

Living Environment, Built Environment and Cognitive Function among Older Chinese Adults: Results from a Cross-Sectional Study

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Abstract

BACKGROUND: Many studies have addressed the relationship between environmental factors and cognitive function; however, evidence from China is very rare.

OBJECTIVES: To discuss the relationship between the living and built environment and cognitive function among older Chinese adults.

DESIGN: The Anhui Healthy Longevity Survey (AHLS) was used to investigate the ability to control major non-communicable diseases through behavioural techniques among adults aged 60 or older dwelling in Anhui Province. A multistage sampling strategy was used to obtain a representative sample. Cross-sectional data were collected for the analyses.

SETTING: The included participants were recruited from four selected cities in Anhui Province, China.

PARTICIPANTS: The participants were adults aged 60 or older and resided in the selected urban or rural communities.

MEASUREMENTS: The Mini Mental State Examination was used to measure the cognitive status of the participants. Mild cognitive impairment (MCI) was defined as illiteracy with MMSE scores lower than 18, MMSE scores lower than 21 among those educated for 0–6 years, or MMSE scores lower than 25 among those with 6 or more years of education. The living environment was assessed by asking the participants about their daily living conditions. The distances between the participants' dwellings and the nearest facilities and the proportions of green/blue spaces within 800 m buffers were calculated based on the textural address to indicate the built environment.

RESULTS: The male participants who lived in a non-dusty environment had higher MMSE scores ($\beta=0.828$, 95% CI: 0.240, 1.416, $p=0.006$) and lower risks of mild cognitive impairment (MCI) (OR=0.651, 95% CI: 0.488, 0.868, $p=0.003$), and the male participants with no access to recreation spaces had lower MMSE scores ($\beta=-1.107$, 95% CI: -1.531, -0.684, $p<0.001$) and higher risks of MCI (OR=1.403, 95% CI: 1.134, 1.737, $p=0.002$). The female participants who lived far from a supermarket had significantly lower MMSE scores (Q3: $\beta=-0.750$, 95% CI: -1.266, -0.233, p adjusted=0.036; Q4: $\beta=-1.184$, 95% CI: -1.745, -0.624, p adjusted<0.001) than those who lived near a supermarket (Q1).

CONCLUSIONS: The living environment and built environment might have sex-specific associations with cognitive function among older adults.

Key words: Environment, cognitive function, older adults.

Introduction

Dementia, which is responsible for a large burden on both society and families, is receiving increasing attention worldwide. Globally, 47 million people are currently living with dementia, and it has been estimated that this number will increase to 74.7 million in 2030 and reach 131 million in 2050 (1). Stable or declining dementia incidence has been reported in some high-income countries (2); however, due to long survival times, the absolute number of people who have dementia or mild cognitive function (MCI) has increased with population ageing (3, 4). Given that dementia cannot be cured with existing therapy, early prevention, which focuses on delaying the progression of cognitive function decline, has been considered a priority to decrease the disease burden of dementia in the future (1, 4, 5).

Factors at the individual level are usually considered the main cause of the occurrence of cognitive function decline. Those risk factors might be genetic (i.e., APOE gene (6)), sociodemographic (i.e., sex, rural area dwelling (7, 8)) and behavioural (i.e., physical inactivity (9, 10), lack of social interaction (11)). Recently, the living environment, which refers to the surroundings of individuals (e.g., breathable clear air, (12), and the built environment, which refers to structures built by humans (e.g., parks and buildings) (13), have attracted the attention of researchers. Accumulating evidence has revealed the links between these environmental factors and cognitive function (14). Many studies have reported that living environmental factors, such as air pollution (15–17), traffic noise (18, 19), or living near major roads (20), might be related to higher risks of dementia. Additionally, the availability of some built environmental features (e.g., green spaces and amenities) are thought to have protective effects against cognitive decline. For example, some studies suggest that convenience in daily life (21, 22) and natural environment availability (e.g., green spaces and gardens) (23) are related to delayed cognitive decline. The mechanisms linking these

environmental factors and cognition might be explained by increased physical activity and social engagement and reduced negative feelings such as depression (24). Interestingly, sex differences were often suggested to exist in these health-related behaviours or psychological well-being status (25-28); however, thus far, sex as a potential modifier in the relationship between environmental factors and cognition has not been well investigated in the existing literature.

Although some research has indicated the possible influence of environmental factors on cognitive function, the strength of the associations seems to vary by setting. For example, local facilities were found to have different relationships with the cognitive function of older adults in countries with different national income levels (29). China is an upper-middle income country that is currently experiencing rapid economic growth, and subsequent rapid urbanization progress along with major environmental change might have the potential to impact cognitive function among older adults. However, research addressing the relationship between environmental factors and cognitive function in China is still very rare.

The objective of the current study was to explore the potential relationships between environmental factors, including the living environment and built environment, and cognitive function among aged Chinese adults. In the context of the predictable dementia burden resulting from the dramatic increase in the number of adults over 60 years of age, the results of this study might provide clues for policymakers to build an age- and dementia-friendly community (30) that can have potential benefit for the maintenance of cognitive function among older adults.

Methods

Study design

The present study was based on data collected from the Anhui Healthy Longevity Survey (AHLS), which was designed to investigate the ability to control major non-communicable diseases through behavioural techniques among adults aged 60 or older who were dwelling in Anhui Province. A multistage sampling strategy was used to obtain a representative sample that considers urban-rural differences. First, four cities (regions) from different geographic locations in Anhui Province were selected purposively. To be more precise, Chuzhou, Lu'an, Xuancheng and Fuyang were chosen to represent the eastern, western, southern and northern geographic locations of Anhui (Supplemental Fig.1), respectively. Second, the geographic jurisdictions of the selected cities (regions) were labelled "urban" or "rural" according to their administrative attributes, and 3-5 communities from "urban" and "rural" areas were selected. Third, the dwellers in the selected urban or rural communities were invited to participate in the current study. The enrolment stopped when the sample size of each city

reached approximately 1500, with dwellers from urban and rural communities accounting for equal shares. The data collection was conducted from July to August 2019. In total, 6211 residents from the four cities were invited.

Participants

In the current study, we excluded participants if they 1) were not able to finish the cognitive function assessment (n=32) or 2) had any missing covariate data (n=331). Finally, 5848 (response rate 94.16%) participants were included in the study. Informed consent was obtained from all participants prior to the survey. All procedures complied with the ethical standards of the Anhui Medical University committee (No. 2020H011).

Cognitive function assessment and the mild cognitive impairment criterion

The Mini Mental State Examination (MMSE) was used to measure the cognitive status of the participants. The total possible score of the MMSE scale was 30 points, with higher scores reflecting better cognitive function (31). MCI had been well accepted as a pre-dementia status with a higher risk of developing dementia (32). Since it has been reported that the education level has a significant impact on MMSE performance (33), the education-based criteria for MCI developed by Zhang et al (34) were employed because almost half of the participants in the current study (49.4%) were illiterate. Specifically, MCI was defined as illiteracy with MMSE scores lower than 18, MMSE scores lower than 21 among those educated for 0-6 years, or MMSE scores lower than 25 among those with 6 or more years of education. The MMSE score and presence of MCI were both employed as dependent variables in the current study (35).

Assessment of the living environment and built environment

In the current study, the living environment was assessed by asking the participants about their daily living conditions. The participants were asked whether they were exposed to noise (i.e., traffic noise (19)) and house dust (36), which cause discomfort and interfere with their daily lives. Moreover, the participants were asked whether they had access to recreational space (i.e., activity and fitness facilities for the elderly) within 1 kilometre of their dwellings.

The distances between participants' dwellings and the nearest supermarket, hospital, restaurant, and park were calculated to indicate the built environment in the current study. First, the full address information of each participant was inputted to an online map tool (<https://www.17ditu.com>) and then converted into latitude and longitude coordinates. Second, information on parks,

restaurants, hospitals and supermarkets were obtained by using Baidu Map and its application designed for locating points of interest (<https://lbsyun.baidu.com/index.php?title=jspopular>). The four facilities, i.e., parks, restaurants, hospitals and supermarkets, were selected as points of interest because in the context of China, these four facilities might support physical activity, social interactions, medication and daily life of the residents, respectively. Third, the distances from the dwellings to the nearest above-mentioned facilities were calculated based on the coordinates of the two points.

In the current study, green space (e.g., park, natural forest) and blue spaces (e.g., lake, river) (29) were also identified based on the land use layer information provided by the Open Street Map (<https://www.openstreetmap.org>). The percentages of green and blue spaces within 800 m buffers were calculated using ArcGIS 10.6 to reflect the environment within a 10-minute walking distance of the older adults.

The distribution of the data was checked by drawing histograms. Because of the nonlinear distributions of the measures of the distance to the nearest facilities, quartile-split variables were used from Q1 (reflecting the shortest distance) to Q4 (reflecting the longest distance). Since the distributions of the percentages of green/blue spaces were extremely skewed, those two environmental features were categorized into “any and none”.

Covariates

The covariates in the current study included sociodemographic characteristics (age, sex, city, urban/rural, years of education, marital status, and income), health-related behaviours (smoking, alcohol consumption, sleep quality and physical activity), chronic diseases (hypertension and diabetes) and mental status (depression). The continuous ages of the participants were self-reported. Years of education were classified into three groups (0, 0–6 years and more than 6 years). Marital status was divided into married and not married (including widowed, divorced, or never married). Participants' yearly income was classified into two groups (lower than 6500 RMB and 6500 RMB or higher).

The participants were categorized into two smoking groups (current smoker, noncurrent smoker) and three alcohol consumption groups (never, former and current). Sleeping quality was assessed by asking the participants “How do you evaluate your sleeping quality in the last month?” The options were “very good”, “good”, “bad” and “very bad”. The continuous daily sedentary hours (37) were self-reported and used as an indicator reflecting the physical activity status of the participants.

Two chronic conditions (hypertension and diabetes) were considered covariates in the current study. The participants were asked whether they had been diagnosed with hypertension/diabetes at a hospital at the county level or above. The participants were classified

into two groups (yes/no).

Depression symptoms of the participants were evaluated by the 9-item depression screening instrument—Patient Health Questionnaire (PHQ-9). The instrument assessed the severity of depression by asking about the frequency of occurrence of the major symptoms of depression in the last 2 weeks. The total score of the PHQ-9 was 30, with higher scores indicating more severe depression symptoms. For the current analysis, total PHQ-9 scores were categorized as “not depressed” (0–4) and “depressed” (5–30). Body mass index (BMI) was calculated with the measured height and weight (weight (kg)/height (m)²). According to the Chinese guidelines for the prevention and control of overweight and obesity for adults (38), overweight was defined as a BMI of 24 or higher.

Statistical analysis

A t-test and an analysis of variance were used to test the hypothesis and compare the means of the MMSE score between the groups. Multilevel regression modelling was first considered to analyse the associations between living and built environmental factors and cognitive function, with a random intercept included to account for the nested data structures, as the individuals might live in very similar community settings, for example, in the same building or village. Therefore, a null (empty) model that simultaneously considered community-level and individual-level factors without any exploratory variable was performed to test the between-community variance. However, the results showed non-significant variance, indicating that the clustering of the cognitive function data might be negligible. Thus, multiple logistic regression and linear regression strategies were employed to assess the associations between living environment, built environment and cognitive function by including MMSE score and MCI as dependent variables. Many potential confounding variables, including sociodemographic factors, behavioural factors, chronic disease and mental health status, were introduced as covariates. Specifically, the living environmental factors (noise, dust and recreation spaces within 1 kilometre) and built environmental factors (distance to the nearest parks, restaurants, hospitals, and supermarkets and the presence of green/blue spaces) were introduced into the regression models one-by-one to test their relationships (Model 1). To test the associations between the studied environmental factors and cognition, those with significant associations with the MMSE or MCI were fit into the fully adjusted models (Model 2). Since many studies have indicated that sex might be related to cognitive decline (39–42) and the environment (43, 44) and that some behaviours (e.g., physical activity and social engagement) that may link environmental factors and cognition vary by sex (25–28), sex-stratified analyses were also performed to explore the

possible role of sex as a modifier.

To test the robustness of the results, multilevel analyses were also performed as sensitivity analyses to simultaneously explore the community-level and individual-level factors. Therefore, a multilevel data structure comprising 5848 individuals (at level 1) nested within 21 communities (at level 2) was used in the analysis. Multilevel linear and logistic regression analyses were conducted by introducing the continuous MMSE and MCI as dependent variables.

All analyses were conducted by using Stata 15.0 for Windows (Stata Corp, College Station, TX) and IBM SPSS 24.0 for Windows (IBM Corporation, Armonk, NY, USA). Microsoft Excel was employed for the preparation of the figures and graphs. To decrease the type I error, the adjusted p values were calculated (Bonferroni correction) when multiple comparisons were performed. The significance level was set at a p value less than 0.05.

Results

Table 1 shows the descriptive information of the participants enrolled in the current study. The mean age of the participants (with a slightly higher proportion of females) was 71.01 years. Some participants lived in a dusty environment (9.8%). Almost half of the participants (49.11%) enrolled in the current study were illiterate. Half of the participants had high blood pressure (50.24%) or were overweight (50.47%). The mean MMSE score was 21.58.

Supplemental Fig 2A shows the median distance from the participants' residence to the nearest facilities (including supermarkets, parks, restaurants and hospitals) in the four selected cities. The median distance to the nearest supermarket did not vary among the four cities (all less than 1 km); however, the distances to the other facilities had larger variations among cities. The longest median distances to the nearest restaurant, hospital and park were longest in Chuzhou. Among the four facilities, parks seem to be most remote from the participants' residences. Supplemental Fig 2B reports the proportions of participants with or without green and blue spaces within 800 m buffers. The proportions of participants with access to green spaces were highest in Xuancheng (64%) and lowest in Chuzhou (19.3%). The proportions of participants with access to blue space were relatively low in Chuzhou (20.3%) and higher in Fuyang (45.7%) and Lu'an (43.9%). However, none of the participants lived with blue space within 800 m buffers in Xuancheng.

The MMSE score distribution comparison among different categories of the studied living environment factors is shown in box plots (Fig. 1A). The participants who had a recreation space near their dwellings exhibited better MMSE scores ($t=-9.148$, $p<0.001$). Fig. 1B shows the MMSE score distribution comparison among different categories of the studied built environmental factors. The

environmental factors distributions by MCI categories are shown in Supplemental Table 1.

Table 1. Basic characteristics of the study population

	N	Mean /Percentage
City		
Lu'an (West)	1542	26.37
Chuzhou (East)	1527	26.11
Xuancheng (South)	1354	23.15
Fuyang (North)	1425	24.37
Sex (Male)	2665	45.57
Age	-	71.01
Urban	2887	49.37
Year of Education		
0	2872	49.11
1-6	1629	27.86
>6	1347	23.03
Marital status		
Married	4254	72.7
Not married	1594	27.3
Individual factors		
Diabetes (%)	924	15.8
Hypertension (%)	2938	50.24
Current smoker (%)	1240	21.20
Drinking status		
Never	3345	57.20
Former	235	4.02
Current	2268	38.78
Physical activity		
Sitting hours	-	4 a
Mental health		
Depression (Yes)	2294	39.23
Sleeping quality		
Very good	1203	20.57
Good	3227	55.18
Bad	1180	20.18
Very bad	238	4.07
Overweight (%)	2946	50.47
Living environment		
Noise (yes)	708	12.1
Dust (yes)	572	9.80
Recreation Space (no)	2365	40.44
MMSE score	-	21.58
MCI status		
Yes	1986	34.00
No	3862	66.00

a. Median

Table 2. The associations between living environment, built environment factors and cognitive function by sexes: Coefficients and 95% CIs for MMSE and Odds Ratios for MCI

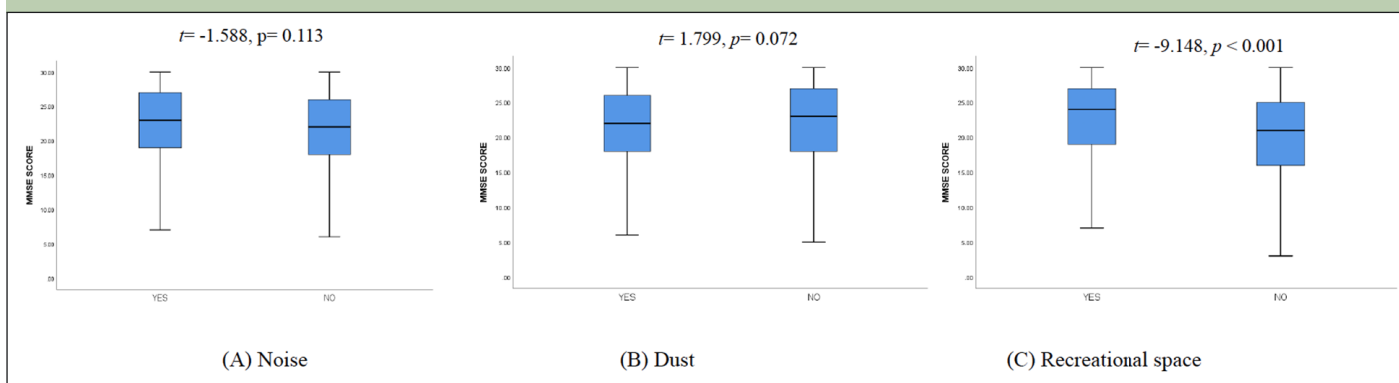
	Both sexes				Male				Female			
	MMSE ^a	p adjusted	MCI ^a	p adjusted	MMSE ^b	p adjusted	MCI ^b	p adjusted	MMSE ^b	p adjusted	MCI ^b	p adjusted
Living environment												
Noise (No) (Ref: yes)	0.059 (-0.320, 0.438)	1	0.945 (0.789, 1.131)	1	-0.026 (-0.561, 0.508)	1	0.876 (0.668, 1.147)	1	0.208 (-0.326, 0.742)	1	0.983 (0.770, 1.254)	1
Dust (No) (Ref: yes)	0.376 (-0.040, 0.792)	0.684	0.808 (0.668, 0.978)	0.261	0.838 (0.248, 1.428)	0.045	0.652 (0.490, 0.868)	0.027	-0.002 (-0.583, 0.580)	1	0.945 (0.731, 1.222)	1
Recreation space (No) (Ref: yes)	-0.673 (-0.969, -0.377)	<0.001	1.158 (1.008, 1.329)	0.342	-1.125 (-1.548, -0.702)	<0.001	1.413 (1.142, 1.748)	0.009	-0.318 (-0.730, 0.094)	1	1.001 (0.832, 1.203)	1
Built environment												
Supermarket Ref: Q1	-		-		-		-		-		-	
Q2	-0.437 (-0.780, -0.093)	0.117	1.192 (1.011, 1.404)	0.333	-0.265 (-0.758, 0.229)	1	1.203 (0.937, 1.543)	1	-0.605 (-1.080, -0.130)	0.117	1.184 (0.951, 1.475)	1
Q3	-0.390 (-0.754, 0.026)	0.324	1.109 (0.930, 1.321)	1	0.044 (-0.466, 0.553)	1	0.901 (0.690, 1.177)	1	-0.750 (-1.266, -0.233)	0.036	1.283 (1.014, 1.624)	0.342
Q4	-0.840 (-1.237, -0.444)	<0.001	1.201 (0.999, 1.444)	0.459	-0.453 (-1.009, 0.103)	0.990	1.032 (0.784, 1.361)	1	-1.184 (-1.745, -0.624)	<0.001	1.341 (1.044, 1.722)	0.189
Restaurant Ref: Q1	-		-		-		-		-		-	
Q2	0.370 (0.021, 0.718)	0.342	0.867 (0.734, 1.025)	0.855	0.099 (-0.406, 0.605)	1	0.945 (0.731, 1.223)	1	0.619 (0.140, 1.099)	0.099	0.802 (0.643, 1.000)	0.450
Q3	-0.377 (-0.784, 0.029)	0.621	1.087 (0.898, 1.317)	1	-0.522 (-1.107, 0.062)	0.720	1.299 (0.968, 1.742)	0.729	-0.249 (-0.811, 0.313)	1	0.934 (0.724, 1.204)	1
Q4	-0.062 (-0.448, 0.324)	1	1.004 (0.837, 1.205)	1	-0.063 (-0.610, 0.485)	1	0.977 (0.738, 1.294)	1	-0.042 (-0.583, 0.500)	1	1.013 (0.795, 1.292)	1
Park Ref: Q1	-		-		-		-		-		-	
Q2	0.211 (-0.205, 0.626)	1	0.921 (0.752, 1.128)	1	-0.140 (-0.727, 0.448)	1	1.064 (0.784, 1.443)	1	0.495 (-0.089, 1.079)	0.864	0.829 (0.630, 1.091)	1
Q3	-0.180 (-0.604, 0.243)	1	0.962 (0.787, 1.175)	1	-0.298 (-0.915, 0.320)	1	0.996 (0.728, 1.363)	1	-0.030 (-0.612, 0.552)	1	0.907 (0.697, 1.181)	1
Q4	-0.367 (-0.792, 0.057)	0.810	1.145 (0.937, 1.400)	1	-0.355 (-0.944, 0.235)	1	1.135 (0.840, 1.532)	1	-0.363 (-0.971, 0.245)	1	1.140 (0.867, 1.497)	1
Hospital Ref: Q1	-		-		-		-		-		-	
Q2	-0.246 (-0.620, 0.127)	1	1.005 (0.838, 1.205)	1	-0.198 (-0.730, 0.334)	1	0.966 (0.734, 1.271)	1	-0.302 (-0.823, 0.218)	1	1.035 (0.812, 1.320)	1
Q3	0.009 (-0.382, 0.400)	1	1.000 (0.831, 1.206)	1	-0.119 (-0.675, 0.438)	1	0.956 (0.719, 1.271)	1	0.125 (-0.471, 0.671)	1	1.024 (0.799, 1.311)	1
Q4	-0.146 (-0.534, 0.243)	1	0.947 (0.789, 1.136)	1	0.068 (-0.486, 0.621)	1	0.898 (0.679, 1.188)	1	-0.267 (-0.809, 0.275)	1	0.956 (0.750, 1.218)	1
Green space within 800m buffers (Any) (Ref: none)	0.224 (-0.058, 0.507)	1	0.959 (0.838, 1.097)	1	0.218 (-0.184, 0.619)	1	0.918 (0.747, 1.128)	1	0.213 (-0.181, 0.607)	1	0.996 (0.832, 1.191)	1
Blue space within 800m buffers (Any) (Ref: none)	0.594 (0.232, 0.957)	0.009	0.863 (0.724, 1.028)	0.891	0.396 (-0.103, 0.895)	1	0.925 (0.714, 1.199)	1	0.705 (0.181, 1.229)	0.072	0.842 (0.661, 1.071)	1

a. The model adjusted sex (male and female), age (continuous), location (urban and rural), city (Chuzhou, Lu'an, Xuancheng and Fuyang), education (0, 0–6 years and more than 6 years), marital status (married and not married), income (lower than 6500 RMB and 6500 RMB or higher), diabetes (yes and no), hypertension (yes and no), drinking status (never, former and current), smoking (current smoker, noncurrent smoker), depression (yes and no), overweight (yes and no), sleep quality (very good, good, bad and very bad), and sedentary hours (continuous); b. The model adjusted age (continuous), location (urban and rural), city (Chuzhou, Lu'an, Xuancheng and Fuyang), education (0, 0–6 years and more than 6 years), marital status (married and not married), income (lower than 6500 RMB and 6500 RMB or higher), diabetes (yes and no), hypertension (yes and no), drinking status (never, former and current), smoking (current smoker, noncurrent smoker), depression (yes and no), overweight (yes and no), sleep quality (very good, good, bad and very bad), and sedentary hours (continuous).

Table 3. The associations between multiple environments factors and cognitive function among males: Coefficients and 95% CIs for MMSE and Odds Ratios for MCI

	MMSE ^a	p	MCI ^a	p
Living environment				
Dust (No) (Ref: yes)	0.828 (0.240, 1.416)	0.006	0.651 (0.488, 0.868)	0.003
Recreational space (No) (Ref: yes)	-1.107 (-1.531, -0.684)	<0.001	1.403 (1.134, 1.737)	0.002

a. The model adjusted age (continuous), location (urban and rural), city (Chuzhou, Lu'an, Xuancheng and Fuyang), education (0, 0–6 years and more than 6 years), marital status (married and not married), income (lower than 6500 RMB and 6500 RMB or higher), diabetes (yes and no), hypertension (yes and no), drinking status (never, former and current), smoking (current smoker, noncurrent smoker), depression (yes and no), overweight (yes and no), sleep quality (very good, good, bad and very bad), and sedentary hours (continuous).

Figure 1A. Box plot showing the MMSE score distribution comparison of different category of the studying living environmental factors

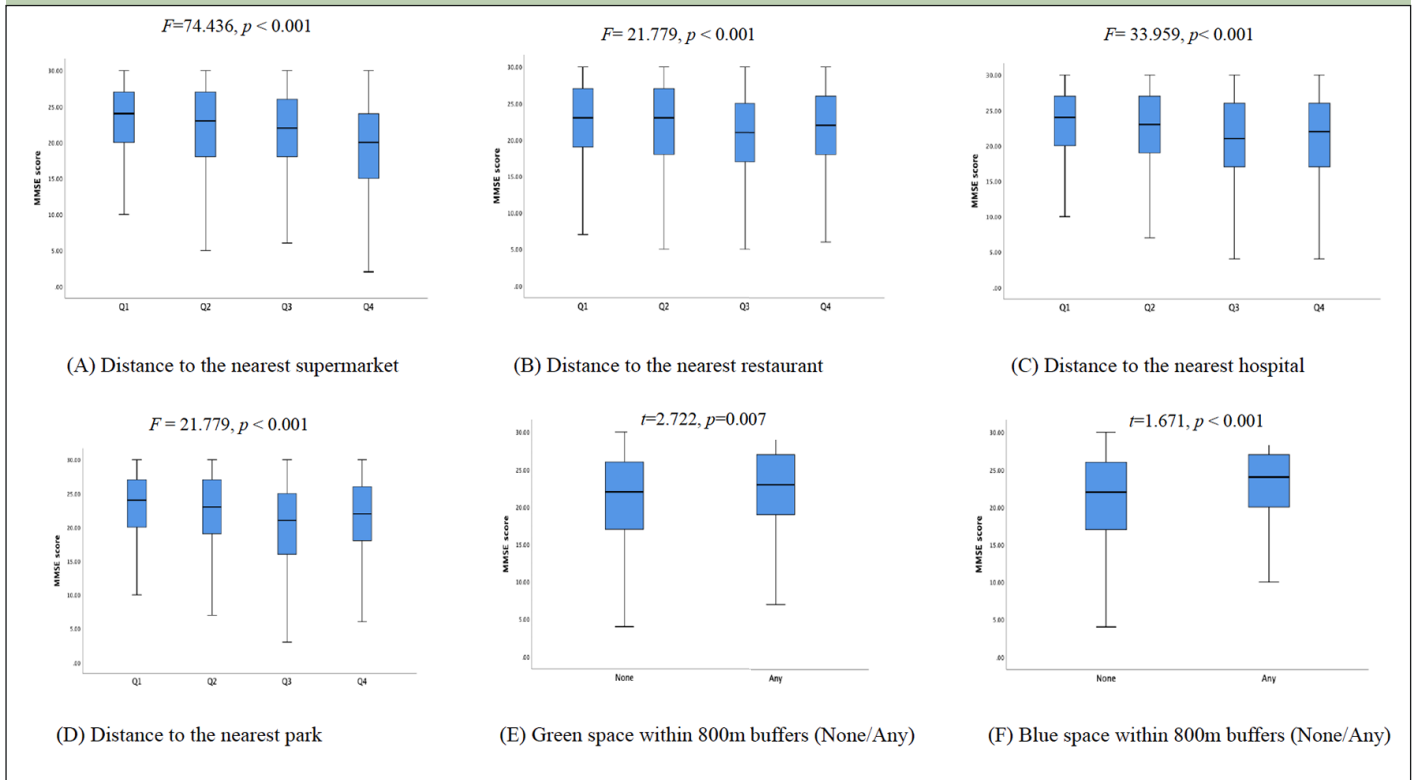
The associations between living environment, built environment factors and cognitive function are shown in Table 2. Among both sexes, the participants without a recreational space near their residence had lower MMSE scores ($\beta = -0.673$, 95% CI: -0.969, -0.377, p adjusted < 0.001). However, the results of the sex-stratified analysis showed that such associations were found only among male participants. The associations between the built environment factors and cognitive function were generally weak, except for the nearest distance to supermarkets. Among females, the participants living far from the supermarkets had lower MMSE scores. For example, it was estimated that the female participants who lived furthest from a supermarket (Q4) had a lower MMSE score ($\beta = -1.184$, 95% CI: -1.745, -0.624, p adjusted < 0.001) than those living nearest to a supermarket (Q1). The presence of local blue spaces was associated with the MMSE scores but not MCI. The participants with any blue space within 800 m buffers around the residence were likely to have higher MMSE scores ($\beta = 0.594$, 95% CI: 0.232, 0.957, p adjusted = 0.009) than those who had no blue space nearby. However, the results of the sex-stratified analysis showed that such associations could only be found among females.

The associations between multiple environmental factors and cognitive function among the male participants are presented in Table 3. Among the male participants, those who lived in a non-dusty environment had higher MMSE scores ($\beta = 0.828$, 95% CI: 0.240, 1.416, $p = 0.006$) and a lower risk of MCI (OR = 0.651, 95% CI: 0.488, 0.868, $p = 0.003$). The male participants with no

access to a recreation space had lower MMSE scores ($\beta = -1.107$, 95% CI: -1.531, -0.684, $p < 0.001$) and a higher risk of MCI (OR = 1.403, 95% CI: 1.134, 1.737, $p = 0.002$).

The sensitivity analysis performed using multi-level regression models revealed similar results to the main analysis (Supplemental Table 2). The male participants living in a non-dusty environment had a lower risk of MCI (OR = 0.649, 95% CI: 0.487, 0.865, p adjusted = 0.027) than those living in a dusty environment. Living without a recreational space near their residence was associated with lower MMSE scores ($\beta = -0.589$, 95% CI: -0.892, -0.285, p adjusted < 0.001) among both sexes. However, such associations were found only among the male participants. The associations between the built environment factors and cognitive function were generally weak, except for the nearest distance to supermarkets, and such associations were found only among the female participants. The female participants living furthest from a supermarket had lower MMSE scores ($\beta = -0.972$, 95% CI: -1.613, -0.332, p adjusted = 0.027). The associations between multiple environmental factors and cognitive function among the male participants are presented in Supplemental Table 3. The male participants who lived in a non-dusty environment had higher MMSE scores ($\beta = 0.828$, 95% CI: 0.243, 1.413, $p = 0.006$) and a lower risk of MCI (OR = 0.651, 95% CI: 0.488, 0.868, $p = 0.003$). The male participants with no access to a recreational space had lower MMSE scores ($\beta = -1.107$, 95% CI: -1.529, -0.686, $p < 0.001$) and a higher risk of MCI (OR = 1.403, 95% CI: 1.134, 1.737, $p = 0.002$).

Figure 1B. Box plot showing the MMSE score distribution comparison of different category of the studying living environmental factors



Discussion

In the current study, we assessed the potential impact of the living environment and built environment on cognitive function among older people who dwell in urban and rural areas of Anhui Province, China. The results of the current study indicate that the living environment and built environment might have the potential to influence the cognitive function of older adults, although the associations seem to be sex specific. Explanations for these potential sex differences should be further explored in future studies. To the best of our knowledge, the current study is the first to assess the associations between environmental factors and cognitive function among older adults dwelling in Anhui, China.

Accumulating evidence suggests that environmental factors might play a role in cognitive function maintenance. For example, a high mix of land uses has been reported to have complex associations with cognitive impairment (45). Natural environments (e.g., gardens, green spaces) were associated with fewer mental disorders among older people (46), which in turn contributed to protecting cognitive function (47, 48). Similar to some previous studies (15, 17, 49), in the current study, male participants living in a non-dusty environment were found to have a lower risk of MCI. Air pollution may influence the physiological ageing process of the brain [50], which might also be linked to cognitive function decline. Generally, the presence of the recreational space might indicate an elevated level of

physical activity (51-53), which contributes to the delay of cognitive function decline (54, 55). However, our results suggest that males might benefit more from recreational spaces than females, which might be explained by the higher likelihood of participating in physical activities among males (56, 57).

In this study, female participants who lived far away from supermarkets were more likely to have poorer cognitive function. In the Chinese context, aged housewives often walk to supermarkets with their friends, and such behaviours might have potential contributions to cognitive function maintenance by resulting in physical exercise and increasing the chances of interpersonal communication. However, such associations were not found among male participants. This may be explained by the different family roles of females and males. In China, females are often responsible for purchasing household goods and preparing cooking materials. Some studies had similar findings to our study results. A study conducted in Japan showed that lower food store availability was associated with poorer cognitive function (58), and a study conducted in the United States also showed that living far from convenience stores was associated with poorer cognitive function (29). Given that purchasing foods and other daily necessities at the market is necessary for daily life and is usually a main reason for going out for older Chinese adults, increasing the availability of food stores may contribute to cognitive function decline prevention (58).

This study had many strengths. First, the representativeness of the sample was guaranteed by a multistage sampling strategy and a large sample size. The sampling process considered geographic characteristics and urban–rural disparities. The large sample size of male and female participants and high responsive rate (94.2%) were also helpful in achieving our study objective. Second, we employed a number of covariates to test the independent role of living environment and built environment by controlling the other potential influencing factors so that the validity of our results was verified. Additionally, the measures of the built environment were objectively calculated instead of self-reported by participants so that the correctness of the measures could be ensured.

However, the study also had several limitations. First, the cross-sectional design made it difficult to draw any conclusions related to cause and effect. Future studies might investigate the association between the environment and cognitive function through a longitudinal design. Second, urbanization and urban expansion that have occurred in many cities in China might have resulted in a massive shift in the built environment (59). This process might mask the true associations between built environmental factors and the cognitive function of older adults. Third, the measures of environment employed in the current study might not reflect the real level of health-related behaviour of the participants. For example, people might ignore the recreational space even if it could be reached in minutes. Finally, political and interpersonal environmental factors, which are essential to cognitive function, were not included in the current study. For example, loneliness and isolation, which have been associated with poorer cognitive function among older adults (60), were not included in the current study. In the future, a more comprehensive framework might be employed to address more environmental factors, such as political and interpersonal environments.

Conclusions

In the current study, the living and built environments were associated with cognitive function among older adults, although such associations seem to be sex specific. Since cognitive function decline is highly prevalent among older adults, our findings might provide clues for building age- and dementia-friendly communities, especially in the context of community planning, and facilities, such as recreation spaces and supermarkets, should be considered. In the future, longitudinal studies with comprehensive measures of environmental exposures are required to verify these associations.

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Conflicts of interest: The authors have no conflicts of interest to report.

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