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Exploring the association between urbanization and self-rated health of the elderly Chinese: Evidence from a national population sample survey

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Keywords: urbanization; self-rated health; older people; national population sample survey; China

ABSTRACT

Objectives This study investigated the association between urbanization and self-rated health of elderly Chinese, particularly how different dimensions of urbanization are related to older people's health and how both the level and rate of urbanization are associated with their health.

Design, participants and outcome measures This study analysed 236,030 individuals (aged 60-79 years) nested within 267 prefecture-level cities from 2005 China's one per cent population sample survey. Self-rated health was the outcome variable. Four groups of predictors assessed prefectures' level and rate of urbanization: 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 urbanization, after adjusting for individual-level covariates. Multiplicative interactions explored variations by education.

Results

The odds of reporting fair or poor health was negatively associated with the level and rate of population concentration and was positively associated with the level of health services. Land use conversion, economic growth, and health service improvements (the forms of rate of urbanization) were not significantly associated with their self-rated health. Education had a moderating effect on the association between urbanization and older people's 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 Chinese elderly, and therefore, the following pathways linking urbanization to health are unclear: lifestyle changes, environmental pollution, and cultivated land reduction.

Strengths and limitations of this study

- The study takes into account the different dimensions of urbanization, thus capturing the complex association between urbanization and self-reported health of the Chinese elderly.
- The study provides an in-depth understanding of the urbanization-health relationship among the Chinese elderly.
- This study used nationally representative survey data covering 267 prefectures across 31 provinces, thus providing a more comprehensive picture of urbanization-health relationships across the country.
- we were unable to capture the causal effect of changes in urbanization over time on older peoples' health outcomes due to the cross-sectional nature of the data.

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INTRODUCTION

The 2018 revision of World Urbanization 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 lion's share of the future growth of the world's urban population is expected to happen in developing 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 developing countries, where urbanization 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 developing country in the world, has been undergoing urbanization at an unprecedented rate over the last three decades.[1] A small but growing body of literature has investigated the effect of urbanization on the Chinese population's health.[6-13 14 15] Most earlier studies used either a single indicator (e.g. urbanization rate) or a composite indicator derived from a set of neighbourhood characteristics (e.g. urbanicity index) to assess the level of urbanization and explore its relationship with individual health.[6-11] However, these studies have failed to recognise urbanization as a multi-faceted process that involves population concentration, economic growth, land-use conversion, infrastructure upgrading, and lifestyle changes, and that different aspects of urbanization may have complex effects on residents' health.[5 16 17 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 those unhealthy migrants who are retired or are close to retirement age may return to their rural and small-town hometowns. It is a traditional Chinese culture: "Fallen leaves return to the roots" which stand for to revert to one's origin. Economic growth and land use change in rapidly industrializing countries are normally accompanied by increased environmental pollution, which is detrimental to residents' health.[2 3 12] 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 urbanization, such as less physical activity and more high-calorie food intake, may also affect residents' health.[8 20 21] Therefore, considering the effects of multiple dimensions of urbanization on residents' health could provide a complete picture of how urbanization affects individual health.

Another limitation of previous studies is that the extent to which the urbanization rate influences residents' health has been rarely examined. For example, a previous study investigated the effect of living in more urbanized areas on health at a given time-point (i.e. urbanicity) in the Chinese context.[6 8] However, highly urbanized areas do not necessarily experience rapid urbanization.[4 5 22] The rate of urbanization 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 20 23] Only a few studies have considered both the level and rate of urbanization simultaneously. For example, Chen et al.[16] investigated the effects of urbanization on health using multiple measures of urbanization dynamics including the level and rate of urbanization; however, their conclusion was drawn from the analysis of a small-scale survey conducted in 27 prefectures, which had the limitations of poor generalizability and homogeneous environmental settings.[24 25] Therefore, including the rate of urbanization in the analytical framework of urbanization-health relationships is essential.

Another research gap is the lack of investigation into the moderating effect of individual attributes on urbanization-health relationships. It is hypothesised that these relationships vary by education, as higher-educated 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.[26 27] It is also hypothesised that highly-educated people and low-educated people have differing propensities to migrate, and the effect of health selective migration varies by education level.[28] Furthermore, higher-educated and lower-educated people differ in their ability to adapt to stress arising from rapid urbanization and consequent social life changes.[5 20 29] Therefore, the moderating effect of education on urbanization-health relationships among older people is worth exploring.

This study aimed to investigate the association between urbanization and self-rated health of elderly Chinese 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 urbanization (population growth, land use change, economic growth, and health service improvement) are related to older people's health and how both the level of and rate of urbanization are associated with their health. The study is significant in several respects. First, it takes into account the different dimensions of urbanization, thus capturing the complex association between urbanization and self-reported health of the Chinese elderly. Second, it provides an in-depth understanding of the urbanization-health relationship among the Chinese elderly. Moreover, this study used nationally representative survey data covering 267 prefectures across 31 provinces, thus providing a more comprehensive picture of urbanization-health relationships across the country.

METHODS

Data

This study used individual micro-data from the 2005 China's one per cent 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 (PPS) sampling. 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). 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. The final dataset included 236,030 individuals from 267 prefecture-level cities. Since it is an analysis of secondary data, this study is exempt from ethics approval.

Patient and public involvement

Patients or the public were not involved in this study.

Measures

Outcome

The outcome variable in this study was self-reported health (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.[30-32] Respondents were asked to assess their overall health status over the past month based on a 3-point scale (good, fair, or poor). To simplify the analysis, we recoded the variable into a binary variable: 0 for good

health and 1 for fair health or poor health.

Predictors

The key predictors used to measure prefectures' urbanization level and rate included four specific dimensions of urbanization (land-use conversion, economic growth, population concentration, and health services). The ratio of urban built-up areas to the entire area, the GDP 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, education, primary endowment insurance, 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 urbanization. The models were initially fitted with covariates only. We then added predictors related to both the level and rate of urbanization. Thereafter, these models were sequentially adjusted for interaction terms between the level or the speed of urbanization on one hand and education on the other. We performed a variance inflation factor (VIF) test and found no multicollinearity among the variables. All analyses were conducted using STATA 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. Respondents were more representative of the younger elderly cohorts, ethnic majority (Han Chinese), not married, local agricultural *hukou*, and individuals with low education (junior high school or below). Only 25% was included primary endowment insurance scheme, and about 40% were included basic medical insurance scheme. About 50% of the respondents lived in rural areas. The average housing area per capita is 32.57 square meters. About 77% lived in houses constructed after 1978, and 30% lived in houses with less than two types of facilities.

Table 1 Summary statistics of variables

	Proportion/Mean (SD)
Self-reported health (%)	
Good	66.19
Fair or poor	33.81
Predictors (prefecture-level variables)	
The ratio of urban built-up areas to the total area in 2005 (%)	1.95 (3.48)
GDP per capita in 2005 (10,000 Yuan)	1.87 (1.49)

Population density in 2005 (population per km^2)	548.98 (443.51)
The number of hospital beds per thousand population in 2005 (bed)	2.93 (1.53)
The change in ratio of urban built-up areas from 2000 to 2005 (%)	59.10 (88.93)
The change in GDP per capita from 2000 to 2005 (%)	87.47 (41.19)
The change in population density from 2000 to 2005 (%)	3.40 (11.88)
The change in number of hospital beds per thousand population from 2000 to 2005 (%)	5.21 (13.46)
Gender (%)	
Female	48.74
Male	51.26
Age (%)	
60-64	33.64
65-69	28.49
70-74	23.09
75-79	14.78
Ethnicity (%)	
Han Chinese	96.49
Minority	3.51
Marital status (%)	
Single, divorced, or widowed	75.34
Married	24.66
Hukou status (%)	
Local agricultural	63.77
Local non-agricultural	28.68
Non-local agricultural	2.33
Non-local non-agricultural	5.18
Education (%)	
No schooling	34.73
Elementary school or junior high school	55.04
Senior high school	6.12
College or above	4.11
Primary endowment insurance (%)	
Attended	24.68
Did not attend	75.32
Basic Medical insurance (%)	
Attended	41.44
Did not attend	58.56
Urbanicity of current residence (%)	
Rural areas	52.20
Urban areas: towns	14.87
Urban areas: cities	32.93
Housing area per capita (m^2)	32.57 (25.98)
Housing construction time (%)	
Before 1978	22.62
After 1978	77.38

Housing facilities (%)	
None, one or two types of facilities	30.91
Three types of facilities	24.84
Four types of facilities	29.52

Table 2 presents the results of the multilevel logistic regression. Model 1 includes covariates only. Older people who were female, of 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.

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

Effects and Variables	**Model 1** **OR (95% CI)**	**Model 2** **OR (95% CI)**
Fixed part		
The ratio of urban built-up areas to the total area in 2005		0.99 (0.97 - 1.01)
The change in ratio of urban built-up areas from 2000 to 2005		0.96 (0.90 - 1.02)
The logarithm GDP per capita in 2005		0.91 (0.81 - 1.01)
The change in GDP per capita from 2000 to 2005		0.94 (0.85 - 1.05)
The logarithm population density in 2005		0.93 (0.87 - 0.99) *
The change in population density from 2000 to 2005		0.74 (0.59 - 0.93) **
The number of hospital beds per thousand population in 2005		1.12 (1.06 - 1.19) ***
The change in number of hospital beds per thousand population from 2000 to 2005		0.91 (0.67 - 1.25)
Females (ref: males)	1.16 (1.14 - 1.19) ***	1.16 (1.14 - 1.19) ***
Age (ref: 60-64)		
65-69	1.81 (1.77 - 1.86) ***	1.81 (1.77 - 1.86) ***
70-74	3.19 (3.10 - 3.27) ***	3.19 (3.11 - 3.27) ***
75-79	4.66 (4.53 - 4.80) ***	4.67 (4.53 - 4.81) ***
Minority (ref: Han Chinese)	1.05 (1.00 - 1.11)	1.05 (0.99 - 1.10)
Single, divorced, or widowed (ref: married)	1.30 (1.28 - 1.33) ***	1.30 (1.28 - 1.33) ***
Hukou status (ref: local agricultural)		
Local non-agricultural	0.92 (0.89 - 0.95) ***	0.91 (0.88 - 0.94) ***
Non-local agricultural	0.73 (0.69 - 0.78) ***	0.73 (0.69 - 0.78) ***
Non-local non-agricultural	0.83 (0.78 - 0.87) ***	0.82 (0.78 - 0.87) ***
Education (ref: no schooling)		
Elementary school or junior high school	0.68 (0.67 - 0.70) ***	0.68 (0.67 - 0.70) ***
Senior high school	0.60 (0.57 - 0.63) ***	0.60 (0.57 - 0.63) ***
College or above	0.55 (0.52 - 0.58) ***	0.55 (0.52 - 0.58) ***
Had primary endowment insurance (ref: did not attend)	0.88 (0.85 - 0.91) ***	0.88 (0.85 - 0.91) ***
Had Basic Medical insurance (ref: did not attend)	0.98 (0.95 - 1.00)	0.98 (0.95 - 1.00)

Urbanicity of current residence (ref: rural areas)		
Urban areas: towns	0.87 (0.84 - 0.89) ***	0.87 (0.84 - 0.89) ***
Urban areas: cities	0.87 (0.84 - 0.90) ***	0.87 (0.84 - 0.89) ***
Housing area per capita (m^2)	0.99 (1.00 - 1.00) ***	0.99 (0.99 - 1.00) ***
Housing construction time after 1978 (ref: before 1978)	0.88 (0.86 - 0.90) ***	0.88 (0.86 - 0.90) ***
Housing facilities (ref: none, one and two)		
Three	0.99 (0.96 - 1.01)	0.99 (0.96 - 1.01)
Four	0.82 (0.80 - 0.85) ***	0.83 (0.80 - 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

Note: OR: odds ratio; 95% confidence intervals in brackets; * p<0.05 to ** p<0.01 to *** p<0.001

The results of Model 2 show that the level and the rate of population concentration were negatively associated with the odds of reporting fair or poor health (level: OR (95% CI) = 0.93 (0.87-0.99); rate: OR (95% CI) = 0.74 (0.59-0.93)), while the level of health services was positively correlated with the odds of reporting fair or poor health (OR (95% CI) = 1.12 (1.06-1.19)). 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 (95% CI) = 0.99 (0.97-1.01); economic growth: OR (95% CI) = 0.91 (0.81-1.01)). 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 (95% CI) = 0.96 (0.9-1.02); economic growth rate: OR (95% CI) = 0.94 (0.85-1.05); health service improvement: OR (95% CI) =0.91 (0.67-1.25)).

The results of the moderating effect of education on the association between the level of urbanization and SRH are shown in Table 3. The level of land use conversion was negatively associated with the SRH of the least educated (OR (95% CI) = 0.98 (0.96-1.00)) and positively associated with the odds of those who had completed primary education reporting fair or poor health (OR (95% CI) = 1.02 (1.02-1.03), 1.04 (1.03-1.05), and 1.03 (1.02-1.05)) (Model 3). The level of economic growth was not significantly associated with the SRH of the least educated (OR (95% CI) = 0.95 (0.88-1.02)) and were positively associated with that of other educational groups (OR (95% CI) = 1.08 (1.05-1.12), 1.19 (1.11-1.26), and 1.14 (1.05-1.24)) (Model 4). The level of population concentration was negatively correlated with the odds of reporting fair or poor health across all educational groups, and the strength of the negative relationship decreased with a higher level of education (OR (95% CI) = 0.84 (0.79-0.89), 1.08 (1.05-1.10), 1.19 (1.13-1.26), and 1.19 (1.11-1.28)) (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 (95% CI) = 1.05 (1.01-1.09), 1.04 (1.02-1.05), 1.07 (1.04-1.10), and 1.04 (1.00-1.07)) (Model 6).

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

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

Note: OR odds ratio; 95% confidence intervals in brackets; * p<0.05, ** p<0.01, *** p<0.001. All models have been adjusted for individual covariates shown in Table 2.

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

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

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

Note: OR odds ratio; 95% confidence intervals in brackets; * p<0.05, ** p<0.01, *** p<0.001. All models have been adjusted for individual covariates shown in Table 2.

DISCUSSION

This study is the first to examine the association between the multiple dimensions of urbanization and SRH among elderly Chinese 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. This can be partially attributed to healthy migration and the "salmon bias" phenomenon.[19 28] Fast-growing and densely populated cities draw numerous healthy and working-aged migrants from rural and small-town areas, and most of these migrants still perceive themselves to be healthy when they cross the age of 60 years (healthy migration phenomenon). Migrants who perceive themselves to be unhealthy are likely to return to their rural and small-town hometowns when they are retired or are close to retirement age ("salmon bias" phenomenon). It is a traditional Chinese culture that people would revert to their origin when they are old. On the other hand, 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 urbanization.[7 8 16] Specifically, people living in more urbanized 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 (i.e., more physical activities and less high-fat and high-calorie intake) which 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 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 urbanization and older people's SRH.

Urbanization may also positively affect people's health through improved healthcare services and quality of life.[5] These pathways are associated with two dimensions of urbanization, economic growth and health service improvements, which are found to be either non-significantly or counter-intuitively 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.

Education had a moderating effect on the association between each of the four dimensions of urbanization 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-urbanized 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 33] 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 healthy 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 urbanization over time on older peoples' health outcomes due to the cross-sectional nature of the data. Second, our estimates of the effect of urbanization on health might be subject to self-selection bias, as older people with certain observed or unobserved characteristics (e.g. having well-educated parents) are more likely to live in more urbanized 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 (e.g. health behaviours, the use of health-care facilities and services, and social capital) through which urbanization affects SRH due to the lack of relevant information in our dataset.

In conclusion, the results show that the odds 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 urbanization and older people's SRH. The possible explanations for the difference between more educated and less educated older people in terms of urbanization-health relationships include healthy 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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Exploring the association between urbanization and self-rated health of the older adults in China: Evidence from a national population sample survey

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ABSTRACT

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

Design The study uses a cross-sectional survey design.

Participants

This study analyzed 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 urbanization: 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 urbanization, after adjusting for individual-level covariates. Multiplicative interactions explored variations by education.

Results

The odds 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 urbanization) were not significantly associated with self-rated health. Education had a moderating effect on the association between urbanization 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 urbanization to health are unclear: lifestyle changes, environmental pollution, and cultivated land reduction.

Strengths and limitations of this study

- The study considers the different dimensions of urbanization, thus capturing the complex association between urbanization and self-reported health of older adults in China.
- It provides an in-depth understanding of the urbanization-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 urbanization-health relationships across the country.
- We were unable to capture the causal effect of changes in urbanization over time on older peoples' health outcomes due to the cross-sectional nature of the data.

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INTRODUCTION

The 2018 revision of World Urbanization 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 lion's share of the future growth of the world's urban population is expected to happen in developing 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 developing countries, where urbanization 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 developing country in the world, has been undergoing urbanization at an unprecedented rate over the last three decades.[1] A small but growing body of literature has investigated the effect of urbanization on the Chinese population's health.[6-15] Most earlier studies used either a single indicator (e.g. urbanization rate) or a composite indicator derived from a set of neighbourhood characteristics (e.g. urbanicity index) to assess the level of urbanization and explore its relationship with individual health.[6-11] However, these studies have failed to recognise urbanization as a multi-faceted process involving population concentration, economic growth, land-use conversion, infrastructure upgrading, and lifestyle changes, and that different aspects of urbanization 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 industrializing 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 urbanization, 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 urbanization on residents' health could provide a complete picture of how urbanization affects individual health.

Another limitation of previous studies is that the extent to which the urbanization rate influences residents' health has been rarely examined. For example, a previous study investigated the effect of living in more urbanized areas on health at a given time-point (i.e. urbanicity) in the Chinese context.[6 8] However, highly urbanized areas do not necessarily experience rapid urbanization.[4 5 24] The rate of urbanization 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 urbanization simultaneously. For example, Chen et al.[16] investigated the effects of urbanization on health using multiple measures of urbanization dynamics including the level and rate of urbanization; however, their conclusion was drawn from the analysis of a small-scale survey conducted in 27 prefectures, which had the limitations of poor generalizability and homogeneous environmental settings.[26 27] Therefore, including the rate of urbanization in the analytical framework of urbanization-health relationships is essential.

Another research gap is the lack of investigation into the moderating effect of individual attributes on urbanization-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 low-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 urbanization and consequent social life changes.[5 22 31] Therefore, the moderating effect of education on urbanization-health relationships among older people is worth exploring.

This study aimed to investigate the association between urbanization 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 urbanization (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 urbanization are associated with their health. Further, it examined the moderating effect of education on the association between each of the four dimensions of urbanization and health. The study is significant in several respects. First, it considers the different dimensions of urbanization, thus capturing the complex association between urbanization and self-reported health of the older adults. Second, it provides an in-depth understanding of the urbanization-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 urbanization-health relationships across the country.

METHODS

Data

This study used individual micro-data 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 (PPS) 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). Post-survey 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 3,701 (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. This study is exempt from ethical approval for the following reasons: first, the micro-data 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 organization that complied with various legal requirements about data protection.

Patient and public involvement

Patients or the public were not involved in this study.

Measures

Outcome

The outcome variable in this study was self-reported health (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 three-point scale (good, fair, or poor). To simplify the analysis, we 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' urbanization level and rate included four specific dimensions of urbanization (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 urbanization. The models were initially fitted with covariates only. We then added predictors related to both the level and rate of urbanization. Thereafter, these models were sequentially adjusted for interaction terms between the level or the rate of urbanization 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 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. 62.12% of respondents were aged between 60 and 69. Respondents were more representative of ethnic majority (Han Chinese), not married, local agricultural *hukou*, and 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 meters. About 77% lived in houses constructed after 1978, and 30% in houses with less than two types of facilities.

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 Yuan)	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 number of hospital beds per thousand 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 number of hospital beds per thousand 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
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

Note: results are presented as proportion for categorical variables and as mean (standard errors) for continuous variables. GDP Gross Domestic Product

Table 2 presents the results of the multilevel logistic regression. Model 1 includes covariates only. Older people who were female, of 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.

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

Effects and Variables	**Model 1 OR (95% CI)**	**Model 2 OR (95% CI)**
Fixed part		
Land-use conversion in 2005		0.99 (0.97 - 1.01)
The change in land-use conversion from 2000 to 2005		0.96 (0.90 - 1.02)
The logarithm GDP per capita in 2005		0.91 (0.81 - 1.01)
The change in GDP per capita from 2000 to 2005		0.94 (0.85 - 1.05)
The logarithm population density in 2005		0.93 (0.87 - 0.99) *
The change in population density from 2000 to 2005		0.74 (0.59 - 0.93) **
The number of hospital beds per thousand population in 2005		1.12 (1.06 - 1.19) ***
The change in number of hospital beds per thousand population from 2000 to 2005		0.91 (0.67 - 1.25)
Females (ref: males)	1.16 (1.14 - 1.19) ***	1.16 (1.14 - 1.19) ***
Age (ref: 60-64)		
65-69	1.81 (1.77 - 1.86) ***	1.81 (1.77 - 1.86) ***

70-74	3.19 (3.10 - 3.27) ***	3.19 (3.11 - 3.27) ***
75-79	4.66 (4.53 - 4.80) ***	4.67 (4.53 - 4.81) ***
Minority (ref: Han Chinese)	1.05 (1.00 - 1.11)	1.05 (0.99 - 1.10)
Single, divorced, or widowed (ref: married)	1.30 (1.28 - 1.33) ***	1.30 (1.28 - 1.33) ***
Hukou status (ref: local agricultural)		
Local non-agricultural	0.92 (0.89 - 0.95) ***	0.91 (0.88 - 0.94) ***
Non-local agricultural	0.73 (0.69 - 0.78) ***	0.73 (0.69 - 0.78) ***
Non-local non-agricultural	0.83 (0.78 - 0.87) ***	0.82 (0.78 - 0.87) ***
Education (ref: no schooling)		
Elementary school or junior high school	0.68 (0.67 - 0.70) ***	0.68 (0.67 - 0.70) ***
Senior high school	0.60 (0.57 - 0.63) ***	0.60 (0.57 - 0.63) ***
College or above	0.55 (0.52 - 0.58) ***	0.55 (0.52 - 0.58) ***
Had primary endowment insurance (ref: did not have)	0.88 (0.85 - 0.91) ***	0.88 (0.85 - 0.91) ***
Had Basic Medical insurance (ref: did not have)	0.98 (0.95 - 1.00)	0.98 (0.95 - 1.00)
Urbanicity of current residence (ref: rural areas)		
Urban areas: towns	0.87 (0.84 - 0.89) ***	0.87 (0.84 - 0.89) ***
Urban areas: cities	0.87 (0.84 - 0.90) ***	0.87 (0.84 - 0.89) ***
Housing area per capita (m^2)	0.998 (0.997 - 0.999) ***	0.998 (0.997 - 0.999) ***
Housing construction time after 1978 (ref: before 1978)	0.88 (0.86 - 0.90) ***	0.88 (0.86 - 0.90) ***
Housing facilities (ref: none, one and two)		
Three	0.99 (0.96 - 1.01)	0.99 (0.96 - 1.01)
Four	0.82 (0.80 - 0.85) ***	0.83 (0.80 - 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

Note: OR: odds ratio; 95% confidence intervals in brackets; * p<0.05, ** p<0.01, *** p<0.001.

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

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

Note: OR: odds ratio; 95% confidence intervals in brackets; * p<0.05, ** p<0.01, *** p<0.001. All models have been adjusted for individual covariates shown in Table 2.

Table 4 presents the results of the moderating effect of education in the association between the rate of urbanization 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 senior high school 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).

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

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

Note: OR odds ratio; 95% confidence intervals in brackets; * p<0.05, ** p<0.01, *** p<0.001. All models have been adjusted for individual covariates shown in Table 2.

DISCUSSION

This study is the first study to examine the association between the multiple dimensions of urbanization 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 urbanization.[7 8 16] Specifically, people living in more urbanized 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 (i.e., 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 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 urbanization and older people's SRH.

Urbanization may also positively affect people's health through improved healthcare services and quality of life.[5] These pathways are associated with two dimensions of urbanization, economic growth and health service improvements, which are found to be either non-significantly or counter-intuitively 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.

Education had a moderating effect on the association between each of the four dimensions of urbanization 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-urbanized 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 urbanization over time on older peoples' health outcomes due to the cross-sectional nature of the data. Second, our estimates of the effect of urbanization on health might be subject to self-selection bias, as older people with certain observed or unobserved characteristics (e.g. having well-educated parents) are more likely to live in more urbanized 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 (e.g. health behaviours, the use of health-care facilities and services, and social capital) through which urbanization affects SRH due to the lack of relevant information in our dataset.

In conclusion, the results show that the odds 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 urbanization and older people's SRH. The possible explanations for the difference between more educated and less educated older people in terms of urbanization-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.

Data sharing statement No data are available

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			4-5
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			5-6
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	6
		(*e*) Describe any sensitivity analyses	
Results			6-11

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6-7
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6-7
		(b) Indicate number of participants with missing data for each variable of interest	
Outcome data	15*	Report numbers of outcome events or summary measures	6
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-9
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9-11
Discussion			12-13
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	
Other information			14-16
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Exploring the association between urbanization and self-rated health of the older adults in China: Evidence from a national population sample survey

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Exploring the association between urbanization and self-rated health of the older adults in China: Evidence from a national population sample survey

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ABSTRACT

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

Design The study uses a cross-sectional survey design.

Participants

This study analyzed 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 urbanization: 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 urbanization, after adjusting for individual-level covariates. Multiplicative interactions explored variations by education.

Results

The odds 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 urbanization) were not significantly associated with self-rated health. Education had a moderating effect on the association between urbanization 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 urbanization to health are unclear: lifestyle changes, environmental pollution, and cultivated land reduction.

Strengths and limitations of this study

- The study considers the different dimensions of urbanization, thus capturing the complex association between urbanization and self-reported health of older adults in China.
- It provides an in-depth understanding of the urbanization-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 urbanization-health relationships across the country.
- We were unable to capture the causal effect of changes in urbanization over time on older peoples' health outcomes due to the cross-sectional nature of the data.

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INTRODUCTION

The 2018 revision of World Urbanization 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 lion's share of the future growth of the world's urban population is expected to happen in developing 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 developing countries, where urbanization 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 developing country in the world, has been undergoing urbanization at an unprecedented rate over the last three decades.[1] A small but growing body of literature has investigated the effect of urbanization on the Chinese population's health.[6-15] Most earlier studies used either a single indicator (e.g. urbanization rate) or a composite indicator derived from a set of neighbourhood characteristics (e.g. urbanicity index) to assess the level of urbanization and explore its relationship with individual health.[6-11] However, these studies have failed to recognise urbanization as a multi-faceted process involving population concentration, economic growth, land-use conversion, infrastructure upgrading, and lifestyle changes, and that different aspects of urbanization 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 industrializing 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 urbanization, 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 urbanization on residents' health could provide a complete picture of how urbanization affects individual health.

Another limitation of previous studies is that the extent to which the urbanization rate influences residents' health has been rarely examined. For example, a previous study investigated the effect of living in more urbanized areas on health at a given time-point (i.e. urbanicity) in the Chinese context.[6 8] However, highly urbanized areas do not necessarily experience rapid urbanization.[4 5 24] The rate of urbanization 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 urbanization simultaneously. For example, Chen et al.[16] investigated the effects of urbanization on health using multiple measures of urbanization dynamics including the level and rate of urbanization; however, their conclusion was drawn from the analysis of a small-scale survey conducted in 27 prefectures, which had the limitations of poor generalizability and homogeneous environmental settings.[26 27] Therefore, including the rate of urbanization in the analytical framework of urbanization-health relationships is essential.

Another research gap is the lack of investigation into the moderating effect of individual attributes on urbanization-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 low-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 urbanization and consequent social life changes.[5 22 31] Therefore, the moderating effect of education on urbanization-health relationships among older people is worth exploring.

This study aimed to investigate the association between urbanization 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 urbanization (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 urbanization are associated with their health. Further, it examined the moderating effect of education on the association between each of the four dimensions of urbanization and health. The study is significant in several respects. First, it considers the different dimensions of urbanization, thus capturing the complex association between urbanization and self-reported health of the older adults. Second, it provides an in-depth understanding of the urbanization-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 urbanization-health relationships across the country.

METHODS

Data

This study used individual micro-data 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 (PPS) 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). Post-survey 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 3,701 (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. This study is exempt from ethical approval for the following reasons: first, the micro-data 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 organization that complied with various legal requirements about data protection.

Patient and public involvement

Patients or the public were not involved in this study.

Measures

Outcome

The outcome variable in this study was self-reported health (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 three-point scale (good, fair, or poor). To simplify the analysis, we 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' urbanization level and rate included four specific dimensions of urbanization (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 urbanization. The models were initially fitted with covariates only. We then added predictors related to both the level and rate of urbanization. Thereafter, these models were sequentially adjusted for interaction terms between the level or the rate of urbanization 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 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. 62.12% 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 meters. About 77% lived in houses constructed after 1978, and 30% in houses with less

than two types of facilities.

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 Yuan)	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 number of hospital beds per thousand 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 number of hospital beds per thousand 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
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

Note: results are presented as proportion for categorical variables and as mean (standard errors) for continuous variables. GDP Gross Domestic Product

Table 2 presents the results of the multilevel logistic regression. Model 1 includes covariates only. Older people who were female, of 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.

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

Effects and Variables	**Model 1** **OR (95% CI)**	**Model 2** **OR (95% CI)**
Fixed part		
Land-use conversion in 2005		0.99 (0.97 - 1.01)
The change in land-use conversion from 2000 to 2005		0.96 (0.90 - 1.02)
The logarithm GDP per capita in 2005		0.91 (0.81 - 1.01)
The change in GDP per capita from 2000 to 2005		0.94 (0.85 - 1.05)
The logarithm population density in 2005		0.93 (0.87 - 0.99) *
The change in population density from 2000 to 2005		0.74 (0.59 - 0.93) **
The number of hospital beds per thousand population in 2005		1.12 (1.06 - 1.19) ***
The change in number of hospital beds per thousand population from 2000 to 2005		0.91 (0.67 - 1.25)
Females (ref: males)	1.16 (1.14 - 1.19) ***	1.16 (1.14 - 1.19) ***

Age (ref: 60-64)		
65-69	1.81 (1.77 - 1.86) ***	1.81 (1.77 - 1.86) ***
70-74	3.19 (3.10 - 3.27) ***	3.19 (3.11 - 3.27) ***
75-79	4.66 (4.53 - 4.80) ***	4.67 (4.53 - 4.81) ***
Minority (ref: Han Chinese)	1.05 (1.00 - 1.11)	1.05 (0.99 - 1.10)
Single, divorced, or widowed (ref: married)	1.30 (1.28 - 1.33) ***	1.30 (1.28 - 1.33) ***
Hukou status (ref: local agricultural)		
Local non-agricultural	0.92 (0.89 - 0.95) ***	0.91 (0.88 - 0.94) ***
Non-local agricultural	0.73 (0.69 - 0.78) ***	0.73 (0.69 - 0.78) ***
Non-local non-agricultural	0.83 (0.78 - 0.87) ***	0.82 (0.78 - 0.87) ***
Education (ref: no schooling)		
Elementary school or junior high school	0.68 (0.67 - 0.70) ***	0.68 (0.67 - 0.70) ***
Senior high school	0.60 (0.57 - 0.63) ***	0.60 (0.57 - 0.63) ***
College or above	0.55 (0.52 - 0.58) ***	0.55 (0.52 - 0.58) ***
Had primary endowment insurance (ref: did not have)	0.88 (0.85 - 0.91) ***	0.88 (0.85 - 0.91) ***
Had Basic Medical insurance (ref: did not have)	0.98 (0.95 - 1.00)	0.98 (0.95 - 1.00)
Urbanicity of current residence (ref: rural areas)		
Urban areas: towns	0.87 (0.84 - 0.89) ***	0.87 (0.84 - 0.89) ***
Urban areas: cities	0.87 (0.84 - 0.90) ***	0.87 (0.84 - 0.89) ***
Housing area per capita (m^2)	0.998 (0.997 - 0.999) ***	0.998 (0.997 - 0.999) ***
Housing construction time after 1978 (ref: before 1978)	0.88 (0.86 - 0.90) ***	0.88 (0.86 - 0.90) ***
Housing facilities (ref: none, one and two)		
Three	0.99 (0.96 - 1.01)	0.99 (0.96 - 1.01)
Four	0.82 (0.80 - 0.85) ***	0.83 (0.80 - 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

Note: OR: odds ratio; 95% confidence intervals in brackets; * p<0.05, ** p<0.01, *** p<0.001.

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

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

Note: OR: odds ratio; 95% confidence intervals in brackets; * p<0.05, ** p<0.01, *** p<0.001. All models have been adjusted for individual covariates shown in Table 2.

Table 4 presents the results of the moderating effect of education in the association between the rate of urbanization 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 senior high school 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).

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

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

Note: OR odds ratio; 95% confidence intervals in brackets; * p<0.05, ** p<0.01, *** p<0.001. All models have been adjusted for individual covariates shown in Table 2.

DISCUSSION

This study is the first study to examine the association between the multiple dimensions of urbanization 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 urbanization.[7 8 16] Specifically, people living in more urbanized 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 (i.e., 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 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 urbanization and older people's SRH.

Urbanization may also positively affect people's health through improved healthcare services and quality of life.[5] These pathways are associated with two dimensions of urbanization, economic growth and health service improvements, which are found to be either non-significantly or counter-intuitively 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.

Education had a moderating effect on the association between each of the four dimensions of urbanization 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-urbanized 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 urbanization over time on older peoples' health outcomes due to the cross-sectional nature of the data. Second, our estimates of the effect of urbanization on health might be subject to self-selection bias, as older people with certain observed or unobserved characteristics (e.g. having well-educated parents) are more likely to live in more urbanized 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 (e.g. health behaviours, the use of health-care facilities and services, and social capital) through which urbanization affects SRH due to the lack of relevant information in our dataset.

In conclusion, the results show that the odds 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 urbanization and older people's SRH. The possible explanations for the difference between more educated and less educated older people in terms of urbanization-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.

Data sharing statement No data are available

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			4-5
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			5-6
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	6
		(*e*) Describe any sensitivity analyses	6
Results			6-11

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6-7
		(b) Give reasons for non-participation at each stage	6-7
		(c) Consider use of a flow diagram	6-7
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6-7
		(b) Indicate number of participants with missing data for each variable of interest	6-7
Outcome data	15*	Report numbers of outcome events or summary measures	6
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-9
		(*b*) Report category boundaries when continuous variables were categorized	6
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9-11
Discussion			12-13
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	13-14
Other information			14-16
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.