ARTICLE

Interventions and public health nutrition

Multiplicity and complexity of food environment in China: full-scale field census of food outlets in a typical district

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Abstract

Objectives Community food environment is closely associated with residents' health status, and it has received substantial research attention in recent years. However, such studies are sparse in China. This study aims to reveal the characteristics of food environment in China.

Subjects A ground-truthing field census of food outlets was conducted in Xi Hu district, Hangzhou. A novel categorizing system was developed to better characterize food outlets in the study area. Geocoding and food environment analysis were performed by Arc-GIS software.

Results A total of 9274 food outlets were identified, of these, 6161 (66.43%) were food service places and 3113 (33.57%) were food stores. Fast-food restaurants (2692) and convenience stores (1764) were the two most numerous outlet types. The density of food outlets was $29.72/km^2$ and 113.97/10,000 people. Availability of BMI-unhealthy food outlets was four times greater than that of BMI-healthy ones. Further, 41.86% of total food outlets provided food-delivery services; among them, fast-food restaurants were the highest (65.53%) providers. In the urban area, the average density of food outlets was $104/km^2$. While, it was only $29/km^2$ in the rural area.

Conclusions Availability of food outlets was excellent in our study area, though it showed regional imbalance. Food environment tends to be obesogenic and high prevalence of food delivery service might increase this trend. Thus, policy makers should guarantee the smooth development of catering industry in China, so as to ensure a balanced nutrition environment.

Introduction

Obesity continues to be a serious public health concern: it has been recognized as a risk factor for cardiovascular disease, type 2 diabetes, hypertension, and several types of cancer [1, 2]. According to World Health Organization

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statistics, more than 1.9 billion adults aged over 18 years were overweight in 2016; of these, over 650 million adults were obese [3]. The worldwide rate of obesity showed an almost threefold increase from 1975 to 2016. It was also shown that the prevalence of overweight and obesity in China have been consistently rising over the past few decades, accounting for 32.3% and 6.2% of the adult population in 2016, respectively [4, 5]. Despite the fact that these prevalence were still lower compared to those observed in Europe and in the US, the prevalence of central obesity in China (44%) was much closer to that reported in the US (54.2%) [6]. Specifically, the prevalence of central obesity was 44% in rural populations, 42.5% in urban populations, and 45.2% in megacity populations [7]. Thus, obesity is also a major public health problem in China.

In response to this worldwide epidemic, many studies have highlighted the importance of molecular genetic, or inherent factors that may cause obesity; however, there are many other factors that lack a proper explanation [8].

Therefore, researchers and health professionals are progressively focusing on upstream factors, such as food environment and policy [9, 10]. Correspondingly, the role of the neighborhood food environment and its potential effects on obesity and other health-related outcomes has attracted great attention [11, 12]. However, there is inconsistency in the association between food environment and health outcomes across race or ethnicity, sex, region, and urbanism; that inconsistency complicates explanations of findings [13]. Thus, to clarify the debate, more studies are needed regarding different cultural and regional backgrounds. However, most of such type studies have been conducted in Western countries. Few studies have examined the neighborhood food environment in developing countries, especially in China [14, 15]. As an important part of Chinese culture, its food is distinctive and varied; that is reflected by the different ways of preparing food and broad use of ingredients.

More importantly, some studies showed that accessibility and availability of unhealthy food outlets like convenience store and fast-food restaurants associated with higher body weight [16, 17]. In contrast, other studies found an inverse association between neighborhood accesses to supermarket and body weight [18]. One recent review showed that the fast-food industry has rapidly increased in China and its contributions on the growth of fast-food consumption (FFC), and presented a positive association between FFC and obesity in China [19]. Another study showed that fast-food industry in China is highly correlated with economic growth, and improving the food environment should be a major component in local economic development plan [20].

It was also found that residents in rural, low income, and minority communities are often affected by poor access to supermarket, and healthy food products, especially high-quality fruits and vegetables [21]. Food environment also influence dietary intake. For example, one study reported that FFC was related to fast food availability in the neighborhood [22]. Another study carried out in Hong Kong found that the perceived availability of fast-food restaurants, and convenience stores were associated with unhealthy (high-fat foods and junk food/soft drinks) dietary intakes [23]. Food environment also influence eating choice, because eating behavior is strongly influenced by food accessibility or the types of available foods [24]. Thus, it is of vital importance to understand the characteristics of food environment in China to better cope with obesity.

Over the past few decades, China has experienced remarkable economic progress and rapid urbanization; this development has had a dramatic impact on the catering industry and diet-related behaviors [25]. With the increasing modernization, Chinese are becoming accustomed to eating away from home in fast-food or other restaurants [26–28].

People's eating patterns have dramatically changed toward a higher proportion of fat, sugar, and sodium [14, 16, 19]. Western fast foods are also popular among Chinese, especially younger people [16, 19].

In addition, with the rapid growth of China's e-commerce market, another challenge has emerged: the change in food shopping habits through the fast-growing online-to-offline (O2O) food-delivery market. As described in our previous study, the O2O food-delivery system is more convenient and user-friendly than traditional methods: orders can be easily selected and placed through a mobile application and promptly delivered [29]. The system has greatly changed the dining experience and expanded the availability and accessibility of food outlets.

Collectively, all the above factors have made the Chinese food environment extremely diverse and complex. Thus, we hypothesized that food environment trends in China is obesogenic and regionally imbalanced. In the United States and other Western countries, commercial databases (secondary data) have largely been used to evaluate a local retail food environment [30, 31]. However, there are no such publicly available databases in China. Thus, in order to better understand the association between the neighborhood food environment and residents' health status, it is necessary to gain detailed knowledge of the Chinese food environment with a ground-truthing field census. Accordingly, in this study, we examined the complex nature of the Chinese food environment to prove our hypothesis.

Here, we chose as our survey destination Xi Hu district in Hangzhou, the capital of Zhejiang Province, eastern China, and conducted a ground-truthing field survey. The objectives of this study were as follows: (1) To pinpoint and categorize all of the food outlets in Xi Hu district; and (2) To identify the characteristics and trends of Chinese food environment.

Methods

Study areas

As a geographically dominant southeastern coastal conurbation, Hangzhou is a typical city in China as its urbanization process is highly consistent with the country. From 1990 to 2015, urban population rose from 1.69 to 4.47 million. During the same period, Gross Domestic Product (GDP) per capital also grew from 3310 RMB to 139,653 RMB [32]. It's GDP level ranked ninth among all metropolitan cities in China in 2016 [33].

Xi Hu district is located in western Hangzhou. It is a large, urban-rural mixed district; it comprises 11 subdistricts, 153 communities as well as villages with about

813,700 residents. The whole area covers $312 \, km^2$; the average population density is $2608/km^2$. Xi Hu district is a representative area of Hangzhou's modernization and development. The GDP level of Xi Hu district ranked the third among all subdistricts in Hang Zhou in 2016 [34]. Long-term plan for this district has been set during the G20 Summit, which was to become the national cultural and creative industry demonstration area, national tourism and leisure demonstration area, and fine urban agriculture region leading by the booming information industry [35].

Data collection

We investigated the whole district with 800-m buffer (Fig. 1). All data were obtained through ground-truthing and direct observation. To assess food availability, we developed a spreadsheet. It contained key information about food outlets, including type of outlet and served foods, seat availability, fruit and vegetable availability, and delivery service availability. The location of each food outlet was accurately positioned using GPS equipment.

To ensure the accuracy of our data, we conducted a three week's pre survey: same area was investigated by a different group of volunteers, and the results were compared. Following the pre-survey results, we revised the classification and definitions of food outlets.

The formal field census was conducted from July 5 to August 29, 2017. Six well-trained investigators collected all the data by walking through the streets in the whole study area. The investigators worked in pairs. They went to locations defined in advance on internet map by bicycle or car. A standard protocol was followed. First, the position (longitude and latitude) of each food outlet was recorded using the GPS device. Second, the spreadsheet was completed. Third, a photograph was taken for every food outlet. Finally, a record was kept on the internet map of their entire course. After each trip, the data was collected in time and subjected to quality control. The buffer was neglected in some areas where the boundary was the Qian Tang River or mountainous ground.

Classification and definitions of food outlets

Food industry in China has not been categorized in full detail. Here, we developed a new categorizing system to characterize the food environment based on the literature and features of Chinese food [15, 36, 37]. Consequently, food outlets were categorized into 9 main types (Table S1) and 33 subtypes (Table S2). On the basis of these main types, we further divided food outlets into two major categories according to service type: food stores and food service places.

We also classified food outlet types as BMI-healthy, BMI-intermediate, and BMI-unhealthy on the basis of the 33 subtypes (Table S2). BMI-healthy food outlets signified stores that provided a range of fresh, frozen, and canned fruit and vegetable selections as well as less oily, less fatty foods; they are associated with better dietary patterns and slower growth in BMI [18, 38, 39]. BMI-unhealthy outlets signified stores that offered few or no fruit and vegetable choices; they provided processed foods or high-fat, high-sugar, oily foods, which are linked with high-energy intake, fat intake, BMI, and weight gain [27, 28, 40]. BMI-intermediate category contained food stores that lacked evidence about healthy or unhealthy food outlet categories; the contribution of these food outlet types to weight is unclear [41]. Table S1 provides details on definitions of the main types.

Statistical analysis

Geocoding and food environment spatial distribution analysis were performed using ArcGIS 10.2 software (ESRI Inc., Redlands, CA, USA). Density of outlets was determined in two different ways: per square kilometer; and per 10,000 people. Nearest-neighbor analysis was used to assess the distance of each food outlet to the nearest same type one and the number of food outlets within 50, 100, 200, and 400 m of each outlet. To compare the spatial distribution of food outlets between urban and rural areas, we downloaded Landsat ETM-2017/02/28 from the US Geological Survey, the boundaries between urban and rural areas were identified by supervised classification and visual interpretation (Fig. S1).

Results

One hundred and sixteen trips covering 3896 km were completed during the census. Consequently, we identified 9274 food outlets in the study area. Among these, 6161 (66.43%) were food service places and 3113 (33.57%) were food stores (Table 1). This might reflect a high rate of eating away from home. The overall density of food outlets in the study area was $29.72/km^2$ and $113.97/10,000$ people. The density of food stores was $9.98/km^2$ and $19.74/10,000$ people; that of food service places was $19.74/km^2$ and $75.72/10,000$ people. Notably, 41.86% of all food outlets provided food-delivery services; among them, ~60% of food service places were food-delivery service providers.

The geographic distribution of the food outlets was uneven. As evident in Fig. 2, most of the food outlets were highly concentrated in the northeastern and northwestern areas, which are densely populated areas such as the centers
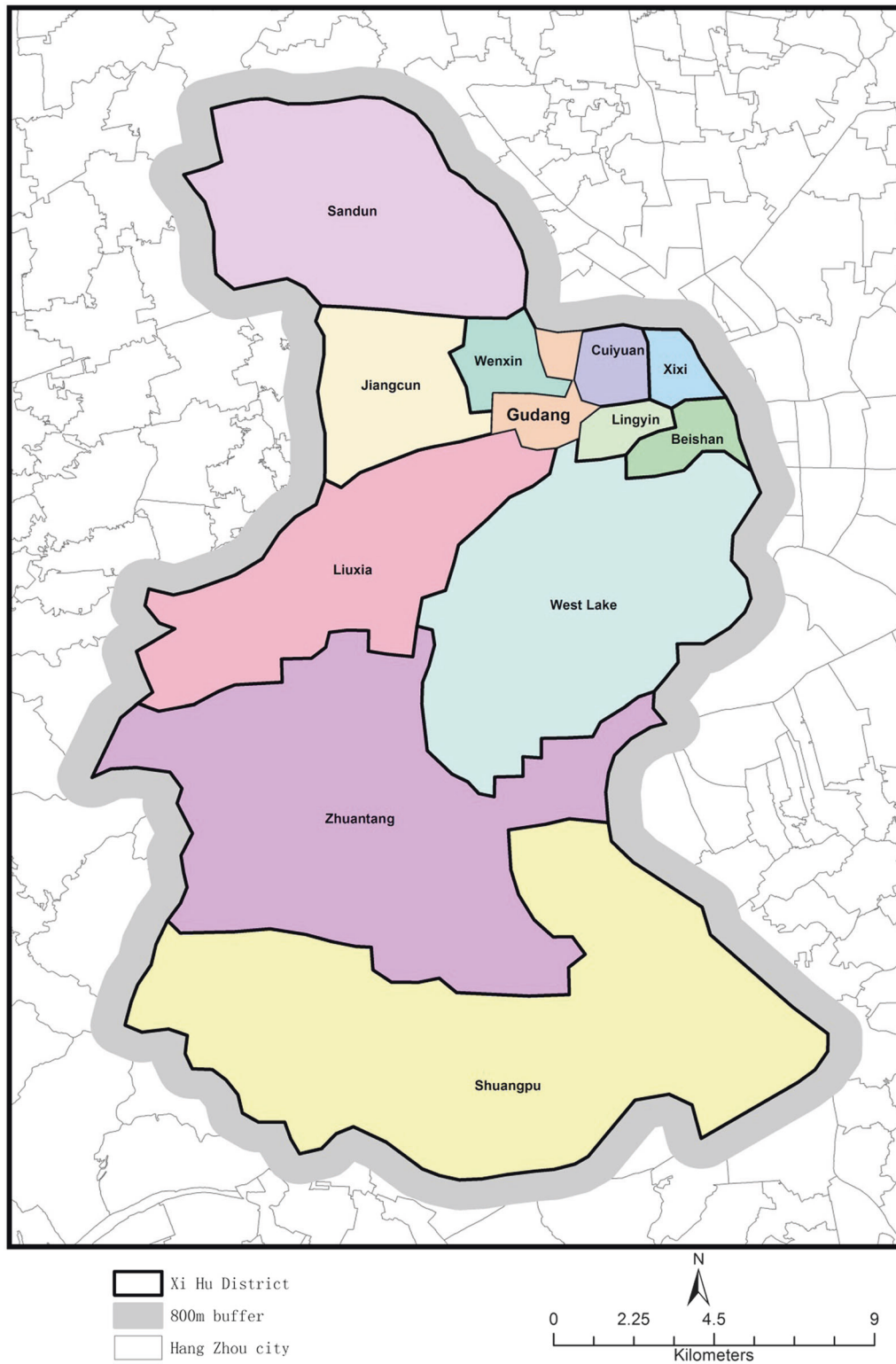
Fig. 1 Geographical map of study area. Subdistricts are marked with different colors and the buffer zone was indicated by gray

for business and commerce. In other parts, such as mountainous areas, the density was extremely low. Differential distribution of food outlets among different subdistricts were shown in Table 2. It could be seen from the results that there was an imbalance in the density of food outlets among the subdistricts.

Table 1 Characteristics of food outlets in Xi Hu (with 800-m buffer)

Outlet type	n	$n\%$	Density ($/km^2$)	Density ($/10{,}000$ people)	Online delivery service availability (%)
Food store	3113	33.57	9.98	38.25	14.03
Mega-supermarket, supercenter	41	0.44	0.13	0.50	14.63
Supermarket, large grocery store	405	4.37	1.36	4.98	11.35
Farmers' market	57	0.62	0.18	0.70	7.84
Convenience store, corner store	1764	19.02	5.65	21.68	8.78
Fruit, vegetable store	846	9.12	2.71	10.40	26.71
Food service place	6161	66.43	19.74	75.72	55.91
Fast-food restaurant	2692	29.03	8.63	33.08	65.52
Full-service restaurant	1713	18.47	5.49	21.05	56.16
Chinese local cuisine restaurant	813	8.77	2.61	9.99	50.43
Bakery, beverage store	943	10.17	3.02	11.59	32.76
Total	9274	100	29.72	113.97	41.86

General characteristics of food outlets by store type

The complexity and multiplicity of food environment in the study area are especially reflected by the diversity of food outlet types (Table S2). As shown in Table 1, fast-food restaurants and convenience stores were the two most common food outlet types with 2692 (29.02%) and 1764 (19.02%) stores. Full-service restaurants ranked the third with 1713 stores (18.47%). Mega-supermarkets and super-centers were the lowest with 41 (0.44%) outlets and mainly located in the northern and central parts of the study area (Fig. 3a). Interestingly, fruit-and-vegetable shops ranked fifth among all food outlets. Even though there was a relatively small number of farmers' markets (only 57), they were evenly distributed across the study area (Fig. 3b).

The geographic distribution and proportion of Chinese and Western fast-food restaurants appear in Fig. 3c. Chinese fast-food restaurants were overwhelmingly more numerous than Western ones in all subdistricts. In West Lake and Lingyin, which are home to famous tourist attractions, the proportion of Western fast-food restaurants was markedly higher than that in other subdistricts (Fig. 3d). Fast-food and full-service restaurants dominated the neighborhood food environment in the study area. This situation may contribute to unhealthy eating behaviors, such as eating away from home.

Clustering level of food outlets

We conducted nearest-neighbor analysis to determine the clustering level of food outlets (Table 3). Regarding the average nearest distance to a same type neighboring food outlet, farmers' markets had the greatest distance

(1097.7 m); fast-food restaurants had the lowest distance (37.4 m). Over 80% of fast-food restaurants' nearest neighboring food outlets (same type) was located within 50 m. They were followed by convenience stores, with an average distance of 70.8 m to the nearest neighboring food outlet. For about 82% of convenience stores, the nearest neighboring food outlet was within a distance of 100 m. For ~75% of food service places, the nearest neighboring food outlet was located within 50 m. For almost 90% of all other types of food outlets, their nearest neighbor was located within 200 m. These results indicated that most of the food outlets are highly clustered in the study area.
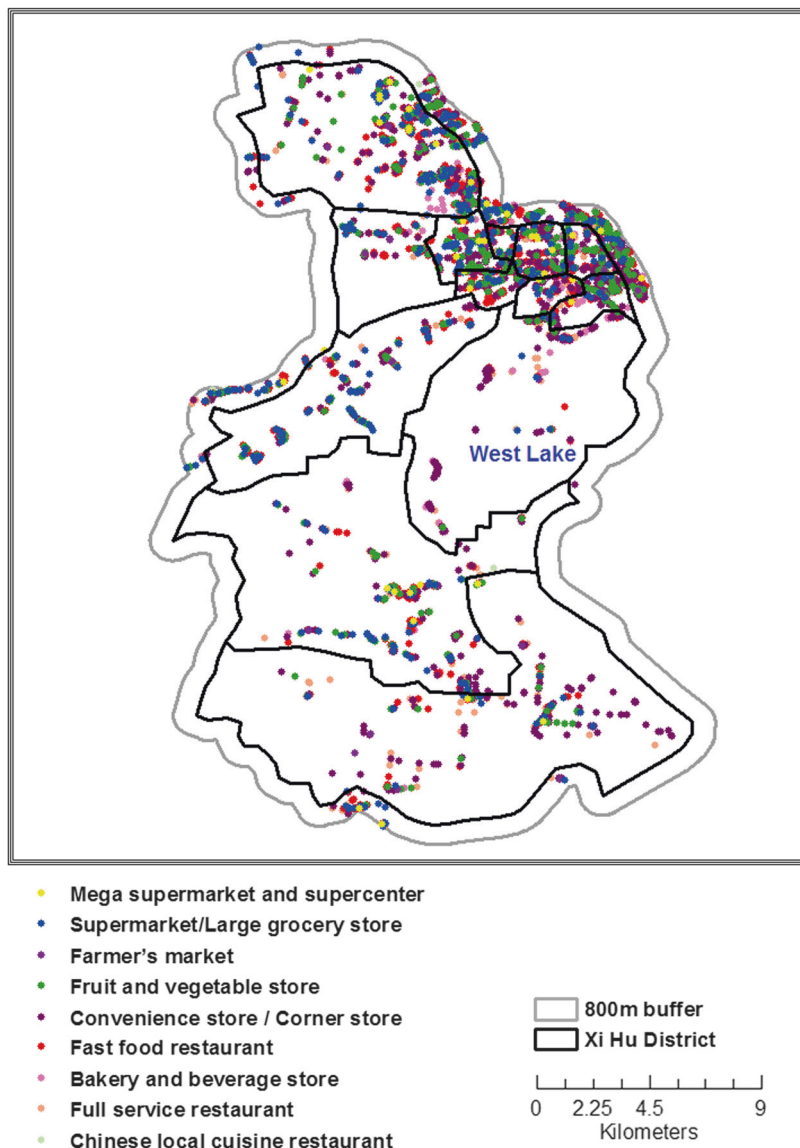
BMI-healthy, BMI-intermediate, and BMI-unhealthy food availability and food delivery service availability

Total number of BMI-unhealthy food outlets (6579) was about four times greater than that of BMI-healthy food outlets (1505); there were 1190 BMI-intermediate food outlets. The density per area for BMI-healthy and BMI-unhealthy outlets was $4.82/km^2$ and $21.09/km^2$, respectively; that of per capita was $18.50/10{,}000$ people and $80.53/10{,}000$ people. As evident from the heat map, density of BMI-healthy food outlets was much lower than that of BMI-unhealthy outlets (Fig. 4a, b). It indicated that food environment in the study area is obesogenic.

Details of food-delivery service availability were presented in Table 1. As a whole, 41.86% of food outlets provided food-delivery service. As for the nine main types, 65.53% of fast-food restaurants provided food-delivery service, making them the highest providers; they were followed by full-service restaurants (56.16%), and Chinese

Fig. 2 Scatter plot of food outlets in the study area. Distribution of food outlets is shown according to nine major categories by different colors

- ● Mega supermarket and supercenter
- ● Supermarket/Large grocery store
- ● Farmer's market
- ● Fruit and vegetable store
- ● Convenience store / Corner store
- ● Fast food restaurant
- ● Bakery and beverage store
- ● Full service restaurant
- ● Chinese local cuisine restaurant

800m buffer
Xi Hu District

0   2.25   4.5   9
Kilometers

N

local cuisine restaurants (50.43%). Notably, bakery and beverage stores as well as fruit-and-vegetable stores also provided substantial delivery services, accounted for 32.77 and 26.71% of them, respectively. Flourishing food delivery service generates double-edged effect on the food environment through expanding the availability of both BMI-healthy and BMI-unhealthy food outlets. According to our results, it seemed that food delivery service might increase the obesogenic trend of the food environment.

Comparison between urban and rural areas

As mentioned above, we identified the boundary between urban and rural areas using remote sensing image data. Number and density of food outlets in urban and rural areas appear in Table 4. Land area of the urban and rural regions in the study area was 68.02 and 29.07 km^2. Number of food outlets in urban and rural areas was 7101 and 846. In urban area, the average density of food outlets reached up to 104/km^2; while in rural area, it was 29/km^2. Fast-food restaurant was the most common food outlet type in both urban and rural areas; the density of fast-food restaurants was three times greater in urban than in rural areas. The density of other types of food outlets was two to seven times higher in urban than in rural areas. These results suggested that there is huge disparity on food environment between urban and rural areas.

Discussion

In this study, we found that the density of food outlets was high in the study area though their distribution was uneven. The number of food service places was two times greater

Table 2 Number and density of food outlets in subdistricts (without 800-m buffer)

Subdistricts' name	Area (km²)	Population	Food outlets (n = 7502)				Food stores (n = 2442)				Food service places (n = 5060)			
			n	n%	Density (/km²)	Density (/10,000 people)	n	n%	Density (/km²)	Density (/10,000 people)	n	n%	Density (/km²)	Density (/10,000 people)
Sandun	37.93	132631	1705	22.72	44.95	128.55	493	20.19	13.00	37.17	1212	23.95	31.95	91.38
Jiangcun	14.80	29272	381	5.08	25.74	130.16	97	3.97	6.55	33.14	284	5.61	19.19	97.02
Gudang	4.64	67349	811	10.81	174.78	120.42	242	9.91	52.15	35.93	569	11.24	122.63	83.59
Cuiyuan	4.02	86267	572	7.62	142.29	66.31	168	6.88	41.79	19.47	404	7.98	100.50	46.83
Xixi	3.02	79503	423	5.64	140.07	53.20	130	5.32	43.05	16.35	293	5.79	97.02	36.85
Wenxin	5.05	87907	598	7.97	68.02	62.44	239	9.79	47.33	27.19	359	7.09	71.09	40.84
Linyin	6.00	46070	201	2.68	33.50	43.63	54	2.21	9.00	11.72	147	2.90	24.5	31.91
Beishan	3.93	29159	445	6.06	113.23	152.61	194	7.94	49.36	66.53	251	4.96	63.87	86.08
Liuxia	36.10	95779	739	9.85	20.47	77.16	196	8.03	5.43	20.46	543	10.73	15.04	56.69
Zhuangtang	78.00	71034	800	10.67	10.26	112.62	243	9.95	3.12	34.21	557	11.01	7.14	78.41
Shuangpu	81.81	65038	374	4.99	4.57	57.50	208	8.52	2.54	31.98	166	3.28	2.03	25.52
West Lake	–	–	453	6.03	–	–	178	7.29	–	–	275	5.43	–	–

than that of food stores. Clustering analysis indicated that most of the food outlets were highly clustered. Availability of BMI-unhealthy food outlets was four times greater than that of BMI-healthy ones, suggesting that the food environment as a whole is obesogenic. Moreover, China's food-delivery service is prosperous, which might increase the obesogenic trend of the food environment.

The latest revision of Chinese Dietary Guidelines recommends healthy eating patterns; it encourages diverse, balanced nutrition, such as less salt, less oil and greater vegetable, milk as well as soybean intake [42]. Conventionally, dietary behavior has been considered an important influencing factor for individual food choice. Recently, an extensive body of research has investigated and highlighted the impact of the neighborhood food environment on dietary behaviors, dietary intake, and residents' health status [12, 43, 44]. It is demonstrated that healthy eating environment is an important contributing factor to resident's health status. However, the characteristics of neighborhood food environment have received little research attention in China. In this study, by systematically measuring and recording with ground-truthing methods, we for the first time provided a complete picture of food environment in a big district.

Here, density of food outlets in the urban area was 104.40/km², which is somewhat higher than that (78.52/km²) observed in New York City in 2009 [38]. The densities of food service places, mega-supermarkets and supermarkets, and fruit and vegetable stores were also higher than those reported in other studies [45, 46]. Notably, the density of fast-food restaurants was 8.63/km², which is much higher than the 0.52/km² in Montreal [47].

Thus, availability of food outlets was excellent in our study area. Possible reasons for high food outlet density in our study area are high population density as well as changes of lifestyle due to rapid economic growth.

In recent years, China's fast-food industry has developed swiftly. Rapid growth of the fast-food industry is related to high consumption of unhealthy food, especially among young people [29]. Many studies have reported the negative influences of fast-food consumption on residents' health status [40, 47–49]. A meta-analysis study has found significantly higher obesity-undernutrition ratios in high-income countries than in middle-income countries and proposed that this difference was due to the impact of exposure to an obesogenic environment [50]. In our study area, there were far more BMI-unhealthy food outlets than the BMI-healthy ones. Fast-food restaurants and convenience stores were top two common food outlet types, accounting for ~50% of the total food outlets. These results indicate that the food environment of the study area as a whole was not beneficial to the residents' health status.

As a center of e-commerce, Hangzhou has a very prosperous food-delivery industry. About 42% of the outlets in our study area offered delivery service; that figure covers all nine main types of stores. Among them, fast-food restaurants were the highest (65.53%) providers. O2O food-delivery platforms are the main reason for the high prevalence of delivery services. In our previous study, we have introduced China's O2O food market in detail [29]. The trend toward increased consumption of delivery food is inevitable in China. O2O food delivery system has brought great changes in food accessibility and availability. However, it also poses certain challenges to the whole public
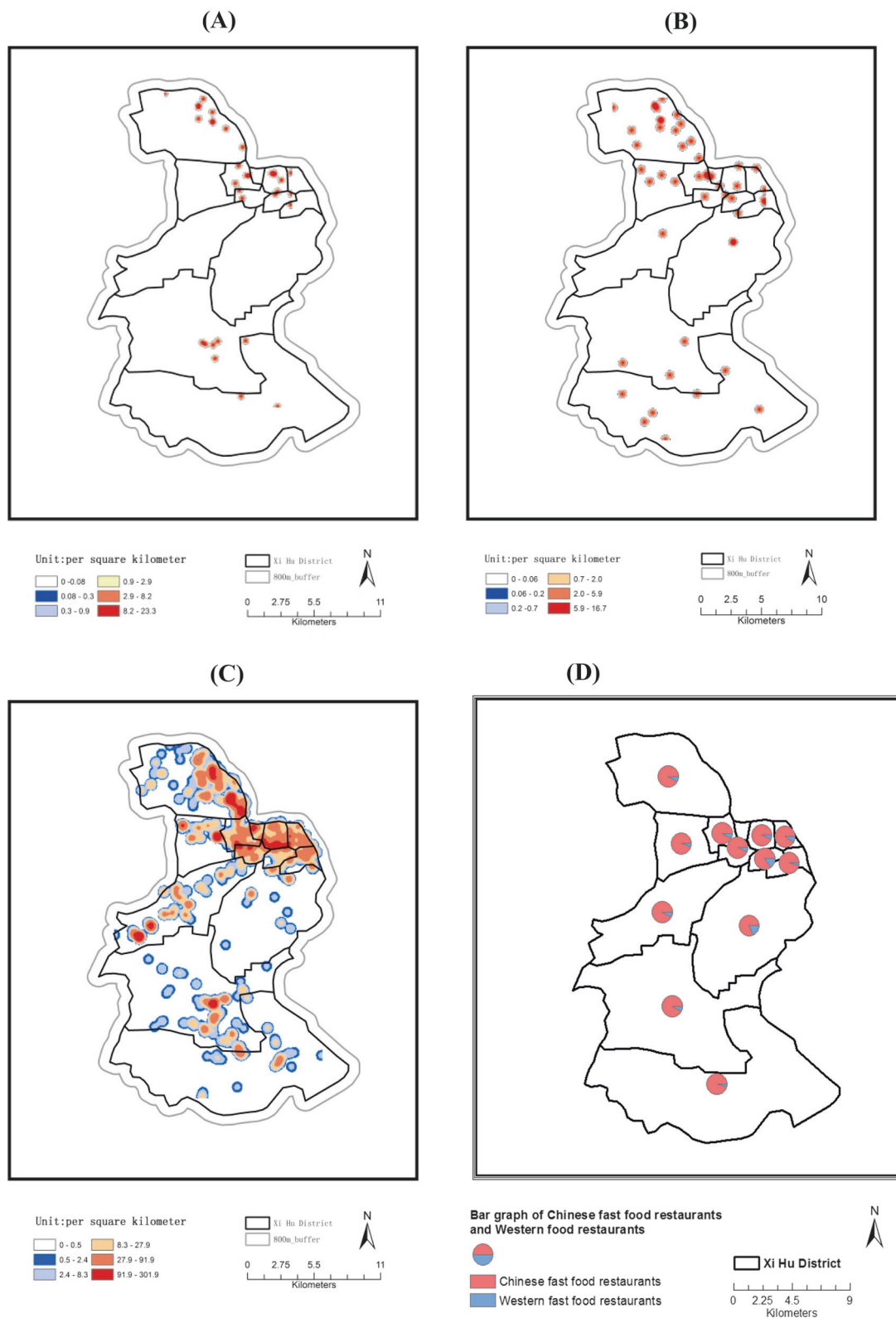
Fig. 3 Distribution heat map and comparison of some typical food outlet types. Heat map of mega-supermarkets and supercenters (**a**), farmers' markets (**b**), and fast-food restaurants (**c**) are shown in order. **d** The proportion of Chinese and western fast foods in different subdistricts

Table 3 Clustering of food outlets (with 800-m buffer)

Outlet type	Number of food outlets having at least one other food outlet (%)				
	Within 50 m	Within 100 m	Within 200 m	Within 400 m	Mean distance (m)
Food store	1790 (57.50)	2283 (73.33)	2660 (85.45)	2907 (93.38)	–
Mega supermarket, supercenter	0 (0)	4 (9.76)	9 (21.95)	13 (31.71)	859.64
Supermarket, large grocery store	122 (30.12)	189 (46.67)	261 (64.44)	354 (87.41)	210.48
Farmers' market	6 (10.53)	6 (10.53)	10 (17.54)	13 (22.81)	1097.72
Convenience store, corner store	1152 (65.31)	1448 (82.09)	1631 (92.46)	1714 (97.17)	70.84
Fruit, vegetable store	510 (60.28)	636 (75.18)	749 (88.53)	813 (96.10)	102.81
Food service place	4617 (74.94)	5387 (87.44)	5804 (94.21)	6034 (97.94)	–
Fast-food restaurant	2263 (84.06)	2523 (93.72)	2624 (97.47)	2662 (98.89)	37.47
Full-service restaurant	1245 (72.68)	1486 (86.75)	1599 (93.35)	1668 (97.37)	59.82
Chinese local cuisine restaurant	540 (66.42)	657 (80.81)	739 (90.90)	789 (97.05)	74.65
Bakery, beverage store	569 (60.34)	721 (76.46)	842 (89.29)	915 (97.03)	77.67
Total	6407 (69.09)	7670 (82.70)	8464 (91.27)	8941 (96.41)	–
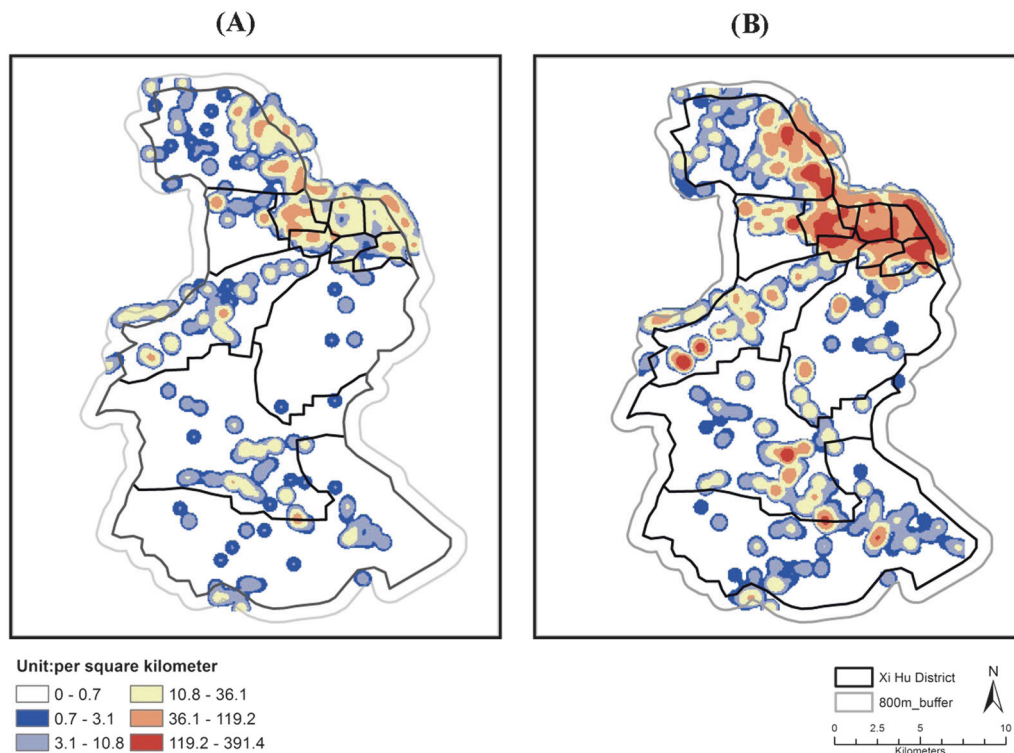
Fig. 4 Density of BMI-healthy and BMI-unhealthy food outlets. Picture **a** represents density of BMI-healthy food outlets, picture **b** represents density of BMI-healthy food outlets. Density of this two types of outlet compared by the same density range legend. The six-different colors symbolize different density range

health system and social environment in China. Thus, it should be strictly regulated.

In addition, great disparities were found between urban and rural areas (Table 4). Food availability is excellent in urban areas, but it is relatively poor in rural areas.

Furthermore, rural regions in our study are the areas adjacent to the urban regions. The situation might even be worse in remote rural areas of China. A study by Jiang et al. have reported that malnutrition is still a major public health concern among younger children in mid-western China

Table 4 Comparison between urban and rural area food outlets in Xi Hu (with 800-m buffer)

Outlet type	Urban area (68.02 km^2)		Rural area (29.07 km^2)	
	n (%)	Density (/km^2)	n (%)	Density (/km^2)
Food store	2328 (32.78)	34.23	292 (34.52)	10.04
Mega supermarket, supercenter	33 (0.46)	0.48	2 (0.24)	0.07
Supermarket, large grocery store	261 (3.68)	3.84	53 (6.26)	1.82
Farmers' market	39 (0.55)	0.57	10 (1.18)	0.35
Convenience store, corner store	1327 (18.69)	19.51	160 (18.91)	5.50
Fruit, vegetable store	668 (9.41)	9.82	67 (7.92)	2.30
Food service place	4773 (67.22)	70.17	554 (65.48)	19.06
Fast-food restaurant	2072 (29.18)	30.46	270 (31.91)	9.29
Full-service restaurant	1260 (17.74)	18.52	169 (19.98)	5.81
Chinese local cuisine restaurant	663 (9.34)	9.75	56 (6.62)	1.93
Bakery, beverage store	778 (10.96)	11.44	59 (6.97)	2.03
Total	7101 (100%)	104.40	846 (100%)	29.10

[51]. One of the major reasons to this endemic might be the inadequate access to healthy food. This public health concern in China should not be neglected. Smooth transition of the food environment should be guaranteed in the process of urbanization.

Studies have shown that farmers' markets increase access to healthy foods at low prices [21]. We found 57 farmers' markets in our study area. They were distributed relatively even, but the density was very low.

As a matter of fact, so many factors together shaped the obesogenic food environment in China. Thus, policy interventions about preventing and reducing obesity are urgently needed. To improve the food environment and reduce the prevalence of obesity, several interventions have been tried in other countries, and could also be applicable in China. Firstly, the Zoning policies prevent land use thought to be harmful to neighborhoods, such as fast food service places. A recent analysis of zoning options for Quebec municipalities describes bylaws that incorporate retail food outlet development around schools [52]. Zoning instruments and land-use planning could address health related issues through built environment factors, such as walkability, transportation, and physical access. Another policy that supports primary agricultural production in city-region is to build positive economic system. This policy could develop a healthier retail environment by strengthening local economic relationships, such as direct producer-consumer relationships that could help to increase the number of farmer's markets and establish complementary routs for retail food distribution and purchasing [53]. In addition, the taxes policy tool is also a potential solution for China. For example, Jennifer et al. found tax on sugar-sweetened beverages could decrease consumption of sugar-sweetened beverages [54]. Moreover, the menu labeling legislation was applied in U.S. [55]. Nutrition information can be made transparent at the point of purchase in places where people eat out, and help local residents to choose healthier diet [56]. Lastly, Philadelphia's policy of constructing corner shops that provide healthy food items [57] would also work in China.

This study has some limitations. China is a multicultural nation. Even though Xi Hu district is a large area within Hangzhou, it may not sufficiently reflect China's food environment. We did not formally assess the inter-rater reliability of our food outlet evaluation tool; however, in the pre survey, we confirmed that there was good inter-rater agreement in three communities, which included more than 200 outlets visited by three independent teams. Due to rapid urbanization, the address and type of food outlets located on the border between urban and rural areas may change rapidly; that could have resulted in invalid data about food outlets. This study also has a number of strengths. First, it is the first in China to characterize and depict the complete picture of a large neighborhood food environment through a ground-truthing survey. Second, as the hub of Chinese e-commerce, Hangzhou has a prosperous food-delivery market. Accordingly, we paid particular attention to the availability of food-delivery services for each food outlet. Our study is also the first to collect food-delivery service data in China. Third, we developed a new categorizing system to characterize the food environment based on the literature and features of Chinese food.

Conclusions

We provided solid evidence toward understanding the characteristics of China's food environment. In our study area, availability of food outlets was excellent, though it showed regional imbalance. BMI-unhealthy food outlets were far more numerous than BMI-healthy ones. The food-delivery service was prosperous, which shaped a more

sophisticated food environment. However, this situation may cause changes in the nutrition environment that influence individual diet behaviors and dietary intake. The distribution of food outlets in urban and rural areas differed greatly. Collectively, our findings have important implications for public health researchers and the government officials in identifying the environmental risk factors associated with obesity and other health outcomes. Policy interventions to eliminate disparities in the food environment are urgently needed.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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