Original Article

# Influence of proximities to food establishments on body mass index among children in China

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**Background and Objectives:** Over the past two decades, food environment has changed, and the obesity and overweight rates have increased dramatically in China. Previous studies have suggested an association between food environment and obesity, while most studies were based on the data from developed countries, and few were conducted in developing countries. **Methods and Study Design:** The current study evaluated the influence of food establishments (distance to and types of grocery store, free market, restaurant, and food stall) on body mass index (BMI) in 348 children aged 6-17 years, surveyed in the 2009 and 2011 China Health and Nutrition Survey in nine provinces. Food establishments were assessed using geographic information system (GIS) data. Weight and height of children were directly measured. **Results:** Our longitudinal analysis suggested boys in the 2nd quartile of the proximity to the nearest grocery store had higher BMI (by 1.6 kg/m$^2$, 95% CI, 0.07 to 3.24) as compared to those in the 1st quartile, while girls in higher quartiles had lower BMI (-1.78 kg/m$^2$, 95% CI: -3.38 to -0.18, 2nd quartile; -1.62 kg/m$^2$, 95%: -3.22 to -0.01, 3rd quartile) as compared to those in the 1st quartile. Boys and girls in the 2nd quartile of the proximity to the nearest Chinese restaurant had lower BMI (-1.69 kg/m$^2$, 95% CI: -3.27 to -0.12; -1.76 kg/m$^2$, 95% CI: -3.26, -0.27, respectively) as compared to those in the 1st quartile. **Conclusions:** Food environment may affect children's BMI in China, while the association is inconsistent with previous studies. Further research is needed.

**Key Words: child, body mass index, food store, obesity, China**

## INTRODUCTION

The increasing global prevalence of childhood overweight and obesity has become a major public health crisis.[1] In China, childhood obesity has become a severe social problem growing since the 1980s.[2] In1985, less than 3% of Chinese children and adolescents were overweight or obese, but by 2010, the combined prevalence reached approximately 15%.[3,4] According to the China Health and Nutrition Survey (CHNS), the mean body mass index (BMI) of Chinese children and adolescents increased from 17.4 kg/m$^2$ in 1991 to 18.3 kg/m$^2$ in 2006. By 2030, the number of obese adults in China was projected to exceed 141 million.[5] Many of these obese adults may be overweight or obese during childhood, as overweight or obese children have a higher risk to become overweight or obese adults as compared to normal-weight children.[6,7] A growing body of research has explored factors that increase childhood obesity risks at individual, household and community levels, which would help develop effective intervention policies.

Recent studies suggest that community food environment can be associated with health-related behaviours such as food consumption and physical activity.[8] Distance to and density of food outlets are both reported to be associated with children's food choice such as consumption of fresh fruit and vegetables, and in turn, have an influence on their weight status.[9] Also, it was demonstrated that fewer convenience stores and fewer supermarkets in the living communities were associated with greater BMI z-score reduction in a group of 8-12 years old children.[10] Miller et al reported an association between increasing number of healthy food establishments and reduced risk of overweight and obesity among 1850 Australian children aged 5-15 years, and they reported that the local food environment around children's homes had an independent effect on children's weight status.[11] However,

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many other studies failed to find significant association between food environment and childhood obesity,[12,13] including a meta-analysis.[14] Therefore, although some research support the influence of built environment on childhood obesity, the impact still appears to be mixed and complex.

The proximity to food establishments and availability of food are two main aspects of a community food environment.[9] The relationship between the prevalence of childhood obesity and the community food environment has been examined by an increasing number of scientists all over the world.[2,15] However, most of the studies focused on the associations between food environment and weight status of adults,[12] and between children's weight status and the food environment around children's schools.[14-16] In addition, few studies have assessed the influences of food environment on the weight status of school-aged children, especially in developing countries, such as China, that have experienced fast food environment changes. Furthermore, in developing countries, objective measures such as geographic information system (GIS) data on food environment are rarely available. To fill these gaps in the literature, the present study aimed to explore the association of proximities to food establishments and BMI of children in China using rich longitudinal data including GIS data collected in a nationwide study.

## METHODS

### *Study population*

The data were drawn from CHNS[17] an ongoing multiwave longitudinal survey started from 1989. It employed a multistage random cluster sampling process to draw households from urban and rural areas. The nine provinces were located in the northern, middle, and southern part of China. The survey was distributed every two or three years. All waves of CHNS collected identical data from same communities and households. The aims and details of the study design can be found on the CHNS website (http://www.cpc.unc.edu/projects/china).

The population of current study consisted of children aged 6-17 years old investigated in both 2009 and 2011. 348 children (175 boys and 173 girls) were included in the final analysis, after excluding observations with missing outcome or predictor variables. Children being excluded from analysis were not significantly different from those being included in terms of socio-demographic characteristics.

### *Outcome variables*

Anthropometric measurements were conducted in both years. Children's height (without shoes) in meters and weight (without heavy clothes) in kilograms were measured using standard techniques and equipment in order to calculate BMI ($kg/m^2$). Repeated measured BMI of each individual was used as the outcome variables to examine the influence of the proximities to food establishments.

### *Exposure variables*

The proximities to four main kinds of food establishments (grocery store, free market, restaurant, and food stall) from surveyed children's home were analyzed. The food environment-related information was provided by a community administrator or representative, who was familiar with the community. Proximity was defined as the Euclidean distance from home to the nearest corresponding food establishment. The proximities were calculated using GIS data after geocoding each child's residential address and food establishments in their communities. Considering that the proximities may have nonlinear effects on BMI, the proximity to each food establishment was categorized into quartiles. Children in the first quartile of proximity were served as the reference group.

Grocery store was defined as indoor stores selling all types of food, including processed and packed food, frozen food, fresh meat and dairy products, aquatic product, fruits and vegetables. Compared with free markets, grocery stores usually had more brands of packed food and less varieties of fresh food. Free markets mainly sold fresh foods like meat, fish, eggs, fruits and vegetables. Foods that need special preservations and packed foods could rarely be seen in free markets. Chinese restaurants refer to the indoor restaurants serving cold and hot Chinese dishes, as well as sweet beverages and alcohol. They typically operated indoors, or inside an enclosed structure having a roof and well-covered walls. Outdoor food stalls were operated outdoors at a fixed place. They may have a roof, but have no wall. Both cooking and eating were done outside. They typically sold staple food, such as pancakes, noodles, and dumplings.

### *Covariates*

The following individual level variables were included in the analyses: age (years), gender, household income per capita (yuan/year), and average daily energy intake (kcal/day). Average daily energy intake was calculated based on the results of three consecutive 24-hour dietary recalls. The surveyed children provided the data for themselves, with the assistance of their parents or care providers.

At community level, urbanicity index and densities of food establishments were included in the analyses. The density of a certain food establishment in a community was calculated as the number of that type of food establishments divided by the area of the community ($m^2$). Urbanicity index[18] was a multidimensional index developed specifically for CHNS to capture urbanization level of Chinese communities. The index consisted of twelve components, of which, each was assigned ten points and summed up to a maximum value of 120 points. These components included population density, transportation infrastructure, housing infrastructure, sanitation, health infrastructure, availability of social services, communication infrastructure, education level, economic activity, variance in education and income level, presence of traditional food markets and presence of western food establishments. A higher index score indicated a higher degree of urbanization.

### *Statistical analysis*

Descriptive analysis was first conducted, to examine the characteristics of the sampled children and their living communities. Generalized Estimating Equation (GEE) models[19] were built to assess the association of proximity

to each food establishment with repeated measures of BMI in boys and girls, respectively. Unadjusted and fully adjusted models were fitted for each gender. Full models adjusted for age, individual daily energy intake, household income per capita, urbanicity index, and densities of interested food establishments. For all analyses we used SAS (version 9.2, SAS Institute Inc. NC).

## RESULTS

Descriptive statistics of the study sample are presented in Table 1. The children's average age was 10.9 years in 2009. Average household income per capita was around 10,000 Yuan (about US$1600) in 2009, and the families with girls had relatively lower household income when compared to the families with boys ($p<0.05$). From 2009 to 2011, boys' average BMI increased from 17.8 kg/m$^2$ to 19.0 kg/m$^2$, and that of girls increased from 16.9 kg/m$^2$ to 18.1 kg/m$^2$.

The mean and standard deviation of community-level variables, including urbanicity index, density of each food establishment in the community, and measure of proximities to each food establishment, are presented in Table 2. The density of free markets was remarkably lower than that of any other food establishments. It was also shown that boys and girls were exposed to the similar food environment at baseline. For example, the average distance to the nearest grocery store was 0.83 (±1.16) and 0.83 (±1.09) km, and the average distance to the nearest Chinese restaurant was 0.68 (±0.90) and 0.69 (±0.88) km, in boys and girls respectively. However, from 2009 to 2011, the average daily energy intake (shown in Table 1) increased more in girls than that in boys, with an increase from 1531 kcal to 1719 kcal in girls and from 1896 kcal to 1960 kcal in boys.

Table 3 shows the result of the regression analysis. The results show some significant association between proximity to food stores and BMI in boys and girls, but the results are mixed. In the unadjusted model (model 1), the interceptions represented the average BMI of boys and girls in the reference group. In all these models, although they were not statistically significant, children, both boys and girls, who lived second nearest to Chinese restaurant (2$^{nd}$ quartile), had lower BMI than those who lived nearest to Chinese restaurants (1$^{st}$ quartile). The BMI of children who lived in a moderate distance to Chinese restaurant (3$^{rd}$ quartile) was lower than that of children in the 2$^{nd}$ quartile of proximity to Chinese restaurants, and was significantly lower than the BMI of children in the 1$^{st}$ quartile. Children in the 4$^{th}$ quartile to Chinese restaurants, however, showed a different pattern.

In the fully adjusted model (model 2), boys in the 2$^{nd}$ quartile of proximity to grocery stores had significantly increased BMIs (1.6 kg/m$^2$, 95% CI: 0.07 to 3.24) than those in the 1$^{st}$ quartile. Girls in higher quartiles of the proximity to the nearest grocery store had lower BMI (-1.78 kg/m$^2$, 95% CI: -3.38 to -0.18, 2$^{nd}$ quartile; -1.62 kg/m$^2$, 95% CI: -3.22 to -0.01, 3$^{rd}$ quartile) compared to those in the 1$^{st}$ quartile. Boys who were in the 2$^{nd}$ Quartile of proximity to free markets had a significantly decreased BMI than boys in the 1$^{st}$ quartile (-2.10 kg/m$^2$, 95% CI: -3.44 to -0.77). The same association was also recorded among girls, but was not significant. Chinese restaurants seemed to have protective effects, with boys and girls in the 2$^{nd}$ quartile of the proximity to the nearest Chinese restaurant having lower BMI (-1.69 kg/m$^2$, 95% CI: -3.27 to -0.12; -1.76 kg/m$^2$, 95% CI: -3.26, -0.27, respectively) compared to those in the 1$^{st}$ quartile. For food stalls, girls who were in the 2$^{nd}$ quartile and 3$^{rd}$ quartile of proximity to food stalls had a significantly increased BMI (2.24 kg/m$^2$, 95% CI: 0.77 to 3.70, 2$^{nd}$ quartile; 1.75 kg/m$^2$,

**Table 1.** Characteristics of surveyed children in China, 2009 and 2011 China Health and Nutrition Survey

| Variables | Survey year | Men | Women |
|---|---|---|---|
| N | | 175 | 173 |
| Age (years) | 2009 | 10.9±2.8 | 10.9±2.8 |
| | 2011 | 12.8±2.8 | 12.8±2.8 |
| BMI (kg/m$^2$) | 2009 | 17.8±3.90 | 16.9±3.50 |
| | 2011 | 19.0±4.31 | 18.1±3.64 |
| Daily energy intake (kcal/day) | 2009 | 1896±591 | 1531±444 |
| | 2011 | 1960±738 | 1719±728 |
| Household income per capita in 2009 (yuan) | | 10807±13432 | 8465±8561 |

**Table 2.** Community characteristics of the surveyed children in China, the 2009 China Health and Nutrition Survey

| Variables | Men | Women |
|---|---|---|
| Sample size | 175 | 173 |
| Urbanicity index[†] | 68.3±19.9 | 69.1±19.2 |
| Grocery store density (number /km$^2$) | 30.8±50.3 | 25.9±41.9 |
| Free market density (number/km$^2$) | 1.85±2.25 | 2.00±2.48 |
| Chinese restaurant density (number/km$^2$) | 70.1±157 | 83.8±179 |
| Food stall density (number /km$^2$) | 72.3±151 | 85.1±189 |
| Distance to the nearest grocery store (km) | 0.83±1.16 | 0.83±1.09 |
| Distance to the nearest free market (km) | 0.75±1.09 | 0.71±0.79 |
| Distance to the nearest Chinese restaurant (km) | 0.68±0.90 | 0.69±0.88 |
| Distance to the nearest food stall (km) | 0.61±0.89 | 0.65±0.91 |

[†]Urbanicity index consisted of twelve components where each was assigned ten points and summed up to a maximum value of 120 points, and a higher index score indicates a higher degree of urbanization.

**Table 3.** Association between distance (quartiles) to the nearest food establishments and BMI among Chinese children in China Health and Nutrition Survey, by gender: regression coefficients (95% CI)[†]

| Proximities | | Men | | Women | |
|---|---|---|---|---|---|
| | | Model 1 | Model 2 | Model 1 | Model 2 |
| Intercept | | 19.5 (17.7, 21.3)[*] | 15.5 (8.99, 22.0)[*] | 18.0 (16.6, 19.3)[*] | 9.61 (3.61, 15.6)[*] |
| Grocery store | Q1 (ref) | | | | |
| | Q2 | 2.63 (1.14, 4.13) | 1.66 (0.07, 3.24)[*] | -1.23 (-3.13, 0.66) | -1.78 (-3.38, -0.18)[*] |
| | Q3 | 0.79 (-0.98, 2.56) | 0.51 (-1.16, 2.17) | -1.34 (-3.05, 0.37) | -1.62 (-3.22, -0.01)[*] |
| | Q4 | -0.72 (-2.55, 1.11) | 0.02 (-1.67, 1.70) | -0.25 (-1.96, 1.46) | -1.23 (-2.88, 0.43) |
| Free market | Q1 (ref) | | | | |
| | Q2 | -2.10 (-3.51, -0.69) | -2.10 (-3.44, -0.77)[*] | -1.39 (-3.30, 0.52) | -0.36 (-1.98, 1.27) |
| | Q3 | 0.80 (-0.91, 2.50) | 0.63 (-0.96, 2.22) | 0.06 (-1.48, 1.61) | 0.08 (-1.38, 1.55) |
| | Q4 | -0.71 (-2.97, 1.54) | -0.24 (-2.22, 1.73) | -3.02 (-5.13, -0.90)[*] | -1.57 (-4.03, 0.90) |
| Chinese restaurant | Q1 (ref) | | | | |
| | Q2 | -1.73 (-3.56, 0.10) | -1.2 (-2.98, 0.57) | -1.21 (-2.77, 0.34) | -1.09 (-2.48, 0.30) |
| | Q3 | -2.76 (-4.61, -0.91)[*] | -1.69 (-3.27, -0.12)[*] | -2.54 (-4.29, -0.8)[*] | -1.76 (-3.26, -0.27)[*] |
| | Q4 | -0.76 (-3.61, 2.09) | -1.97 (-4.00, 0.05) | 0.88 (-1.23, 2.99) | 1.70 (-0.90, 4.29) |
| Food stall | Q1 (ref) | | | | |
| | Q2 | 0.17 (-1.52, 1.85) | -0.73 (-2.18, 0.72) | 3.05 (1.33, 4.77)[*] | 2.24 (0.77, 3.70)[*] |
| | Q3 | 0.13 (-1.84, 2.10) | 0.08 (-1.60, 1.75) | 2.67 (1.05, 4.28)[*] | 1.75 (0.25, 3.25)[*] |
| | Q4 | 0.04 (-2.30, 2.38) | -0.15 (-2.07, 1.77) | 2.49 (0.84, 4.13)[*] | 1.19 (-0.37, 2.76) |

[†]Based on analysis of Generalized Estimating Equation (GEE) analysis.
Model 1: Unadjusted for those covariates included in model 2.
Model 2: Adjusted for age, daily energy intake, household income per capita, urbanicity index and density of food establishments.
Distance to food establishments was divided into quartiles: Q1 represents the minimum distance to food establishments as the reference group in models, while Q4 represents the maximum distance.
[*]Significant at $p<0.05$.

95% CI: 0.25 to 3.25, 3rd quartile) compared to the girls in the 1st quartile of proximity, while a similar association was not found in boys.

## DISCUSSION

We examined the influence of proximity to different food establishments on the BMI of a panel of Chinese children during a two-year period. Given that proximities may have nonlinear impacts on BMI, the proximities were categorized into quartiles. Both unadjusted and fully adjusted models were included in the regression analysis. Separate models were fitted for both genders as boys and girls may experience different susceptibilities and physiological adaptations in relation to food environment.[20] We adjusted for age, daily energy intake, household income, urbanicity index and density of each food establishment in the fully adjusted models. The regression results showed that the proximity to food establishments had a complex influence on children's BMI. Different food establishments had diverse influence on children, and boys and girls might react differently on the same food establishment.

The participants' BMI was negatively associated with the proximity to Chinese restaurants—children had a lower BMI when they lived farther from a Chinese restaurant. A previous study has shown an association between eating away from home and increased risk of obesity in Brazilian males.[21] Another group also reported that students who lived near fast food restaurants had higher BMI values than those who lived far from fast food restaurants.[22] Despite the different features between fast food restaurants and Chinese restaurants, foods in these two kinds of restaurants shared similar nutritional characteristics and may also pose similar health risks when compared with homemade meals. In addition, Chinese restaurants were commonly seen and visited by the surveyed population, and were the major source of eating away from home. The association found in this study is in line with the findings of previous studies; it supports the argument that eating away from home may be a promoting factor of childhood obesity.

Free markets, where a variety of fresh foods were sold, were not actually protecting this group of children from obesity. In contrast to findings from developed countries, boys who lived slightly far away from free markets had a significantly decreased BMI compared with the boys in the reference group. In developed countries, poor access to fresh food is an important risk factor of overweight and obesity because of the replacement with less-healthy processed food. On the other hand, in developing countries or regions, limited access to free market may increase the consumption of family-grown vegetables in rural residents, which may contribute to decreased BMI. In addition, although free markets mainly served fresh food, there were an increasing number of snacks and packed foods available in free markets, especially in rural China. Living close to a free market might have promoted consumption of unhealthy snacks including fried foods and sugar-sweetened beverages. The associations may follow the same mechanisms as convenient stores, which promote childhood overweight and obesity in developed countries, such as the United States.[15] However, given that there were less free markets available compared to other food establishments (see table 2) in terms of density, free market may play a less influential role in promoting healthy eating behaviours.

It is notable that opposite associations were found in boys and girls when assessing the relationship between proximity to grocery stores and BMI. Boys living closer to the grocery stores had lower BMI although there was no evident gradient effect as the distance increased. On the other hand, girls who lived farther from grocery stores had lower BMI. Previously reported evidence suggests that boys and girls significantly differ in eating habits and activity behaviors,[20,23-25] which may support our finding. Considering the rapid development of food market in both urban and rural China, gender-related food choices that lead to differential shopping behaviours in grocery stores may also be one of the explanations for the opposite associations. However, no previous studies reported similar associations. Therefore, further research with a larger sample size is needed to explore the behavioural and biological modifiers and confounders of the relationship between proximity to grocery stores and weight status among boys and girls.

Girls who lived farther from food stalls had higher BMI than those who lived closer. Food stalls often sold staple foods, such as pancakes and noodles, which mainly serve as breakfast in China. For children who were not able to eat at home, food stalls were the primary providers of breakfast. Previous research has demonstrated an association between skipping breakfast and the increased risks of obesity.[26] Living closer to food stalls may reduce the possibility of skipping breakfast. We did not find significant association between proximity to food stalls and BMI in boys. Boys reported lower rates of skipping breakfast than girls, making them less influenced by food stalls.[25]

Conclusively, our findings identified and explained some of the relationships between proximity to food establishments and weight status of Chinese children. We found higher BMI was inversely related with proximity to a Chinese restaurant, and positively with proximity to a free market. Gender differences were also found as when the effects of proximities to grocery store and food stall. However, the association between the food environment and BMI still appears inconsistent between studies. Current results also raised questions about the commonly held perception that easy access to grocery stores and free markets are protective factors of obesity.

Relatively small sample size limited the generalizability of our results. Additionally, household income was only measured in 2009, creating another limitation to capture the income dynamics as an important confounder in our study question. Despite these limitations, our findings add evidence to the viewpoint that community food environment may affect children's food choice so as to change their weight status. This suggests that intervention policies for childhood obesity should target the food environment, not only at a school level, but also at the community level as well. Different mechanisms or potential modifiers and confounders may exist in our country than those that exist in developed countries. Therefore, we call for further research on a larger group

of Chinese children and their respective food environment.

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**AUTHOR DISCLOSURES**

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

This present research has been approved by the Institutional Review committees of the University of North Carolina at Chapel Hill, the National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention, and the University at Buffalo, State University of New York. All participants gave written informed consent for their participation in the survey.

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Original Article

# Influence of proximities to food establishments on body mass index among children in China

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# 到食肆的距离对中国儿童体质指数的影响

**背景与目的：**近二十年来，中国居民的食物环境发生了巨大变化，超重和肥胖率也显著上升。既往研究提示肥胖率上升与食物环境变化之间可能存在一定的关联，但此类研究多数在发达国家开展，很少在发展中国家开展。**方法与研究设计：**本文从队列研究"中国健康与营养调查"中选取了 348 名 6-17 岁的儿童青少年作为研究对象，利用 2009 年和 2011 年两轮调查的身体测量指标及其他相关社会经济学指标，结合地理信息系统（geographic information system, GIS）采集的儿童青少年所居住家庭至最近的食物购买地点或餐馆的直线距离数据（包括便利店、自由市场、中式餐馆、及流动食品摊），分析评价了食物环境变化对中国儿童青少年体质指数的影响。**结果：**两轮数据的纵向分析结果显示，与第一分位相比，居住在与最近的便利店距离为第二分位的男生 BMI 显著升高（平均升高 1.6 kg/m$^2$，95% CI：0.07, 3.24），而居住在更高分位的女孩 BMI 则显著降低（第二分位降低 1.78 kg/m$^2$，95% CI：-3.38, -0.18；第三分位降低 1.62 kg/m$^2$，95%：-3.22, -0.01）。与第一分位相比，居住在与最近中式餐馆距离为第二分位的男生女生 BMI 均显著降低（男生降低 1.69 kg/m$^2$，95% CI：-3.27, -0.12; 女生降低 1.76 kg/m$^2$，95% CI：-3.26, -0.27）。**结论：**食物环境可能影响中国儿童青少年的体质指数，但该作用的具体方向仍需进一步探究。

**关键词：孩子、体质指数、食品商店、肥胖、中国**