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Commercial food environment and cognitive health: findings from 114 urban communities

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ABSTRACT

Background: The association between neighborhood commercial food environments and cognitive function in older adults remains unclear, particularly in high-density urban settings. This study aimed to investigate the relationship between the density of various types of retail food outlets and cognitive function in older adults within community settings.

Methods: We analyzed data from the Beijing Community-based Cognitive Function Screening (CCFS) program, which included 61,842 older adults (mean age: 70.9 years; 60.5 % female) residing in 114 urban communities within the Fifth Ring Road of Beijing. Cognitive function was assessed using adapted versions of the Mini-Mental State Examination (Mini-MMSE; range: 0–13) and the Episodic Memory Test (EMT; range: 0–100). The primary exposure was total restaurant density, representing overall commercial food availability. Secondary exposures included the densities of fast-food restaurants, dessert/drink/pastry shops, and fruit and vegetable stores. Multilevel linear and logistic regression models were used to estimate associations, adjusting for sociodemographic and environmental covariates.

Results: The mean Mini-MMSE and EMT scores were 12.3 (SD 1.3) and 90.6 (SD 9.2), respectively. Each interquartile range (IQR) increase in total restaurant density was associated with lower Mini-MMSE ($\beta = -0.002$, 95 % CI: -0.004 to -0.001) and EMT scores ($\beta = -0.004$, -0.005 to -0.003). Fast-food restaurant density showed similar inverse associations; for Mini-MMSE, each IQR increase was associated with a 0.003-point decrease ($\beta = -0.003$, -0.004 to -0.002), an effect comparable to the decline associated with one additional year of age. In contrast, higher density of fruit and vegetable stores was positively associated with Mini-MMSE scores ($\beta = 0.002$, 0.001 to 0.003), and the ratio of fruit and vegetable stores to fast-food restaurants showed an even stronger association ($\beta = 0.003$, 0.002 to 0.005). No significant associations were found between cognitive outcomes and the density of dessert, drink, or pastry shops.

Conclusions: Our findings suggest that a more balanced neighborhood food environment, characterized by increased access to fruit and vegetable stores, particularly relative to fast-food outlets, may help attenuate the age-related decline in cognitive function among older adults. This underscores the potential for urban planning and policy interventions aimed at promoting healthier food environments to play a meaningful role in maintaining cognitive health and resilience in rapidly ageing urban populations.

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1. Introduction

Commercial determinants of health (CDoH), as defined by the World Health Organization (WHO), refer to private sector activities that impact health outcomes in both beneficial and detrimental ways (World Health Organization, 2023). While commercial entities such as food and beverage outlets play a crucial role in providing essential food services that enhance public health, they are also implicated in rising rates of ill health, environmental damage, and social inequities (Gilmore et al., 2023). The commercial food environment, characterized by the overall density and composition of food outlets within neighborhoods, has emerged as a critical area of concern as global populations increasingly rely on it for daily nutritional needs. The availability of healthy food options within local commercial settings holds substantial potential to shape purchasing behaviors, dietary patterns, and overall health outcomes among individuals (Atanasova et al., 2022). However, the ongoing global nutrition transition is reshaping dietary patterns, driving a surge in the consumption of nutritionally poor processed foods, particularly ultra-processed foods characterized by excessive salt or sugar content, which are directly associated with health parameters spanning mortality, cancer, and mental, respiratory, cardiovascular, gastrointestinal, and metabolic health outcomes (Lane et al., 2021, 2024).

The decline in cognitive function is a pressing global health challenge due to population ageing. Among individuals aged 60 and older, the prevalence of mild cognitive impairment (MCI) can reach as high as 42 % worldwide (Hu et al., 2017). The etiology of cognitive decline is multifactorial, involving a complex interplay of genetic, socioeconomic, and environmental factors, including nutrition (Dominguez et al., 2021). Despite growing evidence linking diet to cognitive health (Dalile et al., 2022), the role of the neighborhood commercial food environment, particularly the overall density and structure composition of food outlets, in cognitive decline remains poorly understood. The associations of the density and distribution of various commercial food outlets, such as fast-food restaurants, fruit and vegetable stores, and dessert/drink/pastry shops, with cognitive health have not been thoroughly investigated, with existing studies yielding weak and mixed conclusions (Zhang and Huang, 2018; Finlay et al., 2020). Addressing this gap is essential for understanding the broader impact of commercial food environments on cognitive health as populations age.

To date, many low- and middle-income countries (LMICs) are experiencing a rapid nutritional transition from traditional, healthy diets, leading to the growth of the commercial food market and an increasing prevalence of non-communicable diseases (Monteiro et al., 2013; Adams et al., 2020). China, the largest LMIC, has the largest population of individuals with MCI globally. Among those aged 60 and older, the updated estimated prevalence of MCI is 15.5 %, affecting approximately 38.77 million individuals (Jia et al., 2020). In Beijing, rapid urbanization, population growth, and economic development have driven a marked nutrition transition in recent years. However, the relationship between the commercial food environment, particularly in the central urban area, and cognitive function among older adults in Beijing remains unclear. Existing research on the association between nutritional intake and cognitive function has primarily focused on individual food consumption (Dalile et al., 2022), with limited attention to the commercial food environment from a community-level perspective. Furthermore, no study to date has conducted a city-wide investigation into the relationship between the commercial food environment and cognitive outcomes in older adults.

In this study, we aim to fill this gap by examining the association between the neighborhood commercial food environment, measured primarily by the overall density of food outlets (total restaurant density), and cognitive function among older adults in Beijing. To capture health-relevant contrasts within this broader environment, we further examine specific outlet subtypes, including Western-style fast-food restaurants and dessert/drink/pastry shops as indicators of less-healthy food environments, and fruit and vegetable stores as indicators of healthier food access. We also explore potential non-linear or threshold effects within these associations.

2. Methods

2.1. CCFS program

For our primary analysis, we utilized data from the Beijing Community-based Cognitive Function Screening (CCFS) program, which was conducted across the central districts of Beijing in 2019 (Beijing Municipal Health Commission, 2021). For more details about the study, please refer to **Supplementary Note 1**. The CCFS program interviews participants in healthcare centers using a set of core questionnaires covering three areas: 1) demographics, 2) medical history, and 3) cognitive tests. The core cognitive tests consist of the Mini-MMSE and the Episodic Memory Test (EMT) (**Supplementary Note 2** for detailed items) (China Association of Gerontology and Geriatrics and Academy of Cognitive Disorder of China, 2019). The Mini-MMSE, an adapted and condensed version of the MMSE (Mini-Mental State Examination), objectively assesses cognitive function in four key domains: memory, orientation, attention, and calculation. The EMT employs an encoding-retrieval paradigm to evaluate an individual's capacity to recall and remember specific events or episodes. All tests used in the CCFS program have undergone rigorous validation and demonstrated good levels of agreement in community-based screening for cognitive functions, including among older people in China (Yang et al., 2021).

2.2. Assessment of the commercial food environment

In addition to collecting individual-level data through the CCFS program, we assessed the community-level commercial food environment by utilizing the geographical coordinates of each community's centroid. In accordance with our conceptual framework, the total restaurant density was defined as the primary indicator of the commercial food environment, representing general food availability and commercial intensity at the community level. To capture health-relevant contrasts within this broader environment, we further examined three specific outlet subtypes: (1) the density of fast-food restaurants (defined as Western-style fried fast-food outlets), (2) the density of dessert, drink, and pastry shops, and (3) the density of fruit & vegetable stores (**Supplementary Note 3**).

Food outlet density was calculated using 2019 point-of-interest (POI) data obtained from Amap (https://www.amap.com/), which provides detailed metadata on outlet names, categories, and geographic coordinates. For each community, the total number of corresponding POIs was aggregated within predefined community-level spatial buffers aligned with official administrative boundaries, and density was expressed as the number of outlets per square kilometer (number per km (Gilmore et al., 2023)). This area-based approach ensured comparability and consistency in exposure assessment across communities of varying geographic size and population density.

Alongside quantifying exposures to the commercial food environment, we also conducted thorough assessments of community-level environmental covariates, including $PM_{2.5}$, residential greenness, economic vitality, population density, and pharmacy density (**Supplementary Note 4**).

2.3. Statistical analyses

Within the framework of the CCFS program, we focused on the area within the Fifth Ring Road as the study region, as it represents the urban core of Beijing characterized by a high population density and a concentration of buildings (Supplementary Figure 1). Participants' characteristics were summarized using percentages (%) for categorical data and means with standard deviations (SD) for continuous data. Given the right-skewed distribution of cognitive function scores (Supplementary Figure 2), these scores were log-transformed to approximate a normal distribution. Distributions of all commercial food environment indicators were examined using histograms.

We first calculated Pearson correlation coefficients among the food outlet subtypes, including fast-food restaurant, dessert/drink/pastry shop, and fruit & vegetable store densities, to assess potential collinearity and confirm their distinct roles within the commercial food environment. Multivariable linear regression models were then employed to examine the associations of per-interquartile-range (IQR) increases in total restaurant density (primary exposure) and each food outlet subtype density (and their ratios) with log-transformed cognitive scores. All models were adjusted for age, sex, marital status, occupational class, educational level, number of chronic conditions, $PM_{2.5}$, residential greenness, economic vitality, population density, and pharmacy density.

To explore non-linear associations, restricted cubic spline (RCS) models with three knots at fixed, equally spaced percentiles (25th, 50th, and 75th) were utilized to evaluate the exposure-response relationship between the density of commercial food outlets and cognitive function. Potential interaction effects between fast-food restaurant density and fruit & vegetable store density were examined using four joint exposure categories (low-low, low-high, high-low, high-high) and a product term for statistical interaction. Cognitive function scores were further classified into categorical variables, and multivariable logistic regression models were used to estimate odds ratios (ORs) for maintaining healthy cognition per IQR increase in commercial food outlet densities. Regression coefficients (β), ORs, and their 95 % confidence intervals (CIs) are reported. All regression analyses and RCS plots were conducted using Stata 16.0 and R 4.4.2 (R Project for Statistical Computing).

3. Results

We conducted the study across 324 community healthcare centers distributed across 114 communities in Beijing, including a total of 61,842 participants in the analysis, with an average of 542.5 participants per community. The mean (SD) age of participants was 70.9 (6.5) years, comprising 60.5 % females and 39.5 % males. Detailed participant characteristics and cognitive performance data are provided in Table 1.

3.1. Distribution of the commercial food environment

The spatial distribution of total restaurant density and outlet subtype densities within the Fifth Ring Road in Beijing is shown in Fig. 1. Frequency distributions of all commercial food environment variables, which exhibited right-skewed patterns, are presented as histograms in Supplementary Figure 3. The median (IQR) density of total restaurants per community was 64.0 (116.7). For specific outlet subtypes, the corresponding values were 4.7 (14.6) for fast-food restaurants, 3.8 (10.8) for fruit & vegetable stores, and 0.5 (5.7) for dessert/drink/pastry shops. The median (IQR) ratios of fruit & vegetable store density to fast-food restaurant density and to dessert/drink/pastry shop density were 0.5 (1.0) and 1.0 (2.0), respectively (Table 2).

Pairwise Pearson correlation coefficients among the three food outlet subtypes showed that all were positively and significantly correlated (p-values <0.001). The strongest correlation was observed between dessert/drink/pastry shop density and fruit & vegetable store density ($r = 0.410$), followed by that between fast-food restaurant and fruit & vegetable store densities ($r = 0.333$). The weakest, though still significant, correlation was between fast-food restaurant and dessert/drink/pastry shop densities ($r = 0.296$) (Supplementary Table 1).

3.2. Characteristics associated with cognitive function

The mean scores were 12.3 (SD 1.3) out of 13 for the Mini-MMSE and 90.6 (9.2) out of 100 for the EMT. Each one-year increase in age was associated with a decrease of 0.003 points in Mini-MMSE scores and 0.002 points in EMT scores, both with p-values <0.001. The differences in Mini-MMSE and EMT scores between males and females were 0.003 and 0.002, respectively (Supplementary Table 2). The spatial distributions of cognitive scores in the six central districts are presented in Supplementary Figure 4. Both cognitive test scores were significantly associated with a range of baseline characteristics, including age, marital status, occupational status, educational level, and the number of chronic conditions (Fig. 2). All these characteristic variables were included as covariates in subsequent analyses, along with additional environmental factors such as $PM_{2.5}$, residential greenness, economic vitality, population density, and pharmacy density (Supplementary Table 3), regardless of their significance in relation to cognitive outcomes.

Table 1
Description of covariates and prevalence of cognitive performance among the study participants, CCFS program (n = 61,842).

Variables	All participants		Mini-MMSE score		EMT score	
	Nos.	%	Mean	SD	Mean	SD
Cognitive performance						
Mean (SD)	-	–	12.35	1.28	90.63	9.19
Age						
Mean (SD)	70.9	6.5	–	–	–	–
Sex						
Male	24,443	39.52	12.36	1.26	90.62	9.33
Female	37,399	60.48	12.34	1.30	90.63	9.12
Districts						
Dongcheng	8200	13.26	12.34	1.23	90.56	9.13
Xicheng	8651	13.99	12.36	1.22	91.49	8.66
Chaoyang	17,376	28.10	12.41	1.23	90.42	9.50
Haidian	11,717	18.95	12.28	1.37	89.81	9.38
Fengtai	14,433	23.34	12.29	1.37	90.91	9.07
Shijingshan	1465	2.37	12.65	0.89	92.10	8.29
Marital status						
Married	59,368	96	12.37	1.26	90.74	9.12
Widow	2168	3.51	11.87	1.77	87.65	10.88
Divorced/Never married/Separate	279	0.45	12.06	1.40	89.58	8.94
Other	27	0.04	12.06	1.09	89.67	6.97
Main occupation						
Non-manual	43,731	70.71	12.36	1.26	91.04	8.97
Manual	9431	15.25	12.27	1.37	89.26	10.10
Others/unemployed	8680	14.04	12.36	1.31	90.04	9.17
Educational level						
Coll./Uni.	13,020	21.05	12.40	1.17	90.71	8.67
High school	13,438	21.73	12.43	1.17	90.87	9.04
Secondary school	23,735	38.38	12.41	1.15	90.79	8.97
Primary school or below	10,519	17.01	12.17	1.55	90.11	10.08
Illiterate	1130	1.83	11.27	2.55	88.08	12.38
Years of schooling						
Mean (SD)	10.0	3.6				
Number of chronic conditions						
0	12,915	20.88	12.48	1.16	90.86	9.01
1 to 2	30,992	50.11	12.37	1.26	90.75	9.14
3 to 4	14451	23.37	12.26	1.35	90.37	9.32
≥5	3484	5.63	12.06	1.59	89.75	9.90

Mini-MMSE = Mini-Mental State Examination (maximum score = 13); EMT = Episodic Memory Test (maximum score = 100).
Mean and standard deviation (SD) are presented for all continuous variables and cognitive performance outcomes.

3.3. Associations between the commercial food environment and cognitive function

Table 3 presents the results of multivariable regression analysis examining the associations of each IQR increase in total restaurant density and food outlet subtype densities with log-transformed cognitive scores. In the fully adjusted model, higher total restaurant density was

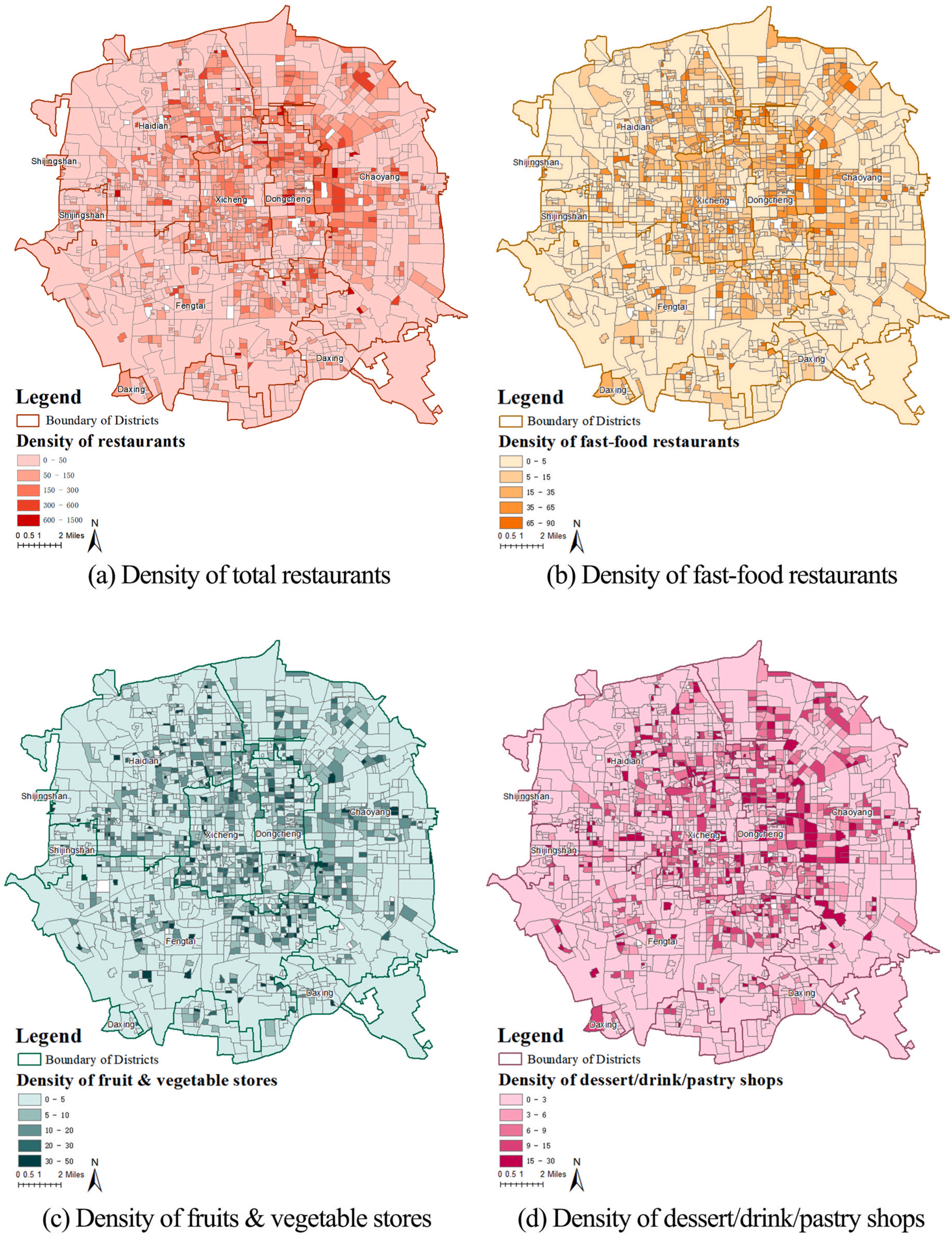

Fig. 1. The spatial distributions of (a) density of total restaurants, (b) density of fast-food restaurants, (c) density of fruit & vegetable stores, and (d) density of dessert/drink/pastry shops within the 5th ring roads in Beijing.

significantly associated with lower Mini-MMSE and EMT scores, with each IQR increase corresponding to decreases of 0.002 and 0.004 in log-transformed Mini-MMSE and EMT scores, respectively.

Among outlet subtypes, a significant inverse association was observed between fast-food restaurant density and log-transformed Mini-MMSE scores, with a coefficient (β) of −0.003 (95 % CI: −0.004 to −0.002). In contrast, higher fruit & vegetable store density and a higher ratio of fruit & vegetable stores to fast-food restaurants were positively associated with Mini-MMSE scores, with coefficients of 0.002 (0.001 to 0.003) and 0.003 (0.002 to 0.005), respectively. A similar pattern was observed for EMT scores, where an increase in fast-food restaurant density was negatively associated with EMT scores, while an increase in the ratio of fruit & vegetable stores to fast-food restaurants was positively associated with EMT scores. However, fruit & vegetable

Table 2
Description of measures of various retail food outlet densities within the study communities, CCFS program.

Commercial Food Environment[a]	Median	IQR (P75-P25)	Mean	SD	Min	Max
Density of total restaurants (number)	64.0	116.7	80.6	78.7	0.0	432.8
Density of fast-food restaurants (number)	4.7	14.6	10.0	13.4	0.0	89.6
Density of fruit & vegetable stores (number)	3.8	10.8	7.4	9.9	0.0	46.8
Density of dessert/drink/pastry shops (number)	0.5	5.7	4.0	6.2	0.0	30.3
Ratio of fruit & vegetable stores to fast-food restaurants	0.5	1.0	0.8	0.8	0.0	5.1
Ratio of fruit & vegetable stores to dessert/drink/pastry shops	1.0	2.0	1.3	1.4	0.0	6.0

[a] Descriptive interpretation is based on the median and interquartile range (IQR) given the skewed distributions; mean and standard deviation (SD) are reported for reference.

store density was inversely associated with log-transformed EMT scores. No significant association was observed for dessert/drink/pastry shop density.

Fig. 3 presents the results of RCS analyses examining the associations of the density of total restaurant and food outlet subtypes and log-transformed cognitive scores. Linear associations were observed between the density of total restaurants, fast-food restaurants, fruit & vegetable stores, and the ratio of fruit & vegetable stores to fast-food restaurants with Mini-MMSE scores. Similar linear patterns were seen for total restaurant and fast-food restaurant densities with EMT scores. Additionally, EMT scores increased with greater density of fruit & vegetable stores and higher ratios of fruit & vegetable stores to fast-food restaurants, although a slight decrease was observed in the lower range of outlet density (0–10) and ratio values (0–1), respectively. U-shaped associations were identified for the density of dessert/drink/pastry shops and for the ratio of fruit & vegetable store density to these outlets in relation to cognitive function scores. The inflection points occurred at approximately 10 dessert/drink/pastry shops and a fruit-to-dessert ratio of 1.0–1.5, below which cognitive scores declined and above which they improved (Supplementary Figure 5).

Interaction analyses (Supplementary Table 4) examined joint exposure categories based on the median cutoffs of fast-food restaurant and fruit & vegetable store densities. Compared with participants residing in high fast-food/low fruit & vegetable areas (reference group), all other

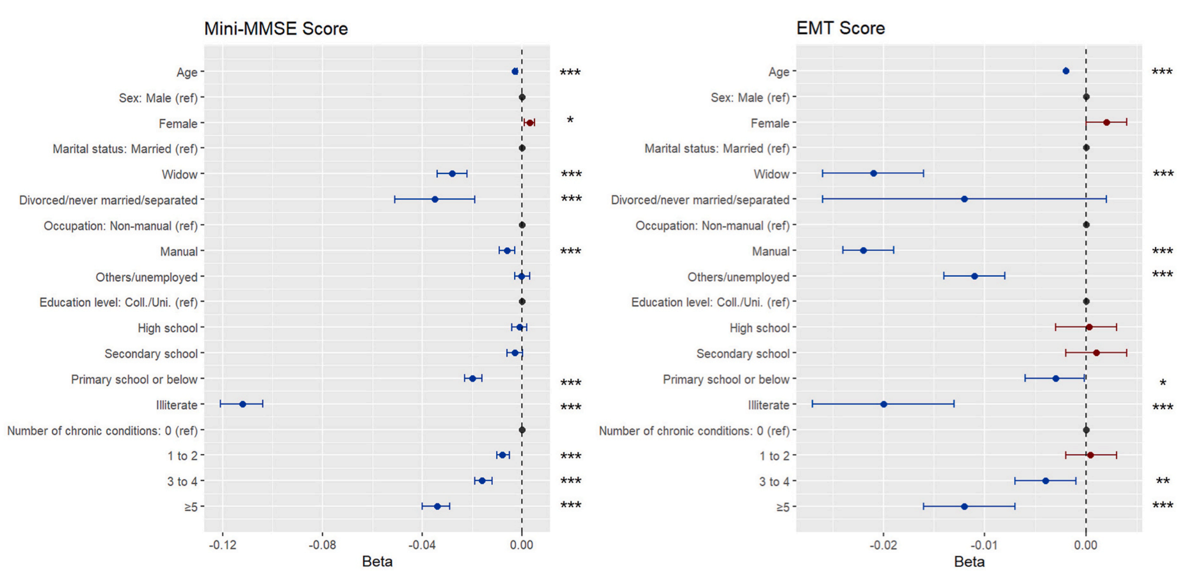

Fig. 2. Association between baseline characteristics and a) Mini-MMSE score and b) EMT score. Dots indicate point estimates and horizontal lines indicate 95 % confidence intervals. P-values were estimated as part of the generalized linear model and are two-sided and not adjusted for multiple comparisons: *p < 0.05, **p < 0.01, ***P < 0.001.

Table 3
Adjusted β with 95 % CI between per IQR increase in measures of various retail food outlet densities and log-transformed cognitive function scores in adjusted multivariable regression models[a].

	Cognitive function tests							
	Log-transformed Mini-MMSE scores				Log-transformed EMT scores			
Commercial Food Environment	β	95 %	CI	p-value	β	95 %	CI	p-value
Density of total restaurants	**−0.002**	**−0.004**	**−0.001**	**<0.001**	**−0.004**	**−0.005**	**−0.003**	**<0.001**
Density of fast-food restaurants	**−0.003**	**−0.004**	**−0.002**	**<0.001**	**−0.005**	**−0.005**	**−0.004**	**<0.001**
Density of fruit & vegetable stores	**0.002**	**0.001**	**0.003**	**<0.001**	**−0.001**	**−0.002**	**−0.001**	**0.001**
Density of dessert/drink/pastry shops	0.001	0.000	0.002	0.069	0.000	−0.001	0.000	0.231
Ratio of fruit & vegetable stores to fast-food restaurants	**0.003**	**0.002**	**0.005**	**<0.001**	**0.002**	**0.001**	**0.003**	**<0.001**
Ratio of fruit & vegetable stores to dessert/drink/pastry shops	−0.001	−0.003	0.000	0.114	−0.001	−0.002	0.000	0.213

Bolding indicates significant (p < 0.05).

[a] All models were adjusted for age, sex, marital status, occupational class, educational level, number of chronic conditions, $PM_{2.5}$, residential greenness, economic vitality, population density, and density of pharmacies.

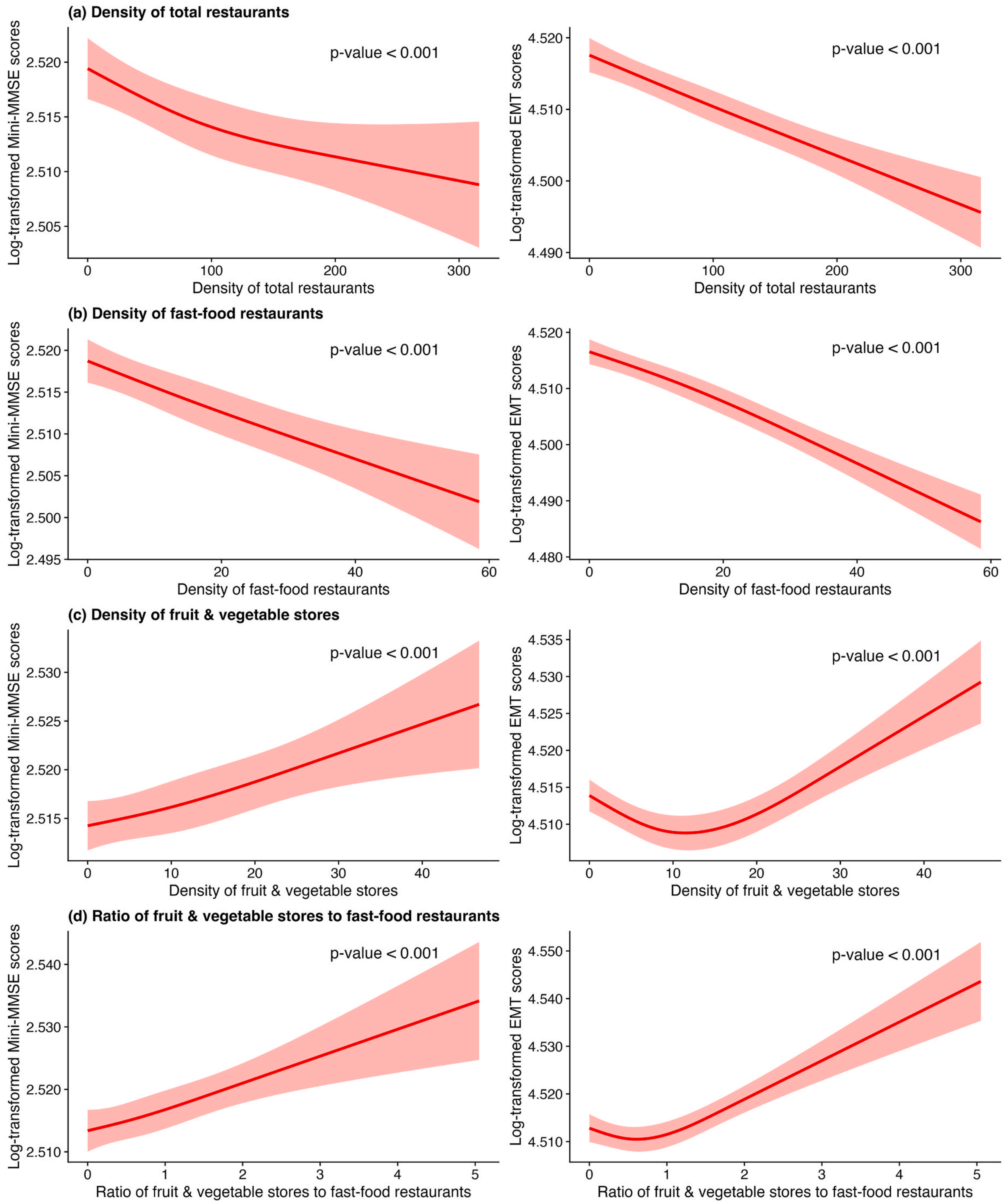

Fig. 3. RCS for the association between per unit increase in a) Density of total restaurant, b) Density of fast-food restaurants, c) Density of fruit & vegetable stores, and d) Ratio of fruit & vegetable stores to fast-food restaurants and log-transformed cognitive scores.

exposure groups had higher Mini-MMSE scores. The low fast-food/high fruit & vegetable group had the largest coefficient (β = 0.009, 0.005 to 0.013), followed by the low fast-food/low fruit & vegetable (β = 0.005, 0.001 to 0.009) and high fast-food/high fruit & vegetable groups (β = 0.005, 0.002 to 0.009). The interaction term was negative and statistically significant (β = −0.0017; p-value = 0.001). For EMT, associations were weaker, but the interaction term remained statistically significant (β = 0.0009; p-value = 0.034).

3.4. Association between the commercial food environment and risk of cognitive decline

After categorizing cognitive function scores, we examined the associations between each IQR increases in commercial food environment indicators and the likelihood of maintaining healthy cognition (Table 4). In the fully adjusted model, total restaurant density was inversely associated with Mini-MMSE defined healthy cognition (OR = 0.986, 0.963 to 1.009), although this association did not reach statistical significance, but was significantly associated with a lower likelihood of maintaining healthy cognition based on EMT (OR = 0.913, 0.878 to

Table 4
Adjusted odds ratio (OR) with 95 % CI between per IQR increase in measures of various retail food outlet densities with maintaining cognitive health in adjusted multivariable regression models[a].

	Normal cognitive functions							
	Mini-MMSE tests				EMT tests			
Commercial food environment	OR	95 %	CI	p-value	OR	95 %	CI	p-value
Density of total restaurants	0.986	0.963	1.009	0.224	**0.913**	**0.878**	**0.949**	**<0.001**
Density of fast-food restaurants	**0.967**	**0.948**	**0.987**	**0.001**	**0.896**	**0.866**	**0.927**	**<0.001**
Density of fruit & vegetable stores	**1.045**	**1.026**	**1.065**	**<0.001**	0.976	0.946	1.008	0.136
Density of dessert/drink/pastry shops	**1.032**	**1.014**	**1.050**	**0.001**	0.972	0.944	1.002	0.064
Ratio of fruit & vegetable stores to fast-food restaurants	**1.086**	**1.059**	**1.114**	**<0.001**	**1.054**	**1.010**	**1.099**	**0.015**
Ratio of fruit & vegetable stores to dessert/drink/pastry shops	0.995	0.966	1.025	0.752	0.987	0.940	1.038	0.617

Bolding indicates significant ($p < 0.05$).
Normal cognitive functions: Mini-MMSE Q1-Q3 total scores = 5, Q4≥4 and Q5≥2; EMT total scores ≥74.3 at age 60 or below, ≥73.5 at age 60–69, and ≥71.5 at age 70 or above.
[a] All models were adjusted for age, sex, marital status, occupational class, educational level, number of chronic conditions, $PM_{2.5}$, residential greenness, economic vitality, population density, and density of pharmacies.

0.949).

Each IQR increase in fast-food restaurant density was associated with a lower likelihood of maintaining healthy cognition as measured by the Mini-MMSE, with an OR of 0.967 (0.948 to 0.987). In contrast, higher fruit & vegetable store density, dessert/drink/pastry shop density, and a higher ratio of fruit & vegetable stores to fast-food restaurants were associated with increased odds of maintaining healthy cognition, with ORs of 1.045 (1.026 to 1.065), 1.032 (1.014 to 1.050), and 1.086 (1.059 to 1.114), respectively. Similar significant associations were observed for fast-food restaurant density and the ratio of fruit & vegetable stores to fast-food restaurants based on EMT defined healthy cognition, with ORs of 0.896 (0.866 to 0.927) and 1.054 (1.010 to 1.099), respectively.

4. Discussion

This study examines the association between the neighborhood commercial food environment and cognitive function among older adult living in urban areas. Our findings demonstrate that a higher overall density of food outlets (total restaurant density) was associated with poorer cognitive performance. Within this broader environment, a greater density of fast-food restaurants was also inversely associated with cognitive scores, whereas a higher density of fruit & vegetable stores, particularly a higher ratio of fruit & vegetable stores to fast-food restaurants, was positively associated with better cognitive function. This research is among the first to examine how different dimensions of the commercial food environment, both overall food outlet density and specific outlet subtypes, relate to cognitive function in older adults residing in high-density urban settings, utilizing city-wide cognitive screening data.

Our study observed linear associations of higher densities of both total restaurants and Western-style fast-food restaurants with worse cognitive performance among older adults in community-based settings. To our knowledge, few studies have evaluated the role of overall restaurant density in cognitive health, although adverse associations between fast-food outlet density and cardiometabolic conditions such as adiposity and diabetes have been explored in the UK and the Netherlands (Mason et al., 2018; Ntarladima et al., 2022). Fast-food restaurant density has been identified as an independent predictor of fast-food dining frequency (Athens et al., 2016), with higher density linked to increased fast-food consumption and reduced healthy food intake (Zhang and Huang, 2018; Athens et al., 2016). Fast-food restaurants are often preferred for their taste and convenience in urban settings; however, their products are typically high in calories, sugar, and fat, which may impair hippocampal-dependent memory and contribute to cognitive decline (Abbott et al., 2019). Although out-of-home eating among older adults in China is lower than among younger adults, it has been steadily rising, with national rates of 5.6 % and higher rates of 15.1 % observed in major cities like Beijing (Yao et al., 2019; Ma et al., 2017). Interestingly, a study in the US suggested contrasting results, indicating that older adults' regular visits to eateries like fast-food restaurants and coffee shops may have a protective effect on cognitive health by promoting social interactions and leisure activities (Finlay et al., 2020). Such discrepancies likely reflect cultural and contextual differences, as Western-style fast-food outlets in China are less popular among older adults than Chinese-style eateries (Wang et al., 2013). In the Chinese urban context, therefore, Western-style fast-food outlets may not directly reflect individual consumption patterns among older adults but instead serve as replicable indicators of neighborhood-level commercial development and less-healthy food accessibility. Their spatial distribution reflects broader environmental features of economic activity, accessibility, and social engagement that may shape community health behaviors and cognitive aging trajectories. In parallel, total restaurant density captures the overall intensity of food-related commercial activity, providing a complementary but more general indicator of the neighborhood food environment.

In high-density urban environments, total restaurant density reflects the overall intensity of food-related commercial activity, but it also encompasses a highly heterogeneous mix of small local eateries and canteens, which may reduce nutritional and functional specificity across communities. In contrast, in China, Western-style fast-food restaurants tend to cluster in areas of greater socioeconomic vibrancy, walkability, and retail accessibility, which are increasingly recognized as social and environmental determinants of cognitive health (Cerin et al., 2025). These outlets are typically located in commercially active and well-connected neighborhoods, reflecting broader urbanization and modernization processes that influence exposure to the built environment. Such environments may influence cognitive aging through multiple pathways, including dietary quality, metabolic risk profiles, environmental stressors, and patterns of social engagement. Taken together, these findings indicate that while both measures capture aspects of neighborhood commercial development, Western-style fast-food density provides a more standardized and health-relevant proxy for urbanized community environments associated with cognitive outcomes.

In our study, we identified a positive association between increased density of fruit & vegetable stores and better cognitive scores among older adults. This finding is consistent with previous evidence showing that greater availability of fresh produce in urban commercial environments predicts increased vegetable and fruit intake and healthier purchasing behaviors (Bodor et al., 2008; Mason et al., 2013). Observational studies and clinical trials have shown that increased consumption of fruits and vegetables has been associated with a reduced risk of cognitive impairment (Zhou et al., 2022; Barnes et al., 2023), with stronger effects observed in Chinese populations (Mottaghi et al., 2018). In Beijing, research on consumer behavior further supports this interpretation, indicating that urban residents, especially older adults, tend to purchase fruits and vegetables from trusted small fruit stores and traditional wet markets rather than from street vendors, largely due to concerns about freshness, pesticide residues, and food safety (Cheng et al., 2016). Our study further suggests that a greater density of fruit & vegetable stores within the commercial food environment yields additional cognitive benefits in urban communities. These findings from a LMIC context provide valuable evidence that such stores not only improve access to fresh produce but also represent safe and trusted food sources for older adults, potentially supporting healthier diets and cognitive health.

Beyond the conventional definition of the commercial food environment, typically based on the absolute number of specific types of food outlets in a given area, we also examined the relative proportion and combined effects of various commercial food outlets on cognitive function in older adults. Our findings provide strong evidence that participants living in areas with a high proportion of healthy food store, particularly a higher ratio of fruit & vegetable stores to fast-food restaurants, exhibited better cognitive scores. Interaction analyses further indicated that these cognitive benefits were most pronounced in neighborhoods with both low fast-food and high fruit & vegetable store densities, while the advantages of healthy food access were attenuated in areas with many fast-food outlets, suggesting that high fast-food density may offset the positive effects of greater fruit and vegetable availability. Similar results have been reported in previous studies showing that areas with higher densities of healthy food stores promote healthier purchasing behaviors (Mason et al., 2013). Meanwhile, the RCS analysis revealed U-shaped relationships for certain food outlet types, such as dessert/drink/pastry shops and the ratio of fruit & vegetable stores to these outlets, indicating that both insufficient and excessive concentrations of particular food outlets may reflect suboptimal neighborhood environments. These findings suggest that optimizing the overall balance between healthy and unhealthy food options at the community level may represent an effective strategy to promote cognitive health among older urban residents.

Key strengths of our study include the city-wide implementation of the cognitive screening program, the large sample size, and the well-established registration system, all of which contribute to the reliability of the data within urban Beijing. However, several limitations warrant consideration. First, as a cross-sectional study, there is a potential for reverse causality, and possible bias due to residential self-selection cannot be excluded. Nevertheless, it is plausible that the neighborhood commercial food environment is not significantly influenced by cognitive function, suggesting that the impact of reverse causality is minimal. Although data on residence duration or *hukou* status were unavailable, all participants were aged 50 years or older and had active health records at local community healthcare centers, indicating relatively stable residency. Moreover, older adults in urban China generally exhibit low residential mobility, which further reduces potential selection bias. Importantly, the highly competitive nature of community-level commercial businesses makes it difficult to assess their longitudinal effects on the cognitive function of elderly residents. Second, given the heterogeneity of restaurant types, the specific categories of food establishments most relevant to cognitive health remain incompletely characterized. Although total restaurant density, encompassing both Chinese and Western dining outlets, was treated as the primary exposure, our analyses further indicated that Western-style fast-food restaurant density, defined using standardized POI classification systems, exhibited stronger and more consistent associations with cognitive decline. These POI systems reliably identify Western-style fast-food outlets, whereas Chinese-style quick-service restaurants, which may be more culturally relevant for older adults in China, cannot yet be consistently distinguished. Nevertheless, the consistency of associations across cognitive indicators supports the robustness of our findings. Future studies should apply more refined classification strategies based on operational characteristics, food preparation methods, or nutritional profiles to better capture the heterogeneity of food environments and to clarify their differential cognitive health implications. Finally, caution should be exercised when generalizing our findings to the broader population of China. Since our study focused on participants aged 50 and above in Beijing, future studies should also include individuals from outside Beijing and those under 50 years of age to enhance the generalizability of the results. Despite these limitations, our study holds significance as the first to employ commercial food environments to assess its impact on cognitive function in older adults in China. Our findings offer valuable insights for policymakers, underscoring the importance of incorporating urban commercial planning considerations for the cognitive health of older adults who are aging in place. Our research highlights the critical importance of thoughtfully designing community commercial food environments for individuals at risk of cognitive decline.

5. Conclusions

In our study, increased neighborhood density of restaurants, in particular fast-food restaurants, was associated with lower cognitive function and reduced odds of maintaining healthy cognition, while higher densities of fruit & vegetable stores, and especially a higher ratio of fruit & vegetable stores to fast-food outlets, were linked to better cognitive performance and a greater likelihood of healthy ageing. Our findings indicate that “food swamps”—urban areas dominated by unhealthy food outlets—are structural risk factors for cognitive decline, while emphasizing that access to produce-rich retail supports diet quality and brain health. Rather than advocating the mere reduction of fast-food outlets, our results suggest that urban food environments should strive for a balanced ecosystem, one that expands access to fruit and vegetable retailers while limiting excessive concentrations of unhealthy food outlets. Zoning policies, community planning initiatives, and food environment interventions that achieve such balance may bolster dietary diversity and cognitive resilience in older adults. Future longitudinal and interventional studies should assess whether reconfiguring local foodscapes toward this equilibrium causally benefits cognitive ageing.

CRediT authorship contribution statement

Weiju Zhou: Writing – review & editing, Writing – original draft, Validation, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Deanna Sim:** Writing – original draft, Visualization, Formal analysis. **Yanxi Zeng:** Visualization, Software, Methodology, Formal analysis. **He Li:** Writing – review & editing, Resources, Project administration, Investigation, Funding acquisition, Data curation. **Xiangwei Dai:** Writing – review & editing, Validation, Software, Resources, Project administration, Investigation, Data curation. **Yaojing Chen:** Writing – review & editing, Validation, Software, Resources, Project administration, Methodology, Investigation, Data curation. **Jiuxuan Gao:** Validation, Software, Methodology, Formal analysis. **Yue Ma:** Visualization, Software, Methodology. **Ying Long:** Writing – review & editing, Visualization, Software, Methodology. **Zhanjun Zhang:** Writing – review & editing, Supervision, Resources, Project administration, Investigation, Funding acquisition, Data curation. **John S. Ji:** Writing – review & editing, Validation, Supervision, Project administration, Funding acquisition, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envres.2025.123640.

Data availability

The data that has been used is confidential.

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