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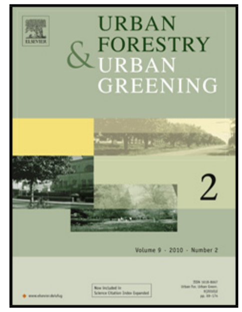

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Association between residential greenness and general health among older adults in rural and urban areas in China

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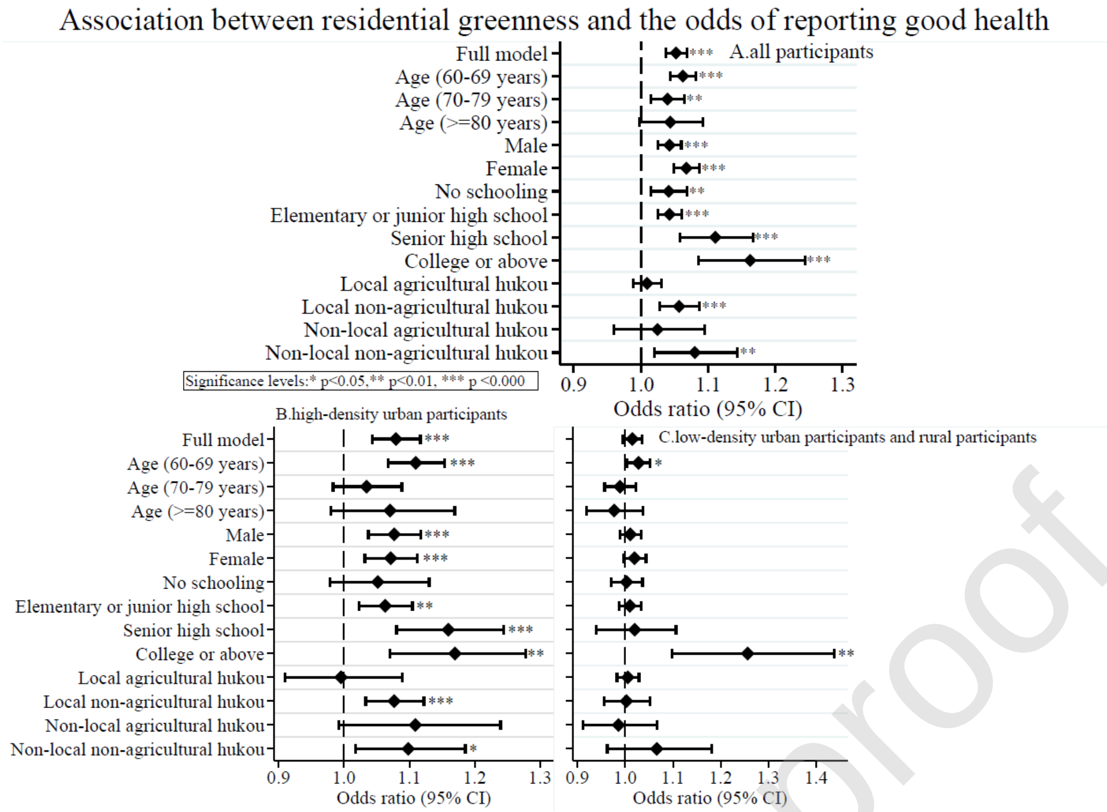
Graphical abstract



Highlights

- This study applies a decennial census dataset covering entire China to examine the greenness-health association.
- It examines the rural-urban disparity in the relationship.
- Greenness was positively associated with the odds of reporting good health.
- The association hinges on the level of urbanicity.
- Demographic traits, SES or urbanicity significantly modified the associations.

Abstract

While it is widely recognized that exposure to residential greenness is beneficial to older adults' health and wellbeing, surprisingly few studies have examined whether the health-promoting effect of residential greenness varies between urban and rural populations in China, a rapidly urbanizing country. In addition, most previous studies on residential greenness-health associations in China have used data collected in a particular city instead of the entire country, resulting in insufficient statistical power and inadequate generalizability. This study assessed the relationship between the amount of surrounding greenness at the township-level and self-rated general health at the individual-level among older adults across the entire country of China, using the geo-referenced micro-data sample of the 2010 China population census and multilevel logistic models. Results indicated that Normalized Difference Vegetation Index (NDVI) was positively associated with self-rated health among all older people, and that the NDVI-health association was stronger in high-density urban areas relative to low-density urban areas and rural areas. Furthermore, the association was stronger for participants who were younger, higher-educated, and non-agricultural *hukou* holders. Our findings provide evidence in support of China's recent endeavour to promote an eco-friendly and greener development strategy.

Keywords: residential greenness; self-rated health; urban-rural difference; multilevel analysis; older adults; China.

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Abbreviations: CI, Confidence Interval; GDP, Gross Domestic Product; MODIS, Moderate-resolution Imaging Spectroradiometer; NDVI, Normalized Difference Vegetation Index; OR, Odds Ratio; $PM_{2.5}$, Fine Particulate Matter; SES, Socioeconomic Status; SRH, Self-Rated Health; VIF, Variance Inflation Factors.

1. Introduction

China's population is currently ageing faster than any other countries around the globe (WHO, 2015). In 2010, the 60-year-old or older population has reached 13.26 percent (177.6 million) of the whole population (The State Council of The People's Republic of China, 2017), and the proportion is projected to account for 28 percent (402 million) by 2040 (Wu and Dang, 2013). This demographic shift poses some significant societal challenges, not least maintaining and improving older adults' health. For example, in 2013, nearly 50 percent of the Chinese population aged over 60 suffered from chronic diseases and 20 percent of them experienced physical dysfunction (Wu and Dang, 2013). Furthermore, in 2010, 25.3 million of the population aged over 60 were in need of daily care and assistance: it is estimated that there will be about 66 million care-dependent older adults by 2050 (WHO, 2015). Therefore, identifying long-term opportunities and effective policy interventions for maintaining and enhancing population health amongst older population is a high priority for policymakers in China.

One emerging opportunity for improving healthy ageing in China is associated with the local availability of green spaces. Evidence is mounting that a large amount of neighbourhood surrounding greenness is conducive to urban residents' health and wellbeing (Huang et al., 2019; Ji et al., 2019; Jia et al., 2018; Liu et al., 2019a; Liu et al., 2019b; Liu et al., 2020). However, most previous studies are constrained to urban population only (Liu et al., 2019a; Liu et al., 2020), and little epidemiological evidence has been provided on the rural-urban disparity in the health-promoting effect of exposure to residential surrounding greenness among Chinese older adults. Relieving psychophysiological stress, restoring attention, reducing exposure to deleterious environments (e.g. traffic noise, air pollution, and heat), encouraging physical activity and promoting social cohesion have been suggested to explain how exposure to residential greenness influences residents' health (Dimitrova et al., 2017; Hartig et al., 2014; Liu et al., 2019a; Markevych et al., 2017). Older people are prone to be dependent on their nearby environments, services, and amenities as a result of limited functional ability (Yen et al., 2009). Examining the linkage between residential greenness and older adults' health outcomes in China is not only scientifically intriguing but also important in evidence-based policy making.

An accumulating body of experimental and epidemiological evidence has suggested that long-term exposure to residential greenness may lead to an array of health benefits, including better self-perceived health (Brindley et al., 2018; Maas et al., 2006; Mitchell and Popham, 2007), lower level of stress and depression

(Liu et al., 2019b; Wheeler et al., 2012), reduced probability of being overweight/obesity (Huang et al., 2020), decreased risk of cardiovascular morbidity and mortality (Ji et al., 2019; Jia et al., 2018), and improvements in physical function (de Keijzer et al., 2019). Several studies showed that older adults were more likely to benefit from residential surrounding greenness, compared to young adults (Huang et al., 2019). One possible explanation to this is that older people are hypothesized to spend more time in their immediate environment than their younger counterparts (Maas et al., 2006).

Although evidence is mounting that residential greenness is beneficial to individuals' health in China (Helbich et al., 2019; Huang et al., 2019; Jia et al., 2018; Liu et al., 2019a), most previous studies on residential greenness-health associations have used data collected in a particular city (e.g. Beijing (Helbich et al., 2019), Guangzhou (Liu et al., 2019a), and Shanghai (Huang et al., 2019)), resulting in the limitation of insufficient statistical power and inadequate generalizability. Only two studies have explored the relationship of greenness to health outcomes (i.e. all-cause mortality and mental health) based on survey data from nationally representative samples in China (i.e. China Longitudinal Health Longevity Survey and China Labour-force Dynamics Survey) (Ji et al., 2019; Liu et al., 2019b). However, the survey data covered merely a small proportion (less than 2 percent) of all township-level divisions in China, and the number of sample members was still relatively small.

In addition, the study population of prior empirical studies is limited to those who are living in high-density urban areas (Jia et al., 2018; Liu et al., 2019a). Evidence on the associations between surrounding greenness and health from Chinese rural areas and small towns is scant, and whether the linkage varies between urban and rural areas or not, remains unknown. It is well known that there are significant differences between urban and rural areas in the accessibility of green spaces, the type of green spaces and the opportunity of the use of green spaces, which influence the nexus between greenness and health (Liu et al., 2019b). For the majority of China's small towns and rural areas, agricultural and natural green spaces are the dominant types of green space, while artificial recreational green spaces such as parks, greenways and ecological corridors are mainly located in high-density central districts of Chinese cities. Green space in urban areas is generally more accessible to potential users than those in rural areas, as urban green spaces were safer, better-maintained and equipped with more facilities than rural green spaces (Ekkel and de Vries, 2017; Xiao et al., 2017). People residing in more urbanized districts are more able and willing to visit and use green spaces for sport and other recreational purposes than those living in small town and rural areas, as urban group is more aware of the importance of health and have more opportunity to use green spaces than the rural group (Ekkel and de Vries, 2017; Markevych et al., 2017).

To address these existing research gaps, the present study examines the relationship between the amount of surrounding greenness at the township level and self-reported general health among older adults across entire China. We have paid special attention to whether greenness-health relationship varied between urban and rural areas. We further explored whether the association was moderated by demographic characteristics (age and sex) and socioeconomic status (education and *hukou* status). The current study adds to the existing body of literature by applying a decennial census dataset covering entire China to test the link between the quantity of surrounding greenness and health among older adults and by examining the rural-urban disparity in the relationship.

2. Data and methods

2.1. Study population

Our study population was extracted from the micro-data sample of the 2010 China population census, which is the most complete and authoritative source of information about population in China. The micro-data sample was randomly drawn from the 2010 China population census database using a systematic sampling technique. The micro-data sample consisted of approximately 4.6 million individuals from 31 provincial-level divisions of Chinese Mainland in 2010. The census data provided information on demographic attributes (e.g. age), socioeconomic status (e.g. educational attainment and hukou status), household characteristics (e.g. housing conditions) and health status of older adults (aged over 60 years). We limited our study population to census participants aged 60 or over, since only those group was required to report their health conditions. The final dataset contained 368,399 older adults living in 24,996 township-level divisions, nested within 2,763 county-level divisions and 337 prefecture-level divisions. Township-level division is situated at the fourth level of structural hierarchy of the administrative division of China, and it can take the form of a subdistrict (*jiēdào*, which is part of a larger urban area), town (*zhèn*, which is a town surrounded by rural areas) and rural township (*xiāng*, which typically has smaller population, a larger proportion of rural population and more remote location than a town). The mean population of the township-level divisions of China is 33,110, and the mean size is about 275 km^2 in 2010. It is worthwhile to note that the township-level division is the smallest geographical unit for which we can access the micro-data sample.

2.2. Measures

2.2.1 Outcome

Self-rated health (SRH) was measured with a single-item survey question on 1st November in 2010, "in general, how would you rate your health over the past month?". Response categories were: 'good health', 'fair health', 'poor health' and 'not able to take care of myself'. We dichotomized the answers into 'good health' and 'fair health or poor health or not able to take care of myself'. We treated the latter category as the group of reference. SRH is a widely applied marker to measure individuals' status of health. Some studies have shown that SRH is a sensitive indicator of predicting mortality, illnesses and health-related behaviour risk (Idler et al. , 1997; Lima-Costa et al., 2012). SRH has been demonstrated as a reliable and effective way to investigate the association between residential greenness exposure and health, particularly when census data and survey data are used (Brindley et al., 2018; Brindley et al., 2019; Dadvand et al., 2016; Mass et al., 2006; Mitchell et al., 2007; Wheeler et al., 2012).

2.2.2 Predictors

The level of residential greenness was assessed by using Normalized Difference Vegetation Index (NDVI), obtained from satellite images collected by the Moderate-resolution Imaging Spectroradiometer (MODIS), onboard NASA's Terra satellite. The MODIS vegetation index products (MOD13Q1) provide NDVI layers every 16 days at 250 meters spatial resolution. We downloaded all NDVI layers for China spanning January to December 2010 from the website of the NASA's Land Processes Distributed Active Archive Center (LP DAAC) (Didan, 2015). NDVI calculates the difference between visible red and near infrared reflectance based on the following formula: NDVI = (Nearinfrared – Red) / (Nearinfrared + Red) (Tucker, 1979). The values for NDVI ranges from -1 to 1. A value less than 0 represents water bodies and snow cover, and a higher positive value indicates a higher vegetation density. In this study, we integrated all remote sensing images over one year to estimate the maximum value of NDVI of each pixel and generate a maximum NDVI composite map for Chinese Mainland in 2010, and then removed pixels with negative NDVI values (Figure 1). We then used QGIS 3.6 software to compute the mean NDVI value of the maximum NDVI composite within the administrative boundary of each township-level division. Figure 1 showed that NDVI values varied substantially in China, and that there was a division along 400 mm precipitation contour. Semihumid and humid regions (to the southeast of the contour) have a much larger NDVI value than semi-arid and arid regions (to the northwest of the contour). We scaled the NDVI values to interquartile range (IQR) values (IQR administrative boundary = 0.18). The association between residential greenness and SRH was interpreted with an interquartile increase in NDVI.

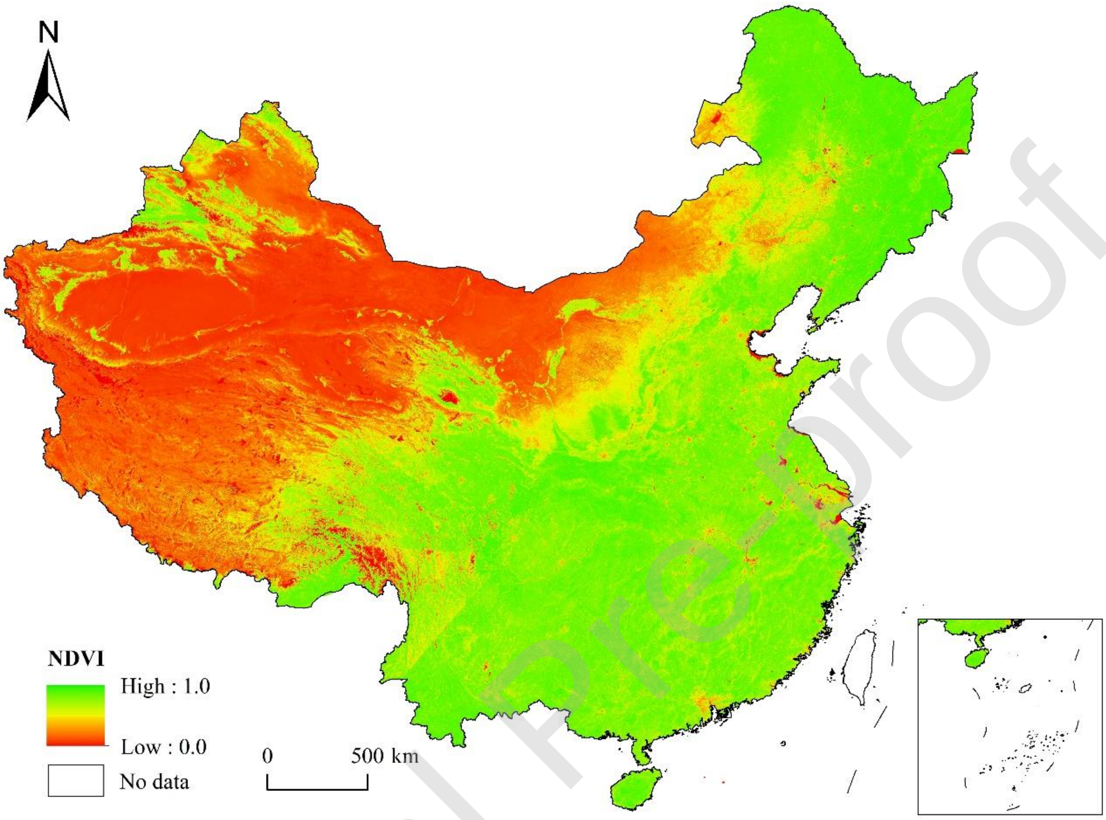

Figure 1. The spatial variation in the value of NDVI in China, 2010

2.3 Analysis

We employed multilevel logistic models to examine the relationship between SRH and residential surrounding greenness. Model 1 contained the predictor of NDVI and covariates. We then investigated the rural-urban differences in residential greenness-SRH association using stratified analysis. Based on the urban and rural classification of the National Bureau of Statistics of China, we divided all township-level divisions into high-density urban areas (sub-districts) and low-density urban areas and rural areas (towns and rural townships) (Models 2-3). The reason behind the combination of towns and rural townships in analysis is that they have numerous similar characteristics such as land-use composition, residents' socioeconomic status and cultural background, and the features and quality of green spaces (for example, city parks and gardens versus farmland and woodland). We also dichotomized township-level divisions with the median (494.90 population per km^2) population density of the divisions as cut-off point (Models 4-5). Furthermore, stratified analyses were used to explore variations in the NDVI-SRH association by age, sex, education and hukou status.

We performed several sensitivity analysis to test the robustness of our findings: 1) we considered the categories of 'poor health' and 'not able to take care of myself' as the reference group (and the categories of 'good health' and 'fair health' as the other group), as well as treated the category of 'not able to take care of myself' as the reference group (and the categories of 'good health', 'fair health', and 'poor health' as the other group), 2) we converted the continuous variable of NDVI into a categorical variable, 3) we excluded township-level divisions with an area larger than 500 km^2 to ensure that the level of greenness was constrained to participants' immediate residential surroundings, 4) we excluded the sample to those aged over 80 years, as these groups had a higher risk of mortality (which may lead to selection bias by death), 5) we further excluded the sample to those who had been away from their registered community residence during the time point of the census, 6) we changed the area of greenness exposure from participants' township-level division to a circular buffer around the centroid of their township-level division (with a radius of 1 kilometre, 3 kilometres or 8 kilometres). The Variance Inflation Factors (VIF) of all variables were less than 5, which suggested the absence of severe multicollinearity. Data were analysed with statistical software Stata 14.0.

2.4 Covariates

We adjusted for an array of township- and individual-level covariates in regressions. Characteristics of living-dwelling environment have an important role to play in determining older adults' health. In the present study, four township-level covariates, including a social deprivation index, Gross Domestic Product (GDP) per square kilometre, population density and annual average $PM_{2.5}$ concentrations, were taken into account. Social deprivation index was calculated as the sum of Z scores of four indicators: the percent of population unemployed, the percent of population with secondary school education or below, the percent of population engaging in the low-skill or elementary occupations, and the percent of population who are tenants. A higher value denotes a more deprived area. Data on GDP (provided at a spatial resolution of 1-kilometer), population density (provided at a spatial resolution of 1-kilometer) and $PM_{2.5}$ concentration (provided at a spatial resolution of 1-kilometer) were downloaded from Resource and Environment Data Cloud Platform website (Liu et al., 2005) and Socioeconomic Data and Applications Centre website (Hammer et al., 2020). We treated these variables as continuous variables.

We also adjusted for a series of individual-level demographic attributes, socioeconomic status (SES) and housing characteristics. The demographic attributes include age (60-69 vs 70-79 vs >=80), sex (female vs male), ethnicity (Han Chinese vs minority) and household arrangement (living alone vs living with someone). Individual SES was measured by two indicators: educational attainment (no schooling vs elementary school or junior high school vs senior high school vs college or above) and *hukou* status (governmental household registration system, a marker of socioeconomic status and cultural background; local agricultural *hukou* vs local non-agricultural *hukou* vs non-local agricultural hukou vs non-local non-agricultural hukou). Housing characteristics included housing facilities (the presence of toilet, bathroom, water supply and kitchen; none, one, two or three types of facilities vs four types of facilities), housing construction time (before 1980 vs after 1980) and per capita housing space (continuous variable). All individual- and family-level variables were derived from the micro-data set of 2010 China population censes.

3. Results

Table 1 presents descriptive characteristics of variables that have been included in the analysis. Of the 368,399 respondents, 160,068 (43.45%) reported good self-rated health. Respondents were more representative of younger older adults (60-69 years, 56.41%), ethnic majority (Han Chinese, 92.53%), those with junior high school education or below (90.72%), those with local agricultural *hukou* (65.87%), those not living alone (92.20%), those dwelling in houses equipped with four types of facilities (90.55%) and those in houses constructed after 1980 (82.01%). The mean per capita housing space was 32.17 m^2. The median NDVI for the administrative boundary was 0.77 (25^{th} to 75^{th} percentile 0.64-0.82). The proportion of low-density urban participants and rural participants (73.82%) was larger than that of high-density urban participants (26.18%).

Table 1. Summary statistics of variables

Variables	All participants (n= 368,399)	Participants living in high-density urban areas (n= 96,442)	Participants living in low-density urban areas and rural areas (n= 271, 957)
Outcome			
Self-reported health (n, %)			

Good health	160,068 (43.45)	47,435 (49.19)	112,651 (41.42)
Fair health	145,468 (39.49)	38,082 (39.49)	107,386 (39.49)
Poor health	51,811 (14.06)	8,538 (8.85)	43,273 (15.91)
Not able to take care of myself	11,034 (3.00)	2,387 (2.48)	8,647 (3.18)
Predictor			
NDVI (median (p25 - p75))	0.77 (0.64 - 0.82)	0.50 (0.35 - 0.66)	0.78 (0.70 - 0.82)
Covariates			
Social deprivation index (mean (SD))	-0.62 (1.23)	-1.34 (1.70)	-0.46 (1.04)
Annual average $PM_{2.5}$ concentrations (μg/m^3) (mean (SD))	37.13 (19.00)	49.34 (17.18)	34.23 (17.99)
The GDP per square kilometre in 2010 (log, Yuan) (mean (SD))	6.13 (1.88)	8.41 (1.20)	5.71 (1.67)
The population density in 2010 (log, population per km^2) (mean (SD))	5.58 (1.63)	7.59 (1.37)	5.20 (1.38)
Age (years) (n, %)			
60-69	207,826 (56.41)	53,032 (54.99)	154,794 (56.92)
70-79	118,027 (32.04)	32,267 (33.46)	85,760 (31.53)
>=80	42,546 (11.55)	11,143 (11.55)	31,403 (11.55)
Sex (n, %)			
Female	188,637 (51.20)	50,253 (52.11)	138,384 (50.88)
Male	179,762 (48.80)	46,189 (47.89)	133,573 (49.12)
Marital status (n, %)			
Single, divorced, or widowed	108,497 (29.45)	24,445 (25.35)	84,052 (30.91)
Married	259,902 (70.55)	71,997 (74.65)	187,905 (69.09)
Ethnicity (n, %)			
Han Chinese	340,882 (92.53)	93,519 (96.97)	247,363 (90.96)
Minority	27,517 (7.47)	2,923 (3.03)	24,594 (9.04)
Education (n, %)			
No schooling	94,956 (25.78)	12,954 (13.43)	82,002 (30.15)
Elementary school or junior high school	239,254 (64.94)	60,066 (62.28)	179,188 (65.89)
Senior high school	21,566 (5.85)	13,385 (13.88)	8,181 (3.01)
College or above	12,623 (3.43)	10,037 (10.41)	2,586 (0.95)
Hukou status (n, %)			
Local agricultural hukou	242,676 (65.87)	16,805 (17.42)	225,871 (83.05)
Local non-agricultural hukou	91,318 (24.79)	58,265 (60.41)	33,053 (12.15)
Non-local agricultural hukou	11,944 (3.24)	5,832 (6.05)	6,112 (2.25)
Non-local non-agricultural hukou	22,461 (6.10)	15,540 (16.11)	6,921 (2.54)
Living alone (n, %)			
Yes	28,729 (7.80)	7,694 (7.98)	21,035 (7.73)
No	339,670 (92.20)	88,748 (92.02)	250,922 (92.27)
Housing area per capita (m^2) (mean (SD))	32.17 (23.81)	31.28 (23.95)	32.49 (23.75)
Housing construction time (n, %)			
Before 1980	66,285 (17.99)	11,867 (12.30)	54,418 (20.01)

After 1980	302,114 (82.01)	84,575 (87.70)	217,539 (79.99)
Housing facilities (n, %)			
None, one, two or three types of facilities	34.802 (9.45)	1,766 (1.83)	33,036 (12.15)
Four types of facilities (toilet, bathroom, water supply and kitchen)	333,597 (90.55)	94,676 (98.17)	238,921 (87.85)

Note: results are presented as number (proportions) for categorical variables and as mean (standard deviation (SD)) for continuous variables.

Table 2 displays the results of multilevel logistic models. Model 1 explores the association between the amount of surrounding greenness and older adults' SRH while controlling for township- and individual-level covariates. The results demonstrated that the amount of greenness was positively related to the odds of reporting good health (OR=1.05, 95% CI 1.04 to 1.07). For an increase of one IQR in NDVI within the township-level divisions, the odds of reporting good health increased by 5%. This finding indicated that older adults who dwelled in areas with more greenness had a higher propensity to report good health, than those living in areas with less greenness. Models 2-3 show the results of stratified analyses by urban-rural classification. In high-density urban areas, more greenness was significantly and positively related to the odds of rating good health (OR=1.08, 95% CI 1.04 to 1.12). However, there was no evidence that residential greenness was associated with SRH in low-density urban areas and rural areas (OR=1.01, 95% CI 0.99 to 1.44). Models 4-5 (Supplemental materials: Table S1) present the results of stratified analyses by population density. Similarly, the amount of surrounding greenness was significantly and positively linked to the likelihood of self-reported good health in both high population density areas (OR=1.07, 95% CI 1.04 to 1.10), but not in low population density areas (OR=1.00, 95% CI 0.97 to 1.02).

Table 2 Multilevel logistic regression estimates of reporting good health

Effects and variables	Model 1	Model 2	Model 3
	All participants	High-density urban areas	Low-density urban areas and rural areas
	OR (95%CI)	OR (95%CI)	OR (95%CI)
Fixed part			
NDVI (IQR)	1.05*** (1.04 - 1.07)	1.08*** (1.04 - 1.12)	1.01 (0.99 - 1.04)
Social deprivation index (SD)	0.98*** (0.96 - 0.99)	0.98** (0.96 - 0.99)	0.96*** (0.95 - 0.98)
Annual average $PM_{2.5}$ concentrations (μg/m^3)	0.99*** (0.99 - 0.99)	0.99*** (0.99 - 0.99)	0.99*** (0.99 - 0.99)
The logarithm population density in 2010 (population per km^2)	0.94*** (0.92 - 0.96)	0.94*** (0.91 - 0.97)	0.97 (0.95 - 1.00)
The logarithm GDP per square kilometre in 2010 (Yuan)	1.22*** (1.20 - 1.24)	1.18*** (1.14 - 1.22)	1.22*** (1.19 - 1.24)
Age (ref: 60-69) (years)			
70-79	0.39*** (0.38 - 0.39)	0.41*** (0.40 - 0.43)	0.38*** (0.37 - 0.38)

>=80	0.22*** (0.21 - 0.22)	0.23*** (0.22 - 0.24)	0.21*** (0.20 - 0.22)
Male (ref: female)	1.25*** (1.23 - 1.27)	1.20*** (1.17 - 1.24)	1.28*** (1.25 - 1.30)
Married (ref: single, divorced, or widowed)	1.36*** (1.33 - 1.38)	1.26*** (1.21 - 1.31)	1.39*** (1.36 - 1.42)
Minority (ref: Han Chinese)	1.05** (1.01 - 1.09)	0.92 (0.84 - 1.00)	1.09*** (1.05 - 1.13)
Education (ref: no schooling)			
Elementary school or junior high school	1.46*** (1.43 - 1.49)	1.44*** (1.37 - 1.51)	1.46*** (1.43 - 1.49)
Senior high school	1.72*** (1.66 - 1.79)	1.70*** (1.60 - 1.80)	1.75*** (1.66 - 1.85)
College or above	1.80*** (1.72 - 1.88)	1.81*** (1.69 - 1.94)	1.78*** (1.62 - 1.95)
Hukou status (ref: local agricultural hukou)			
Local non-agricultural hukou	1.09*** (1.07 - 1.12)	1.12*** (1.06 - 1.18)	1.11*** (1.08 - 1.15)
Non-local agricultural hukou	1.33*** (1.27 - 1.39)	1.38*** (1.28 - 1.48)	1.32*** (1.24 - 1.40)
Non-local non-agricultural hukou	1.17*** (1.13 - 1.21)	1.26*** (1.19 - 1.34)	1.05 (0.99 - 1.11)
Living alone (ref: no)	0.82*** (0.8 - 0.85)	0.84*** (0.79 - 0.90)	0.81*** (0.78 - 0.85)
Housing area per capita (m^2)	1.00*** (1.00 - 1.00)	1.00*** (1.00 - 1.00)	1.00*** (1.00 - 1.00)
Housing construction time after 1980 (ref: before 1980)	0.87*** (0.86 - 0.89)	0.84*** (0.81 - 0.88)	0.89*** (0.87 - 0.91)
Housing facilities (ref: none, one, two and three)	1.06*** (1.03 - 1.09)	1.16* (1.03 - 1.29)	1.06*** (1.03 - 1.09)
Constant	0.18*** (0.16 - 0.19)	0.22*** (0.16 - 0.30)	0.17*** (0.15 - 0.19)
Random part			
Var (township-level constant)	0.40*** (0.37 - 0.41)	0.32*** (0.30 - 0.35)	0.41*** (0.39 - 0.43)
Number of townships	24 996	4 145	20 851
Number of individuals	368 399	96 442	271 957
AIC	452144.02	121701.08	330291.20
ICC	0.11	0.09	0.11

Note: OR odds ratio; 95% confidence intervals in brackets; IQR interquartile range; SD standard deviation; * p<0.05, ** p<0.01, *** p<0.001.

Figure 2 presents the results of stratified analysis by age, sex, education and *hukou* status. For age-stratified analysis, NDVI was linked to report good health in 60-69 years (OR=1.06, 95% CI 1.04 to 1.08) and 70-79 years cohorts (OR=1.04, 95% CI 1.01 to 1.07). For sex-stratified analysis, the amount of surrounding green space was associated with better SRH in both males (OR=1.04, 95% CI 1.03 to 1.06) and females (OR=1.07, 95% CI 1.05 to 1.09) sub-groups, but the association was stronger for females. Interestingly, for education-stratified analyses, the level of residential greenness was linked to the possibility of reporting good health across all educational groups (OR=1.04, 95% CI 1.01 to 1.07, OR=1.04, 95% CI 1.02 to 1.06, OR=1.11, 95% CI 1.06 to 1.17, and OR=1.16, 95% CI 1.09 to 1.24, respectively), and the strength of the positive association increased with higher level of education. For *hukou* status stratified analyses, the amount of surrounding greenness was related to the likelihood of reporting good health, only in those respondents who had non-agricultural *hukou* (OR=1.06, 95% CI 1.03 to 1.09 and OR=1.08, 95% CI 1.02 to 1.14, respectively). Similar social patterns were found in high-density urban participants with an exception of sex sub-groups. We found that the positive associations between residential greenness and the odds of reporting good health were comparatively stronger for males (OR=1.08, 95% CI 1.04 to 1.12) compared with females (OR=1.07, 95% CI 1.03 to 1.11) in high-density urban areas. In stratified analysis for low-density urban participants and rural participants, we observed a significantly positive relationships between residential greenness and the probability of reporting good health among those aged 60-69 years (OR=1.03, 95% CI 1.00 to 1.05) and those who had college or above education (OR=1.26, 95% CI 1.10 to 1.44).

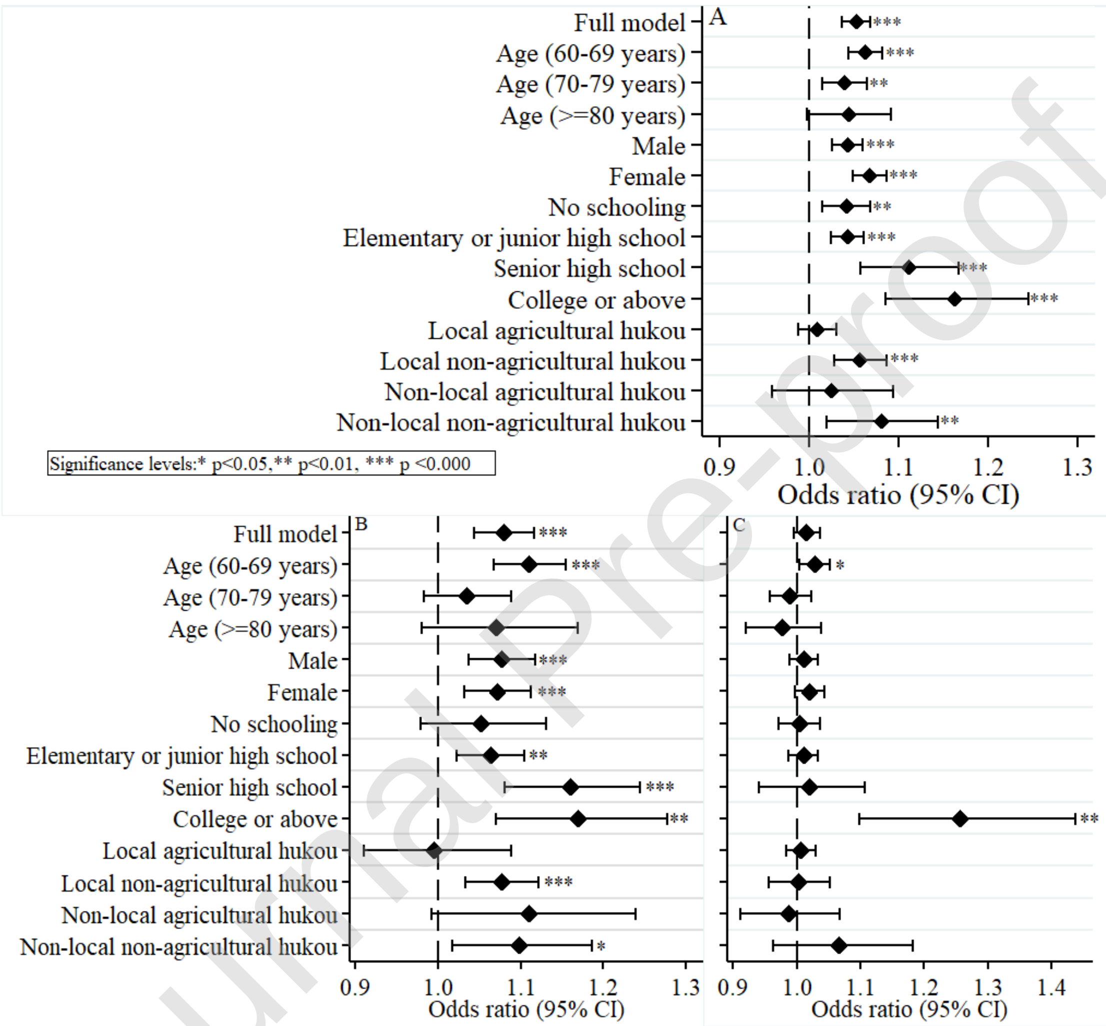

Figure 2 Association between NDVI and the odds of reporting good health stratified by age, sex, education and *hukou* status

Note: Points denote odds ratio. Bars denote 95% confidence interval; Significance levels: * p < 0.05, ** p < 0.01, *** p < 0.000.

A, all participants; B, high-density urban participants; C, low-density urban participants and rural participants;

All models have been adjusted for covariates in Table 1.

Figure 3 reveals the results of sensitivity analysis. The associations were similar in sensitivity analyses using different reference groups. When the amount of surrounding greenness is categorized as tertiles, similar relationships could be identified. In addition, the direction and statistical significance of residential greenness on SRH does not vary substantially after restricting the sample to those who resided in township-level divisions with an area less than 500 km^2, those aged 60-79 years, and those who had dwelled in their registered community residence during the census time point. Moreover, the estimates based on greenness with 1-kilometre, 3-kilometre or 8-kilometre buffers were consistent with the estimates based on the amount of surrounding greenness in township-level divisions.

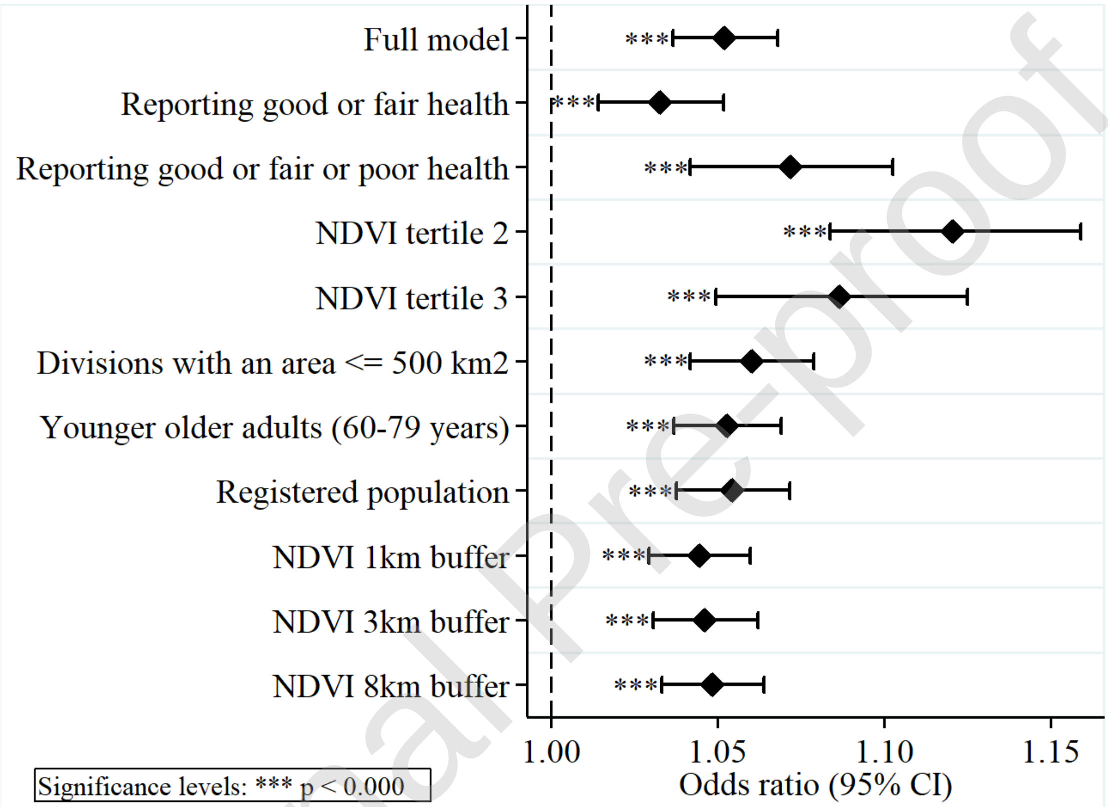

Figure 3 Results of sensitivity tests

Note: Points denote odds ratio. Bars denote 95% confidence interval. Significance levels: *** p < 0.000.

All models have been adjusted for covariates in Table 2.

Reporting good or fair health and Reporting good or fair or poor health respectively represent the estimates using the categories of 'poor health' and 'not able to take care of myself' as the reference group, and the category of 'not able to take care of myself' as the reference group. Divisions with an area <= 500 km2, Younger older adults (60-79 years) and Registered population represent, respectively, the estimates of NDVI and the odds of reporting good health association after restricting the sample to those who resided in township-level divisions with an area less than 500 km^2, those aged 60-79 years, and those who had dwelled in their registered community residence during the time point of the census. NDVI 1 km buffer, NDVI 3 km buffer and NDVI 8 km buffer represent the estimates based on NDVI with 1 kilometre or 3 kilometres or 8 kilometres buffers.

4. Discussion

Our observational study based on a national large sample shows that older people in China living in township-level divisions with larger amount of green spaces were more likely to report good health. Furthermore, the residential greenness-health association varied in terms of the level of urbanicity, with stronger associations for high-density urban areas compared to those in low-density urban areas and rural areas. Additionally, we found stronger beneficial relationships among younger participants, those who had college or above education, and those who had non-agricultural *hukou*.

Previous studies have produced relatively consistent evidence on the beneficial effect of exposure to residential greenness to SRH (Brindley et al., 2019; Brindley et al., 2018; Cole et al., 2019; Dadvand et al., 2016; de Vries et al., 2003; Mears et al., 2020; Reid et al., 2018; Sugiyama et al., 2008; Triguero-Mas et al., 2015; van Dillen et al., 2012; Vries et al., 2013; Wheeler et al., 2012). For example, an ecological study in the Netherlands found that the quantity of surrounding greenness in participants' residential environment was positively related to participants' self-assessed health (Maas et al., 2006). Another study conducted in England also exhibit that people living in an area with a greater amount of greenness was related to better SRH (Mitchell and Popham, 2007). Two Dutch studies showed that both the amount and the quality of neighbourhood greenness and street planting were linked to better subjective general health (de Vries et al., 2013; van Dillen et al., 2012). Studies carried out in Spain reported that the amount of neighbourhood greenness and the accessibility of green spaces were correlated with better general health (Dadvand et al., 2016; Triguero-Mas et al., 2015). A cross-sectional study in Shanghai, China, revealed that higher neighbourhood greenness and proximity to residential green space was related to better SRH among older adults (Huang et al., 2019).

This study has identified new evidence that support the existence of salotugenic effect of the amount of surrounding greenness with older adults' SRH, based on a nationally representative and geographically heterogeneous samples. The present study found that older adults dwelling in greener areas were more likely to rate good health. Several potential biopsychosocial mechanisms may explain the beneficial association of greenness. Firstly, residential greenness provides a resource for stress reduction and psychological restoration, thereby increasing well-being and improving perceived health status (Liu et al., 2019a; Markevych et al., 2017; Triguero-Mas et al., 2015). Secondly, green vegetation can mitigate exposure to environmental nuisances (e.g. noise, air pollution and heat) that are hazardous to residents' health (Franchini and Mannucci, 2018; Markevych et al., 2017). Thirdly, residential surrounding greenness supports local social cohesion, residential satisfaction and healthy and active lifestyle by offering an accessible and attractive spaces for social interaction, entertainment participation, and physical exercise, which have positive impacts on older adults' health (Markevych et al., 2017; Sugiyama et al., 2008).

Our results of a positive relationship between surrounding greenness and SRH are stronger in high-density urban areas, compared with low-density urban areas and rural areas. Some high-density urban areas in China have well-equipped and accessible parks and greenways, which provides an attractive space for senior citizens to engage in outdoor activities such as recreational, entertainment, body-building and social activities, thus, promoting older adults' perceived health. Low-density urban areas and rural areas, usually consisting of large portion of forest and agricultural land, by itself possesses stress-reducing and pollution mitigating capacities that could contribute to human health (Ekkel and de Vries, 2017). However, green space in low-density urban areas and rural areas are generally characterised by wild and inaccessible environment, which does not support residents to conduct recreational and social activity. Abovementioned reason could a possible explanation for the insignificant coefficients between surrounding greenness and SRH in low-density urban areas and rural areas. Another possible explanation is that, residents of high-density urban areas are more aware of the importance of health and the benefits of using green spaces than those of low-density urban areas and rural areas, which facilitates and encourages the former group to visit and use green space more frequently than the latter group. Prior studies conducted in England found that the greenness-health association varied between urban and rural areas. The relationship held for all urban areas and rural low-income areas, but not for higher income suburban and higher income rural areas (Mitchell and Popham, 2007).

We found that the greenness-SRH relationship was significant in younger older adults aged 60-69 years and aged 70-79 years, which was broadly in consistent with results from the two prior studies (Huang et al., 2019; Maas et al., 2009). Compared with those aged above 80 years, younger respondents were more likely to have better mobility functions as well as stronger desire to contact with the green environment in their living environment for exercise, entertainment activities, and social interaction (Huang et al., 2019; Yen et al., 2009). We also observed that the greenness-SRH association was stronger for females than males. This finding was in line with previous literature that reported that females benefit more from residential green space than males (Huang et al., 2019; Tamosiunas A 2014; Triguero-Mas et al., 2015). One explanation could be that older Chinese females have a higher likelihood of using green space, because they shoulder more responsibility of taking care of grandchildren than older Chinese males (Huang et al., 2019; Yang et al., 2019), hence perform physical activities such as Tai Chi and square dancing in this environment more frequently. Inconsistent with earlier European works that observe that the link of greenness to SRH is stronger for participants with lower education attainment (Mass et al., 2016; Mass et al., 2009), our finding showed that older adults with a higher education level benefit more from living in greener neighbourhoods than those with a lower education level. One explanation could be that better-educated respondents are more aware of the importance of health and, therefore, more willing to visit nearby green spaces more frequently than their less-well-educated counterparts. The effect among those with college education and above is very large compared to other factors. Lastly, our result showed that the greenness-SRH association was pronounced for non-agricultural *hukou* holders. This finding to some extents reflected the fact that residents with local non-agricultural *hukou* usually have higher socio-economic status and dwell in areas with well-equipped green spaces.

Some limitations of our study should be noted: firstly, the cross-sectional design had a limited capability for inferring causation, and we were unable to assess the effect of earlier life exposure to greenness on later life health outcomes. Secondly, although we had adjusted several potential confounders in the multilevel analyses, other residual confounders such as behavioural risk factors (e.g. physical activity, tobacco use and alcohol consumption), socioeconomic status (e.g. income and employment), chronic conditions (e.g. the presence or absence of non-communicable diseases) and some unobserved individual characteristics (e.g. genetic vulnerability) were not adjusted due to the unavailability of these data in the census dataset. This may lead to self-selection bias and omitted-variable bias in our regression estimates. Thirdly, the use of self-rated measure may result in outcome misclassification, due to the subjective health expectations. In fact, health cognition and health-related behaviours may vary significantly between high-density urban areas, low-density urban areas, and rural areas, as well as between high population density areas and low population density areas, and between high and low socioeconomic status group. Fourthly, we used the mean NDVI value of the maximum NDVI composite within the administrative boundary to assess residential greenness exposure. It is noted that this value represented the density of vegetation in summer, and seasonal differences in NDVI varied substantially across China. For example, seasonal difference in NDVI in North China (where deciduous plants are more prevalent) is larger than difference in South China (where evergreen plants are more commonly seen). Neglecting the seasonal difference in NDVI may lead to an underestimate in the greenness-health relationship. Fifthly, green spaces and blue spaces are usually close to each other in some places, and previous studies have found that blue spaces could be an important public recreational and health resource (Helbich et al., 2019; Huang et al., 2019; Liu et al., 2020). The present study has omitted all water pixels from the satellite images when calculating NDVI values. Future research is needed to take into account the health benefit of living near to water bodies when assessing the association of residential greenness with health. Sixthly, our greenness assessment is based on relatively large spatial units (township-level) instead of at respondents' home address, which could result in errors of exposure measurement. Seventhly, this study has adopted a vegetation index NDVI to assess the level of residential greenness, which may not be able to capture the quality and the type of residential greenness adequately, due to data unavailability. Last but not least, more recent census data are needed to scrutinize the change in greenness-health association if they are available.

5. Conclusion

This study has demonstrated that, in China, older adults residing in township-level divisions with larger amount of surrounding greenness are prone to have better health. The relationship is contingent on the level of urbanicity, with stronger associations for high-density urban areas than low-density urban areas and rural areas. The association was stronger for the younger, the higher-educated, and local non-agricultural *hukou* holders. In the context of rapid urbanization and population aging in China, our findings have significant implications for policy makers and urban planners in creating healthy city, preventing the negative effects of urbanization on public health and promoting health aging through increasing the supply of green spaces and improving quality of green infrastructures.

Credit Author Statement

Baishi Huang and Ye Liu conceived and designed the study. Baishi Huang and Cuiying Huang performed statistical analysis. Baishi Huang and Ye Liu drafted the manuscript with contribution from Cuiying Huang, Zhiqiang Feng, Jamie R. Pearce, Hongsheng Zhao, and Zehan Pan. All authors contributed to the subsequent revisions of the manuscript and approved the final version of the submitted manuscript.

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References

Brindley, P., Cameron, R.W., Ersoy, E., Jorgensen, A., Maheswaran, R., 2019. Is more always better? Exploring field survey and social media indicators of quality of urban greenspace, in relation to health. Urban For. Urban Gree. 39, 45-54.

Brindley, P., Jorgensen, A., Maheswaran, R., 2018. Domestic gardens and self-reported health: a national population study. Int. J. Health Geogr. 17, 31.

Cole, H.V.S., Triguero-Mas, M., Connolly, J.J.T., Anguelovski, I., 2019. Determining the health benefits of green space: does gentrification matter? Health Place. 57, 1-11.

Dadvand, P., Bartoll, X., Basagana, X., Dalmau-Bueno, A., Martinez, D., Ambros, A., Cirach, M., Triguero-Mas, M., Gascon, M., Borrell, C., Nieuwenhuijsen, M.J., 2016. Green spaces and general health: roles of mental health status, social support, and physical activity. Environ. Int. 91, 161-167.

de Keijzer, C., Tonne, C., Sabia, S., Basagana, X., Valentin, A., Singh-Manoux, A., Maria Antó, J., Alonso, J., Nieuwenhuijsen, M.J., Sunyer, J., Dadvand, P., 2019. Green and blue spaces and physical functioning in older adults: longitudinal analyses of the Whitehall II study. Environ. Int. 122, 346-356.

de Vries, S., van Dillen, S.M., Groenewegen, P.P., Spreeuwenberg, P., 2013. Streetscape greenery and health: stress, social cohesion and physical activity as mediators. Soc. Sci. Med. 94, 26-33.

de Vries, S., Verheij, R.A., Groenewegen, P.P., Spreeuwenberg, P., 2003. Natural environments—healthy environments? An exploratory analysis of the relationship between greenspace and health. Environ. Plann. A. 35, 1717-1731.

Didan, K., 2015. MOD13Q1 MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid V006 [Data set]. NASA EOSDIS Land Processes DAAC. Accessed 2019-08-15 from https://doi.org/10.5067/MODIS/MOD13Q1.006.

Dimitrova, D. D., Dzhambov, A. M., 2017. Perceived access to recreational/green areas as an effect modifier of the relationship between health and neighbourhood noise/air quality: results from the 3rd European Quality of Life Survey (EQLS, 2011–2012). Urban For. Urban Gree. 23, 54-60.

Ekkel, E.D., de Vries, S., 2017. Nearby green space and human health: evaluating accessibility metrics. Landsc. Urban Plann.. 157, 214-220.

Franchini, M., Mannucci, P.M., 2018. Mitigation of air pollution by greenness: a narrative review. Eur. J. Intern. Med. 55, 1-5.

Hammer, M.S., van Donkelaar, A., Li, C., Lyapustin, A., Sayer, A.M., Hsu, N.C., Levy, R.C., Garay, M.J., Kalashnikova, O.V., Kahn, R.A., Brauer, M., Apte, J.S., Henze, D.K., Zhang, L., Zhang, Q., Ford, B., Pierce, J.R., Martinm R.V., 2020. Global estimates and long-term trends of fine particulate matter concentrations (1998-2018). Environ. Sci. Technol. 54(13), 7879-7890.

Hartig, T., Mitchell, R., de Vries, S., Frumkin, H., 2014. Nature and health. Annu. Rev. Public Health. 35, 207-228.

Helbich, M., Yao, Y., Liu, Y., Zhang, J., Liu, P., Wang, R., 2019. Using deep learning to examine street view green and blue spaces and their associations with geriatric depression in Beijing, China. Environ. Int. 126, 107-117.

Huang, B., Liu, Y., Chen, Y., Wei, H., Dong, G., Helbich, M., 2020. Establishing associations between residential greenness and markers of adiposity among middle-aged and older Chinese adults through multilevel structural equation models. Int. J. Hyg.

Envir. Heal. 230, 113606.

Huang, B., Liu, Y., Feng, Z., Pearce, J.R., Wang, R., Zhang, Y., Chen, J., 2019. Residential exposure to natural outdoor environments and general health among older adults in Shanghai, China. Int. J. Equity Health. 18, 178.

Idler, E.L., Benyamini, Y., 1997. Self-rated health and mortality: a review of twenty-seven community studies. J. Health Soc. Behav. 38, 21-37.

Ji, J.S., Zhu, A., Bai, C., Wu, C-D., Yan, L., Tang, S., Zeng, Y., James, P., 2019. Residential greenness and mortality in oldest-old women and men in China: a longitudinal cohort study. Lancet Planet. Health. 3, e17-e25.

Jia, X., Yu, Y., Xia, W., Masri, S., Sami, M., Hu, Z., Yu, Z., Wu, J., 2018. Cardiovascular diseases in middle aged and older adults in China: the joint effects and mediation of different types of physical exercise and neighborhood greenness and walkability. Environ. Res. 167, 175-183.

Lima-Costa, M.F., Cesar, C.C., Chor, D., Proietti, F.A., 2012. Self-rated health compared with objectively measured health status as a tool for mortality risk screening in older adults: 10-year follow-up of the Bambuí Cohort Study of Aging. Am. J. Epidemiol. 175, 228.

Liu, H., Jiang, D., Yang, X., Luo, C., 2005. Spatialization approach to 1km grid GDP supported by remote sensing. Geo-Spat. Inf. Sci. 7(2), 120-123.

Liu, Y., Wang, R., Grekousis, G., Liu, Y., Yuan, Y., Li, Z., 2019a. Neighbourhood greenness and mental wellbeing in Guangzhou, China: what are the pathways? Landsc. Urban Plann. 190, 103602.

Liu, Y., Wang, R., Lu, Y., Li, Z., Chen, H., Cao, M., Zhang, Y., Song, Y., 2020. Natural outdoor environment, neighbourhood social cohesion and mental health: using multilevel structural equation modelling, streetscape and remote-sensing metrics. Urban For. Urban Gree. 48, 126576.

Liu, Y., Wang, R., Xiao, Y., Huang, B., Chen, H., Li, Z., 2019b. Exploring the linkage between greenness exposure and depression among Chinese people: mediating roles of physical activity, stress and social cohesion and moderating role of urbanicity. Health Place. 58, 102168.

Maas, J., Verheij, R.A., de Vries, S., Spreeuwenberg, P., Schellevis, F.G., Groenewegen, P.P., 2009. Morbidity is related to a green living environment. J. Epidemiol. Commun. Health. 63, 967-973.

Maas, J., Verheij, R.A., Groenewegen, P.P., de Vries, S., Spreeuwenberg, P., 2006. Green space, urbanity, and health: how strong is the relation? J. Epidemiol. Commun. Health. 60, 587-592.

Markevych, I., Schoierer, J., Hartig, T., Chudnovsky, A., Hystad, P., Dzhambov, A.M., de Vries S., Triguero-Mas M., Brauer M., Nieuwenhuijsen M.J., Lupp G., Richardson E.A., Astell-Burt T., Dimitrova D., Feng X., Sadeh M., Standl M., Heinrich J., Fuertes E., 2017. Exploring pathways linking greenspace to health: theoretical and methodological guidance. Environ. Res. 158, 301-317.

Mears, M., Brindley, P., Jorgensen, A., Maheswaran, R., 2020. Population-level linkages between urban greenspace and health inequality: the case for using multiple indicators of neighbourhood greenspace. Health Place, 62, 102284.

Mitchell, R., Popham, F., 2007. Greenspace, urbanity and health: relationships in England. J. Epidemiol. Commun. Health, 61, 681-683.

Reid, C.E., Kubzansky, L.D., Li, J., Shmool, J.L., Clougherty, J.E., 2018. It's not easy assessing greenness: a comparison of NDVI datasets and neighborhood types and their associations with self-rated health in New York City. Health Place, 54, 92-101.

Sugiyama, T., Leslie, E., Giles-Corti, B., Owen, N., 2008. Associations of neighbourhood greenness with physical and mental health: do walking, social coherence and local social interaction explain the relationships? J. Epidemiol. Commun. Health, 62, e9-e9.

Tamosiunas, A.G.R., Grazuleviciene, R., Luksiene, D., Dedele, A., Reklaitiene, R., Baceviciene, M., Vencloviene, J., Bernotiene, J., Radisauskas, R., Malinauskiene, V., Milinaviciene, E., Bobak, M., Peasey, A., Nieuwenhuijsen, M.J.,, 2014. Accessibility and use of urban green spaces, and cardiovascular health: findings from a Kaunas cohort study. Environ. Health. 13, 20-31.

The State Council of The People's Republic of China, 2017. National population development plan (2016 - 2030), Beijing, China.

Triguero-Mas, M., Dadvand, P., Cirach, M., Martinez, D., Medina, A., Mompart, A., Basagaña, X., Gražulevičienė, R., Nieuwenhuijsen, M.J., 2015. Natural outdoor environments and mental and physical health: relationships and mechanisms. Environ. Int. 77, 35-41.

Tucker, C.J., 1979. Red and photographic infrared linear combinations for monitoring vegetation. Remote Sens. Environ. 8, 127-150.

van Dillen, S.M., de Vries, S., Groenewegen, P.P., Spreeuwenberg, P., 2012. Greenspace in urban neighbourhoods and residents' health: adding quality to quantity. J. Epidemiol. Commun. Health, 66, e8.

Vries, S.D., Dillen, S.M.E.V., Groenewegen, P.P., Spreeuwenberg, P.J.S.S., 2013. Streetscape greenery and health: stress, social cohesion and physical activity as mediators. Soc. Sci. Med. 94, 26-33.

Wheeler, B.W., White, M., Stahl-Timmins, W., Depledge, M.H., 2012. Does living by the coast improve health and wellbeing? Health Place, 18, 1198-1201.

WHO, 2015. China country assessment report on ageing and health, Geneva.

Wu, Y., Dang, J., 2013. Blue book of aging: China report of the development on aging cause. Beijing: Social Sciences Academic Press.

Xiao, Y., Wang, Z., Li, Z.G., Tang, Z.L., 2017. An assessment of urban park access in Shanghai - Implications for the social equity in urban China. Landsc. Urban Plan. 157, 383-393.

Yang, B.Y., Markevych, I., Bloom, M.S., Heinrich, J., Guo, Y., Morawska, L., Dharmage, S.C., Knibbs, L.D., Jalaludin, B., Jalava, P., Zeng, X.W., Hu, L.W., Liu, K.K., Dong, G.H., 2019. Community greenness, blood pressure, and hypertension in urban dwellers: the 33 Communities Chinese Health Study. Environ. Int. 126, 727-734.

Yen, I.H., Michael, Y.L., Perdue, L., 2009. Neighborhood environment in studies of health of older adults: a systematic review. Am. J. Prev. Med. 37, 455-63.