dohrenwend BP, Ng-Mak DS, et al. The Latino mortality paradox: a test of the "salmon bias" and healthy migrant hypotheses. *Am J Public Health* 1999;89:1543–8.
20. Wang R, Liu Y, Xue D, et al. Cross-sectional associations between long-term exposure to particulate matter and depression in China: The mediating effects of sunlight, physical activity, and neighborly reciprocity. *J Affect Disord* 2019;249:8–14.
21. Wang R, Xue D, Liu Y, et al. The Relationship between Air Pollution and Depression in China: Is Neighbourhood Social Capital Protective? *Int J Environ Res Public Health* 2018;15:1160–73.
22. Harpham T. Urbanization and mental health in developing countries: a research role for social scientists, public health professionals and social psychiatrists. *Soc Sci Med* 1994;39:233–45.
23. Abuladze L, Kunder N, Lang K, et al. Associations between self-rated health and health behaviour among older adults in Estonia: a cross-sectional analysis. *BMJ Open* 2017;7:e013257.
24. Ng SW, Norton EC, Popkin BM. Why have physical activity levels declined among Chinese adults? Findings from the 1991–2006 China Health and Nutrition Surveys. *Soc Sci Med* 2009;68:1305–14.
25. Chen M, Zhang H, Liu W, et al. The global pattern of urbanization and economic growth: evidence from the last three decades. *PLoS One* 2014;9:e103799.
26. Xu Z, Ouyang A. The Factors Influencing China's population distribution and spatial heterogeneity: a prefectural-level analysis using geographically weighted regression. *Appl Spat Anal Policy* 2018;11:465–80.
27. Xiang H, Yang J, Zhang T, et al. Analyzing In-Migrants and Out-Migrants in Urban China. *Appl Spat Anal Policy* 2018;11:81–102.
28. Mackenbach JP, Stirbu I, Roskam AJ, et al. Socioeconomic inequalities in health in 22 European countries. *N Engl J Med* 2008;358:2468–81.
29. Ross CE, Mirowsky J. Refining the association between education and health: the effects of quantity, credential, and selectivity. *Demography* 1999;36:445–60.
30. Norman P, Boyle P, Rees P. Selective migration, health and deprivation: a longitudinal analysis. *Soc Sci Med* 2005;60:2755–71.
31. Feng Z, Phillips DR, Jones K. A geographical multivariable multilevel analysis of social exclusion among older people in China: Evidence from the China Longitudinal Aging Social Survey ageing study. *Geogr J* 2018;184:413–28.
32. Feng Z, Wang WW, Jones K. A multilevel analysis of the role of the family and the state in self-rated health of elderly Chinese. *Health Place* 2013;23:148–56.
33. Wu Z, Schimmele CM. Psychological disposition and self-reported health among the 'oldest-old' in China. *Ageing Soc* 2006;26:135–51.
34. Lima-Costa MF, Cesar CC, Chor D, et al. Self-rated health compared with objectively measured health status as a tool for mortality risk screening in older adults: 10-year follow-up of the Bambuí Cohort Study of Aging. *Am J Epidemiol* 2012;175:228–35.
35. Liu Y, Xu W. Destination Choices of Permanent and Temporary Migrants in China, 1985–2005. *Popul Space Place* 2017;23:e1963–17.
36. Liu Y, Shen J. Modelling Skilled and Less-Skilled Interregional Migrations in China, 2000–2005. *Popul Space Place* 2017;23:e2027–17.
37. Kinge JM, Strand BH, Vollset SE, et al. Educational inequalities in obesity and gross domestic product: evidence from 70 countries. *J Epidemiol Community Health* 2015;69:1141–6.