Public Health Nutrition: 23(3), 457–473 doi:10.1017/S1368980019002167

Review Article

Impact of neighbourhood food environment on diet and obesity in China: a systematic review

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Submitted 16 January 2019: Final revision received 17 April 2019: Accepted 9 May 2019: First published online 12 September 2019

Abstract

Objective: This study systematically reviewed literature on the neighbourhood food environment in relation to diet and obesity among residents in China.

Design: A keyword search of peer-reviewed articles was performed in Cochrane Library, PubMed, and Web of Science. Eligibility criteria include study designs: longitudinal/cohort studies or cross-sectional studies; study participants: people of all ages; exposures: neighbourhood food environment (e.g. restaurants, supermarkets, wet markets, fast-food restaurants, or convenience stores); outcomes: diet and/or body weight status; and country: China.

Results: Seventeen studies met all criteria and were included. Among the eight studies that assessed the neighbourhood food environment in relation to diet, six reported at least one statistically significant relationship in the expected direction, whereas the remaining two exclusively reported null effects. Among the eleven studies that assessed the neighbourhood food environment in relation to body weight or overweight/obesity, ten reported a significant association whereas the remaining one reported a null relationship. Variety, density, and proximity of food outlets were positively associated with local residents' dietary diversity, portion size, and daily caloric intake. Density and proximity of fast-food restaurants and convenience stores were positively associated with local residents' adiposity in some but not all studies. Evidence linking any specific food outlet type to diet/obesity remains lacking due to the small number of studies and heterogeneities in food environment measures, geographical locations, and population subgroups.

Conclusions: The neighbourhood food environment may influence diet and obesity among Chinese residents but the evidence remains preliminary. Future studies adopting an experimental study design and objective/validated environment and dietary measures are warranted.

Keywords
Diet
Body weight
Chinese
Food environment
Literature review

In the past three decades obesity has evolved from a minor issue that concerned only a few endocrinologists to a major challenge associated with morbidity and premature mortality worldwide[1–3]. Obesity is associated with an elevated risk of various chronic diseases, such as type-2 diabetes, hypertension, dyslipidemia, coronary heart disease, and certain types of cancer, and consumes substantial social resources[4–9]. The global obesity rate among men and women increased from 3·2 % and 6·4 % in 1975 to 10·8 % and 14·9 % in 2014, respectively[10]. It is projected that, by 2025, global obesity prevalence may reach 18 % in men and exceed 21 % in women, and severe obesity may exceed 6 % in men and 9 % in women[10].

The socio-ecological model emphasizes the role of social, economic, and built environment in individuals' obesogenic behaviours. In particular, the neighbourhood food environment has received increasing attention and been hypothesized to be linked with diet quality and

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obesity among local residents. A large body of literature has examined neighbourhood food environment in relation to diet and/or obesity. Roy *et al.*[11] reviewed the relationship between neighbourhood food environment and dietary behaviour among young adults in college and university settings. Nutrition labelling, healthy food provision and portion size were found to be associated with diet quality among students[11]. A review by Engler-Stringer *et al.*[12] found moderate evidence linking community food environment to diet among children and adolescents – the majority of included studies reported at least one positive association between neighbourhood food environment and diet, whereas the remaining four studies reported a null relationship. Holsten[6] reviewed community food environment and obesity in the USA and Australia in both children and adults, and found mixed results – five studies reported significant findings whereas the other two reported a null relationship. Gamba *et al.*[5] reviewed the influence of community food environment on obesity among Americans of all ages, and found 80 % of studies reported at least one significant result. Cobb *et al.*[10] reviewed the relationship of local food environment and obesity in the USA and Canada. Among the 71 studies included in the review, the estimated impact of local food environment on obesity was predominantly null[10]. Osei-Assibey *et al.*[13] reviewed the relationship between neighbourhood food environment and prevalence for overweight and obese children under eight years of age. Their results suggest that restricting food advertising, providing food items in smaller portions and offering alternatives to sugar-sweetened beverages (SSB) were associated with reduced childhood obesity. Williams *et al.*[14] reviewed the influence of food outlets near schools on food purchases, consumption and body weight among children. They found little evidence regarding the impact of the retail food environment surrounding schools on food purchases or consumption, but some evidence linking retail food environment to students' body weight[14].

In sum, despite the large body of literature that assessed the neighbourhood food environment in relation to diet and/or obesity, study findings have been rather mixed and inconclusive. Discrepancies across studies could be partially due to heterogeneous populations and geographical locations, and differences in research methodologies (e.g. cross-sectional *v.* longitudinal study design) and measurements (e.g. objective *v.* self-perceived neighbourhood food environment measures). The majority of studies on the neighbourhood food environment and diet/obesity exclusively focused on children and adults in developed countries (e.g. USA, Canada, UK, New Zealand, or Australia), whereas research on populations residing in the developing countries is relatively lacking. The types and conditions of the neighbourhood food environment between developed countries and developing countries are often remarkably different, and so are people's dietary patterns and habits. Findings learned from the developed world may not be directly transferable to the developing country setting, which calls for studies specific to the latter.

Since the market reforms in 1978, China has transitioned from a centrally-planned to a more market-oriented economy and has experienced rapid economic and social development[15]. In spite of that, China's market reforms are far from complete, and its per capita income remains that of a developing country and is less than a quarter of the average of OECD countries[15]. There are still an estimated 373 million Chinese below the 'upper middle income' international poverty line of $5·5 a day[15]. The rapid urbanization in China has produced multiple megacities and numerous mid- to large-size cities, with built environment areas exponentially increased. At the same time, partially attributable to the transition towards a high-energy Western diet and a sedentary lifestyle, the prevalence of obesity in China has increased substantially during this period. Based on data from the China Health and Nutrition Survey, the obesity rate in China increased from 2·9 % among men and 4·6 % among women in 1991 to 11·8 % among men and 11·0 % among women in 2011[16]. The rapid rise in obesity prevalence coincides with the increasing prevalence of type-2 diabetes, dyslipidemia, non-alcoholic fatty liver disease, and cardiovascular disease among the Chinese population[16]. The food environment and its evolution over time might profoundly impact Chinese people's diet and body weight. This study, to our knowledge, is the first that systematically reviews the existing literature regarding the impact of neighbourhood food environment on diet and adiposity in China. Findings from this review can be informative to policymakers and stakeholders in an effort to design and modify certain features of the neighbourhood food environment that promote healthy diet, increase diet diversity, and contribute to a healthy weight among the Chinese population. This review also identifies limitations and gaps in this field that warrant future research. Given the rapid urbanization, economic development, and nutrition transition in China, the review could serve as an important piece of scientific evidence to inform urban designs conducive to healthy eating.

Methods

Study selection criteria

Studies that met all of the following criteria were included in the review: (i) study designs: longitudinal studies, cohort studies, or cross-sectional studies; (ii) study participants: people of all ages; (iii) exposures: neighbourhood food environment (e.g. restaurants, supermarkets, wet markets, fast-food restaurants, or convenience stores); (iv) outcomes: diet and/or body weight status; (v) article type: peer-reviewed publications; (vi) search timeframe: from the inception of an electronic bibliographic database to 8 August 2018; (vii) country: China; and (viii) language: articles written in English.

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Table 1 Search algorithm

The search algorithm included all possible combinations of keywords from the two groups: (1) 'food environment', 'food environments', 'obesogenic environment', 'obesogenic environments', 'nutrition environment', 'nutrition environments', 'eating environment', 'eating environments', 'food-rich environment', 'food-rich environments', 'retailing environment', 'retailing environments', 'food availability', 'food access', 'access to food', 'availability of food', 'accessibility of food', 'grocery', 'groceries', 'greengrocer', 'greengrocers', 'supermarket', 'supermarkets', 'shopping center/centre', 'shopping centers/centres', 'shopping street', 'shopping streets', 'food shopping', 'restaurant', 'restaurants', 'food industry', 'food industries', 'food retail', 'food retails', 'food retailer', 'food retailers', 'food operator', 'food operators', 'catering enterprise', 'catering enterprises', 'retail food source', 'retail food sources', 'food outlet', 'food outlets', 'food basket', 'food baskets', 'vegetable basket', 'vegetable baskets', 'retail outlet', 'retail outlets', 'food vender', 'food venders', 'food bank', 'food banks', 'food pantry', 'food pantries', 'food establishment', 'food establishments', 'food desert', 'food deserts', 'food swamp', 'food swamps', 'food store', 'food stores', 'chain store', 'chain stores', 'food service place', 'food service places', 'food service provider', 'food service providers', 'food facility', 'food facilities', 'fast-food', 'fast-foods', 'fast-food', 'convenience store', 'convenience stores', 'corner store', 'corner stores', 'fruit store', 'fruit stores', 'food market', 'food markets', 'farmer's market', 'farmer's markets', 'free market', 'free markets', 'open-air market', 'open-air markets', 'wet market', 'wet markets', 'open market', 'open markets', 'open public market', 'open public markets', 'shopping mall', 'shopping malls', 'takeaway', 'carryout', 'take-out', 'cafeteria', 'cafeterias', 'cafe', 'cafes', 'café', 'cafés', 'coffee shop', 'coffee shops', 'coffee house', 'coffee houses', 'ice cream stand', 'ice cream stands', 'ice-cream stand', 'ice-cream stands', 'ice cream shop', 'ice cream shops', 'ice-cream shop', 'ice-cream shops', 'ice cream store', 'ice cream stores', 'ice-cream store', 'ice-cream stores', 'snack bar', 'snack bars', 'snack shop', 'snack shops', 'dessert shop', 'dessert shops', 'dessert house', 'dessert houses', 'vending machine', 'vending machines', 'canteen', 'canteens', 'market stall', 'market stalls', 'food stall', 'food stalls', 'street vendor', 'street vendors', 'burger joint', 'burger joints', 'pizzeria', 'pizzerias', 'sandwich shop', or 'sandwich shops'; and (2) 'China', or 'Chinese'.
The MeSH terms 'China' and 'Chinese' were included in the PubMed search. All keywords in PubMed were searched with the '[All fields]' tag, which are processed using Automatic Term Mapping. The search function TS = Topic was used in Web of Science, which launches a search for topic terms in the fields of title, abstract, keywords, and Keywords Plus.

Studies that met any of the following criteria were excluded from the review: (i) studies that incorporated no outcome pertaining to diet and body weight status; (ii) studies that evaluated a food environment beyond the neighbourhood or local level (e.g. city, country, or urban–rural comparison); (iii) studies without human participants; (iv) studies conducted in experimental rather than naturalistic settings; (v) articles not written in English; (vi) letters, editorials, study/review protocols, or review articles; or (vii) Chinese participants residing outside mainland China, Hong Kong, and Macao.

Search strategy

A keyword search was performed in three electronic bibliographic databases: the Cochrane Library, PubMed, and Web of Science. The search algorithm is documented in Table 1. Titles and abstracts of the articles identified through the keyword search were screened against the study selection criteria. Potentially relevant articles were retrieved for evaluation of the full text. Two co-authors of this review independently conducted title and abstract screening and identified potentially relevant articles. Inter-rater agreement was assessed using the Cohen's kappa ($\kappa = 0{\cdot}8$).

Data extraction and preparation

A standardized data extraction form was used to collect the following methodological and outcome variables from each included study: authors, publication year, country, study design, sample size, age range, proportion of female participants, sample characteristics, statistical model, attrition rate, geographical coverage, setting, type of food environment measure, detailed measure of food environment, type of diet measure, detailed measure of diet, type of body weight status measure, detailed measure of body weight status, estimated effects of food environment on diet or body weight status, and key findings on the relationship between food environment and diet or body weight status.

Data synthesis

A tabulation of extracted data by two co-authors of this review revealed that no two studies provided quantitative estimates for the impact of the neighbourhood food environment on diet and/or body weight status focusing on the same food environment, diet, and body weight measure. This precluded meta-analysis. Therefore, we summarize the common themes and findings of the included studies narratively.

Study quality assessment

We used the National Institutes of Health's Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies to assess the quality of each included study. This assessment tool rates each study based on fourteen criteria. For each criterion, a score of one was assigned if 'yes' was the response, whereas a score of zero was assigned otherwise. A study-specific global score ranging from zero to fourteen was calculated by summing up scores across all criteria. The study quality assessment helped measure the strength of scientific evidence but was not used to determine the inclusion of studies.

Results

Identification of studies

Figure 1 shows the study selection flow chart. We identified 8115 articles in total through the keyword and reference

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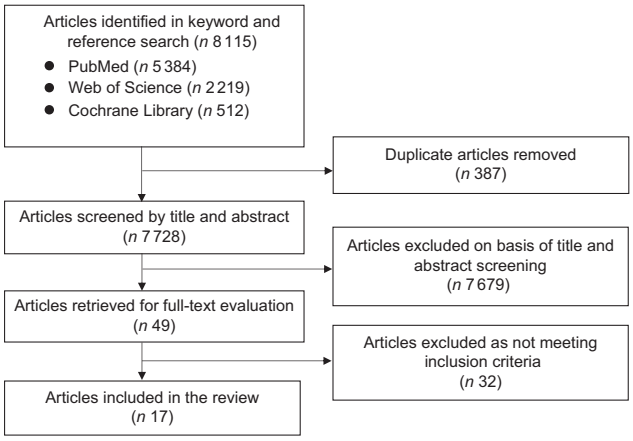

Fig. 1 Study selection flowchart

search. After removing duplications, 7728 unique articles underwent title and abstract screening, in which 7679 articles were excluded. The full texts of the remaining forty-nine articles were reviewed against the study selection criteria. Of these, thirty-two articles were excluded. The primary reasons for exclusion are lack of neighbourhood food environment measures, no outcome reported on diet and obesity, and participants' residence outside mainland China, Hong Kong and Macao. The remaining seventeen studies that examined the relationship between neighbourhood food environment and diet and/or body weight status were included in the review[17–33].

Basic characteristics of the included studies

Table 2 summarizes basic characteristics of the seventeen included studies. One study was conducted in Hong Kong, China, one study was conducted in two cities (i.e. Guangzhou and Hechi), one study was conducted in four cites (i.e. Beijing, Shanghai, Nanjing and Xi'an), one study was conducted nationally, five studies were conducted in a single city (i.e. Xi'an, Kunming, Wuhan or Nanjing), and the remaining eight studies were conducted in nine Chinese provinces. All included studies were published in or after 2010. Six studies exclusively focused on diet, nine studies exclusively focused on body weight status, and the remaining two studies examined both diet and body weight status. Nine studies adopted a longitudinal study design, and the remaining eight studies adopted a cross-sectional study design. Sample sizes were generally large but varied substantially across studies. One study had a sample size between twenty and ninety-nine, five had a sample size between 100 and 999, six had a sample size between 1000 and 9999, and the remaining five had a sample size above 10 000. The mean and median sample size were 8517 and 1804, respectively, with a standard deviation of 10 436 and a range from 12 to 28 063. The majority (*n* 9) of studies recruited adults aged 18 years and older, and the remaining eight recruited children and/or adolescents aged 6–18 years. Most included studies (*n* 13) recruited both males and females who were largely equally distributed in the samples, and the remaining four studies did not report the gender distribution in their samples. A variety of statistical models were applied across studies, including linear regression, logistic regression, multilevel latent class model, Bayesian hierarchical regression, generalized estimating equation, and Poisson regression. The majority of studies (*n* 12) adjusted for some individual sociodemographics (i.e. age, sex, perceived family affluence, highest parental education, and BMI z-score) in the statistical analyses.

Table 3 summarizes measures of food environment, diet, and body weight status among the included studies. The majority (*n* 12) of the studies adopted subjective food environment measures reported by school administrators, community leaders, local officials, parents, and/or participants themselves; whereas five studies adopted objective food environment measures. Specific subjective measures of food environment included both general questions (e.g. 'Whether a grocery store was available within a 5-min walking distance from home?' or 'How many supermarkets/wet markets/fast-food restaurants are there in your neighbourhood?') and more specific characteristics pertaining to the food environment (e.g. walking distance to a convenience store). Only two studies used subjective food environment measures known to be validated in previous research (i.e. perceived neighbourhood environment questionnaires). Objective food environment measures were constructed based on geographical information system (GIS) (e.g. proximity to a grocery store, free market, restaurant, or food stall), global positioning system (GPS) via smart phone (e.g. number of food establishments), Wuhan Geographic Information Center (e.g. point-of-interest data for supermarkets, fresh food markets, fast-food restaurants, convenience stores, and indoor restaurants), and Baidu Map (e.g. locations of wet markets and supermarkets, and density of neighbourhood food establishments).

Diet outcomes included food consumption (*n* 5), diet diversity (*n* 2), and nutrient intakes (*n* 1). Seven studies measured diet using questionnaires administered to parents and/or participants themselves, whereas one study used a smart phone to record a voice-annotated video. Parent- and/or self-reported diet questionnaires included both standardized questionnaires (e.g. a translated version of an eight-item instrument NEWS-A) and general questions (e.g. 'How many times per week did you drink sugary beverages/eat snacks/eat at a Western-style fast-food restaurant/eat at a street food stall in the last three months?'). Among the studies that adopted subjective diet measures, only one study used measures known to be validated in previous research (i.e. food frequency questionnaire). Body weight status included body mass index (BMI) (*n* 4), overweight (*n* 2), obesity (*n* 2), and waist-to-height ratio/waist-to-hip ratio (*n* 2). BMI-related measures were based on both objectively measured (*n* 9) and self-reported (*n* 1) height and weight.

Table 2 Basic characteristics of the studies included in the review

Study ID	First author (year)	Country	Study design	Sample size	Age (years)		Female (%)	Sample characteristics	Statistical model	Attrition rate (%)	Geographical coverage	Setting
					Mean or range	SD						
1	Ho (2010)[21]	Hong Kong China	Cross-sectional	24 796	Mean age 14·5		58·1	Students in secondary schools	Logistic regression	27·8	Food shop near home in a city	Urban
2	Li (2011)[25]	China	Cross-sectional	1804	11–17		49·8	Students in Junior high schools	Multivariate regression	0·7	Western fast food restaurants near school in a city	Urban
3	Zhang (2012)[33]	China	Cross-sectional	9788	Mean age 48·8		52·4	Adults	Multilevel latent class cluster model	12	Food retail environment in 218 communities in nine provinces	Urban
4	Wang (2012)[17]	China	Longitudinal	185	6–18			School-aged children	The difference-in-differences	17	Community built environment in nine provinces	Urban and rural
5	Xu (2013)[29]	China	Longitudinal	28 063	44–51		52·1	Adults	Bayesian hierarchical regressions	3·6	Characteristics of the communities in nine provinces	Urban and rural
6	Du (2014)[26]	China	Longitudinal	24 396	32–65		51·5	Adults	Random intercept-slope growth models		Rural communities in nine provinces	Rural
7	Hua (2014)[27] suburban	China	Longitudinal	575	13–18		56·5	High school students		5·2	Three neighbourhoods in a city	Urban and
8	Li (2014)[23]	China	Cross-sectional	497	8–10		48·3	Primary school-aged children	Multiple logistic regression analysis	2·2	Perceived neighbourhood environments in two cities	Urban
9	Seto (2016)[22]	China	Cohort study	12	18–31		66·7	University students				
10	Tian (2016)[20]	China	Longitudinal	12 842	18–65		52·2	Adults	Random effects multivariable regression	17·2	Nearby restaurants in neighbourhoods in nine provinces	Urban and rural
11	Zhang (2016)[32]	China	Longitudinal	348	6–17		49·7	Children	Generalized Estimating Equation		Food establishments in communities in nine provinces	Urban and rural
12	Jia (2017)[19]	China	Cross-sectional	1648	11·6	2·0	49·3	Primary and middle school students	Cluster robust regression models	11·6	School vicinity food stalls in four Mega-cities	Urban
13	Johar (2017)[31]	China	Longitudinal	4678	20 years and older			Adults			Western-style fast-food restaurant at community level in nine provinces	Community
14	Li (2017)[30]	China	Cross-sectional	9208	14·7	0·9	48·6	Ninth Graders in middle school	Multilevel models	16·7	Restaurants close to school from twenty-eight regions nationally	Urban and rural
15	Wang (2017)[18]	China	Longitudinal	24 542	Mean age 49·9		54	Adults	Multivariable regression and polynomial regression		Food facilities from nine provinces	Urban and rural
16	Zhou (2017)[28]	China	Cross-sectional	189	35–49			Middle-aged adults	Multivariate linear regression		In a city	
17	Zhong (2018)[24]	China	Cross-sectional	1210				Households	Poisson regression model		Residential communities in a city	Urban

Table 3 Measures of food environment, diet and body weight status in the studies included in the review

Study ID	First author (year)	Type of food environment measure	Detailed measure of food environment	Type of diet measure	Detailed measure of diet	Type of body weight status measure	Detailed measure of body weight status
1	Ho (2010)[21]	Self-report questionnaire	The perceived presence of McDonald's, KFC, Hong Kong-style fast-food shops, Chinese, Western and Hong Kong-style restaurants and 24-h convenience stores near home	Self-report questionnaire	Food consumption: 1. high-fat foods 2. junk food/soft drinks 3. fruit 4. vegetables	Self-report	1. Height 2. Weight 3. BMI *z*-score
2	Li (2011)[25]	School doctors report questionnaire	Western fast food restaurants near school within 10-min walk			Objectively measurement	1. Height 2. Body weight 3. BMI
3	Zhang (2012)[33]	Community heads and community accountants report questionnaire	1. The number of food retailing businesses 2. The penetration of supermarkets in each community			Objectively measurement	1. Height 2. Body weight 3. BMI
4	Wang (2012)[17]	Self-report questionnaire	Neighbourhood densities of: 1. wet markets 2. supermarkets 3. fast food restaurant	Self-report questionnaires	Nutrition intake: 1. total caloric intake 2. total protein intake 3. total fat intake 4. total carbohydrate intake		
5	Xu (2013)[29]	Local officials report questionnaire	The number of Western styles fast-food restaurants such as McDonald's and Kentucky Fried Chicken in the community or within 1 km if outside the community			Objectively measurement	1. Weight 2. Height 3. Waist and hip circumferences 4. Body mass index 5. Waist-to-height ratio 6. Waist-to-hip ratio
6	Du (2014)[26]	Community leader report questionnaire	1. Fast-food restaurants 2. Indoor restaurants 3. Fixed outdoor food stalls			Objectively measurement	1. Height 2. Weight 3. Body mass index
7	Hua (2014)[27]	Objective measure	The existence and density of the food establishments			Objectively measurement	1. Height 2. Weight 3. Body mass index
8	Li (2014)[23]	Parent report questionnaire	Walking distance to a convenience store	Parent-report questionnaire	Food consumption: 1. snacks 2. fruit 3. vegetables	Objectively measurement	1. Height 2. Weight 3. Body mass index
9	Seto (2016)[22]	Objective measure	The number of food establishments	Self-record by phone	Food consumption: 1. meal 2. snack		
10	Tian (2016)[20]	Community leader report questionnaire	1. Fast food restaurants 2. Indoor restaurants 3. Outdoor food stands	Self-report questionnaire	1. Food consumption: the types, amounts, types of meals (breakfast, lunch, dinner, snack), location 2. Eating away from home	Objectively measurement	1. Height 2. Weight 3. Body mass index

Table 3 *Continued*

Study ID	First author (year)	Type of food environment measure	Detailed measure of food environment	Type of diet measure	Detailed measure of diet	Type of body weight status measure	Detailed measure of body weight status
11	Zhang (2016)[32]	Objective measure: geographic information system	The proximities to four main kinds of food establishments: 1. Grocery store, 2. Free market 3. Restaurant 4. Food stall			Objectively measurement	1. Height 2. Weight 3. Body mass index
12	Jia (2017)[19]	School administrators report questionnaire	Food regulations in school vicinity food stalls	Self-report questionnaire	Food consumption: 1. sugary beverage 2. snack 3. fast food 3. street food consumption	Objective measurement	1. Weightv 2. Height 3. Body mass index 4. Waist circumference
13	Johar (2017)[31]	The community representative report questionnaire	The availability of Western fast-food restaurants			Objective measurement	1. Body mass index 2. Arm fat ratio 3. Waist-to-hip ratio
14	Li (2017)[30]	School administrators reported questionnaire	Restaurants close to school			Self-report	1. Body weight 2. Height 3. Body mass index
15	Wang (2017)[18]	Subjective measure	Access to food markets	Self-report questionnaire	Diet diversity: 1. food variety 2. food items 3. food group		
16	Zhou (2017)[28]	Objective measure	1. Supermarket 2. Fresh food market 3. Fast food restaurant 4. Convenience store 5. Full service restaurants			Objective measurement	1. Weight 2. Height
17	Zhong (2018)[24]	Objective measure	Proximity to wet markets and supermarkets	Self-report questionnaire	Diet diversity: 1. food items 2. food groups		

Key findings

Food environment in relation to diet

A wet market is a market that sells fresh meat and produce. Indoor restaurants refer to those that are operated indoors or inside an enclosed structure that has a roof and well-covered walls, and in which cooking and eating are performed indoors. Food stalls refer to those that are operated outdoors at a fixed place; it may have a roof, but no walls, and cooking and eating are performed outdoors. Table 4 summarizes the estimated effects of food environment on diet and/or body weight status among study participants in China. Among the eight studies that provided some quantitative estimates of the relationship between food environment measures and diet, six reported at least one statistically significant relationship in the expected direction, whereas the remaining two exclusively reported null effects. Among the statistically significant findings, the density of wet markets was found to be positively associated with all four measurements of nutrient intakes (i.e. total energy, protein, total fat, and carbohydrate intakes), and the impact was largest among children from low-income households[17]. The number of nearby food facilities (e.g. fast-food restaurants, indoor restaurants, food stalls, food carts, bakeries, fruit shops, and supermarkets) was found to be positively associated with dietary diversity among local residents[18]. Policies on school vicinity food stalls (SVFS) were found to be associated with less frequent intake of SSB, snacks, and fast-food at school, especially among boys[19]. In contrast, the number of indoor restaurants in a neighbourhood was found to be positively associated with the frequency of eating away from home[20]. Perceived availability of fast-food shops and convenience stores was positively associated with consumption of junk food/soft drinks and high-fat foods[21]. Greater access to food establishments (e.g. bakery, bar, cafeteria, convenience store, grocery or supermarket, liquor store, meal delivery, meal takeaway, and restaurant) was found to be associated with larger portion size[22]. Perceived availability of restaurants in a neighbourhood was associated with reduced vegetable and fruit intake[21]. Policies on SVFS were associated with higher frequency of street food consumption among students[19]. Among the statistically nonsignificant findings, perceived availability of convenience stores and fast-food shops was not found to be associated with vegetable and fruit intake[21]. Perceived availability of restaurants was not associated with consumption of junk food/soft drinks and high-fat foods[21]. Walking distance to a convenience store was not associated with children's consumption of unhealthy snacks or fruit/vegetables[23]. Distance to a wet market was not associated with urban households' diet diversity, and access to a supermarket had limited influence on households' dietary diversity[24]. Number of food stalls and fast-food restaurants was not associated with the frequency of eating away from home[20].

Food environment in relation to body weight

Among the eleven studies that estimated the relationship between food environment and body weight status, ten reported a statistically significant association, whereas the remaining one reported a null relationship. The availability of western fast-food outlets in a school area was positively associated with BMI[25]. The number of indoor restaurants was associated with increased BMI[26], but the effect tended to concentrate among men[20]. More developed inner-city neighbourhoods had a higher number of fast-food restaurants and convenience stores than surrounding neighbourhoods, and adolescents who lived in those inner-city neighbourhoods had a higher percentage of overweight[27]. Residents living in districts with a higher density of convenience stores were more likely to be obese[28]. Number of Western fast-food restaurants was associated with increased waist-to-height ratio and waist-to-hip ratio among rural residents[29]. On the other hand, the presence of restaurants close to a school was not associated with overweight or obesity among students[30]. The number of neighbourhood outdoor food stalls was associated with lower BMI among rural residents[26]. The number of fast-food restaurants was negatively associated with BMI among urban and rural women[26,29]. The density of fresh food markets was negatively associated with obesity among local residents[28]. Policies on SVFS were associated with lower risks of overweight, obesity and central obesity among boys[19].

Study quality assessment

Table 5 reports criterion-specific and global ratings from the study quality assessment. The included studies on average scored eight out of fourteen, with a range from six to eleven. All studies included in the review clearly stated the research question and objective, specified and defined the study population, had a participation rate above 50 %, recruited participants from the same or similar populations during the same time period, and prespecified and uniformly applied inclusion and exclusion criteria to all potential participants. Most studies measured and statistically adjusted key potential confounding variables for their impact on the relationship between exposures and outcomes (n 14), implemented valid and reliable outcome measures (n 12), and examined different levels of the exposure in relation to the outcome (n 10). In contrast, none of the studies had the outcome assessors blinded to the exposure status of the participants, provided a sample size justification using power analysis, or measured exposures of interest (e.g. food environment characteristics) prior to the outcomes. Eight studies had a reasonably long follow-up period that was sufficient for changes in outcomes to be observed, assessed the exposures more than once during the study period, and six studies implemented valid and reliable exposure measures.

Table 4 Estimated effects of food environment on diet or body weight status in the studies included in the review

Study ID	First author (year)	Estimated effects of food environment		Main findings of study	
		Diet	Body weight status	Diet	Body weight status
1	Ho (2010)[21]	1. Perceived availability of fast-food shops and convenience stores were positively associated with moderate/high consumptions of high-fat foods (ORfast = 1·10 and ORcon = 1·15) and junk food/soft drinks (ORfast = 1·10 and ORcon = 1·10). 2. Significant negative associations of the perceived availability of restaurants with intakes of vegetables and fruit were observed (ORveg = 0·87 and ORfruit = 0·83). 3. The positive relationship between reporting fast-food shops with intake of junk food/soft drinks were observed only in boys and those with low perceived family affluence. 4. The negative association of reporting restaurants with fruit consumption was found in those with low and middle perceived family affluence only.		1. The perceived availability of restaurants was not significantly associated with consuming high-fat foods and junk food/soft drinks. 2. No significant association between the perceived availability of convenience stores and fast-food shops with fruit and vegetable intakes was observed. 3. Perceived availability of neighbourhood fast-food shops, restaurants, and convenience stores may have a negative impact on adolescent dietary intakes particularly for those from poorer families.	
2	Li (2011)[25]		BMI was positively associated with the availability of western fast food outlets in school area (Coefficient 0·7, 95 % CI: 0·1, 1·2).		BMI was positively associated with the availability of western fast food outlets in school area.
3	Zhang (2012)[33]		1. The non-availability of fast food and snack food was the main reason for their 'Don't eat' behaviour. 2. Members in Cluster 2, 'Don't like', tended to be middle-aged men, they seemed to dislike everything despite living in the saturated food business community. 3. Members in Cluster 3, 'Neutral', were typically middle-aged women, although they lived in the 'Saturated food retail environment', they managed to obtain a relatively lower overweight and obesity rate. 4. Consumers in Cluster 4, 'Like all', they represent the youngest urban women, they lived in the 'Saturated food retail environment', had the lowest overweight and obesity rates.		1. The higher overweight and obesity rates from the 'Don't eat' segment was not related to fast food or snack food preferences since members in this segment did not have access to these products given the retail environment in which they resided. The main reasons for their heavy bodies may be explained by their dietary knowledge, which encourages them to eat more and become heavier. 2. Consumers in Cluster 2 may perceive Western fast food as luxurious and expensive and thus 'Dislike' it because of its unaffordability. Alternatively, they purchase other local food products to satisfy their appetite since they live in a saturated food retail environment, where consumers have abundant access to both supermarkets and other food stores.

Table 4 *Continued*

Study ID	First author (year)	Estimated effects of food environment		Main findings of study	
		Diet	Body weight status	Diet	Body weight status
					3. The lower BMI in Cluster 3 ('Neutral') and Cluster 4 ('Like all') may be explained by their relatively higher social status as well as their proper dietary knowledge toward less sugar/fat and more physical exercise.
4	Wang (2012)[17]	1. One additional wet market within five square kilometres is associated with an increase of 31·41 kcal in daily caloric intake ($P < 0·01$), 3·38 g of carbohydrate in daily carbohydrate intake ($P < 0·1$), 1·339 g of protein in daily protein intake ($P < 0·01$), and 1·412 g of fat in daily fat intake ($P < 0·01$). 2. Every 1000 Yuan increase in household income per capita reduces the neighbourhood wet market ' s effect on caloric intake (by 2·74 kcal per day, $P < 0·1$) and on fat intake (by 0·15 g of fat per day, $P < 0.05$),		1. The density of wet markets is positively associated with all four different measurements of nutrition intake. 2. Accessibility to wet markets has larger positive caloric/fat intake effect on children from households of lower income.	
5	Xu (2013)[29]		1. Each new fast-food restaurant opened was associated with a 0·36 future increase in WHtR in urban men. 2. Each additional existing fast-food restaurant was associated with a 0·18 future decrease in BMI in urban women and a 0·55 future increase in WHtR in rural men. 3. A fast-food restaurant opening in the past was associated with a future increase of 0·39 and 0·32 in WHtR and 0·46 and 0·38 increases in WHpR for rural women and men, respectively. 4. It was also associated with a 0·53 future decrease in WHpR in urban women. Moreover, each additional fast-food restaurant in the previous wave was associated with a 0·57 increase in WHtR and a 0·76 increase in WHpR in urban women.		1. Number of Western fast-food restaurants is positively associated with subsequent increases in WHtR and WHpR among rural population. 2. More fast-food restaurants are positively associated with a future increase in WHpR for urban women. 3. Increased availability of fast food between two waves is related to increased WHtR for urban men over the same period. 4. A past increase in number of fast-food restaurants is associated with subsequent increases in WHtR and WHpR for rural population.

Table 4 *Continued*

Study ID	First author (year)	Estimated effects of food environment		Main findings of study	
		Diet	Body weight status	Diet	Body weight status
6	Du (2014)[26]		Among rural men an increase of one indoor restaurant in the neighbourhood was associated with a 0·01 kg/m^{2}increase in BMI, and an increase of one fixed outdoor food stall was associated with a 0·01 kg/m^2 decrease in BMI, whereas among women, an increase of one indoor restaurant in the neighbourhood was associated with a 0·005 kg/m^2 increase in BMI, and an increase of one fast-food restaurant and one fixed outdoor food stall was associated with a 0·02 and 0·004 kg/m^2 decline in BMI, respectively.		The density of neighbourhood restaurants were found to be significantly related to BMI in rural China.
7	Hua (2014)[27]		The mean BMIs of those who lived at three locations were 21·7, 21·4 and 21·3 kg/m^2 (SD 3·58, 3·97, and 3·83) for males, and 21·6, 20·5 and 20·8 kg/m^2 (SD 3·11, 2·78, and 3·55) for females, respectively. Also consistent with the distribution of western-style fast food restaurants and convenience stores in three neighbourhoods, with the neighbourhood within the first ring having the highest count of western-style fast food restaurants and convenience stores.		More developed inner city neighbourhoods had a higher number of fast food restaurants and convenience stores than surrounding neighbourhoods. Adolescents who lived in the more developed inner neighbourhoods also had a higher percentage of overweight.
8	Li (2014)[23]	Associations between walking distance to a convenience store and consumption frequencies for unhealthy snacks and fruit/vegetables: (1–5 min as reference group) 1. Over 10 min: (coefficient: 0·08 CI 95 %: 2·34 (−0·19, 4·86), $P = 0·07$) 2. 6–10 min: (Coefficient: 0·06 CI 95 %: 0·80 (−0·36, 1·97) $P = 0·18$)		No evidence was found of a significant relationship between walking distance to a convenience store and children's consumption of unhealthy snacks or fruit and vegetables.	

Table 4 *Continued*

Study ID	First author (year)	Estimated effects of food environment		Main findings of study	
		Diet	Body weight status	Diet	Body weight status
9	Seto (2016)[22]	1. Food environment variable (coefficient 0·32, 95 % CI [0·16, 0·49]), indicating a 32 % increase in portion sizes per food establishment encountered within 0·25 km of one's Staypoints. 2. All types of food tended to perform relatively well in predicting portion sizes. Only the keywords 'café' ($R^2 = 0·31$), 'meal take-away' ($R^2 = 0·31$), and 'restaurant' ($R^2 = 0·31$), performed slightly better. 3. The effect sizes for café and meal takeaway establishments on portion sizes were also large (coefficients of 6·2 and 14·7, respectively).		Greater access to food establishments was associated with consumption of larger food portions.	
10	Tian (2016)[20]	People living in neighbourhoods with large numbers of indoor restaurants are more likely to eat away from home ($P < 0·05$).	Higher frequency of eating away from home is positively associated with BMI, but this effect is only significant for men ($P < 0·05$). Moreover, while eating dinner or breakfast away from home contributes to BMI increase for men ($P < 0·05$), no such association is found for lunch.	The frequency of eating away from home is positively associated with the number of indoor restaurants, but not significantly associated with the numbers of outdoor food stands and fast food restaurants.	Eating dinner and breakfast away from home is positively associated with BMI for Chinese men.
11	Zhang (2016)[32]		Boys in the second quartile of the proximity to the nearest grocery store had higher BMI (by 1·6 kg/m^2, 95 % CI, 0·07, 3·24) as compared with those in the first quartile, while girls in higher quartiles had lower BMI (−1·78 kg/m^2, 95 % CI: −3·38, −0·18, 2nd quartile; −1·62 kg/m^2, 95 %: −3·22, 0·01, third quartile) as compared with those in the first quartile. Boys and girls in the second quartile of the proximity to the nearest Chinese restaurant had lower BMI (−1·69 kg/m^2, 95 % CI: −3·27, −0·12; −1·76 kg/m^2, 95 % CI: −3·26, −0·27, respectively) as compared with those in the first quartile.		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.

Table 4 *Continued*

Study ID	First author (year)	Estimated effects of food environment		Main findings of study	
		Diet	Body weight status	Diet	Body weight status
12	Jia (2017)[19]	1. Policies on SVFS were associated with less frequent intake of sugary beverage (OR = 0·70[0·61, 0·80]), snack (OR = 0·78[0·67, 0·92]), and fast food (OR = 0·56[0·39, 0·80]). The associations were stronger for boys. 2. Policies on SVFS were associated with higher frequency of street food consumption (IRR = 1·61, 95 % CI = [1·26, 2·07]).	Policies on SVFS were associated with lower likelihood for overweight/obesity (OR = 0·51[0·35, 0·73]); and central obesity (OR = 0·63[0·48, 0·84]) in boys.	1. Policies on SVFS were associated with less frequent intakes of sugary beverage, snack, and fast food among students, especially for boys. 2. Policies on SVFS were associated with higher frequency of street food consumption	Policies on SVFS were associated with lower risks of overweight/obesity and central obesity, especially for boys.
13	Johar (2017)[31]		The emergence of a Western fast-food restaurant accelerates WHR growth by 0·014, or 67 % relative to the mean WHR growth in treated communities.		1. In the short term, which is 3–5 years after a Western fast food opened, generally, BMI and WHR increase while AFI shrinks. 2. Mid-term effect of Western fast foods, about 5–7 years after the opening of the first Western fast-food outlet in the community has a significant impact on WHR. 3. No strong support that these foods are the driving force behind the obesity epidemic.
14	Li (2017)[30]		The presence of restaurants close to school was associated with lower BMI (Beta: −0·27, SE: 0·14), although the magnitude of these associations was quite small.		1. In urban areas, none of the school factors were significantly associated with overweight/obesity, for either boys or girls. 2. The presence of restaurants close to school was associated with lower BMI, although the magnitude of these associations was quite small.
15	Wang (2017)[18]	Dietary diversity was positively associated with food accessibility ($P < 0·01$)		Dietary diversity is positively associated with the number of nearby food facilities, and that increasing food diversity might be attributable to higher food accessibility	
16	Zhou (2017)[28]		Density of fast food restaurant and density of convenience store determinants are identified for men BMI. (Standardized coefficients: 0·713, 0·409, $P < 0·001$)		1. The total obesity incidence is negatively correlated with density of fresh food market. 2. Food environment has significant effects on obesity prevalence among the middle-aged adults. 3. Women obesity associates with healthy food environment, while men obesity correlates with unhealthy food environment. 4. Food environment is the most important determinant of men obesity. 5. Residents are prone to become obese who live in districts with higher density of convenience stores.

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Table 4 *Continued*

Study ID	First author (year)	Estimated effects of food environment		Main findings of study	
		Diet	Body weight status	Diet	Body weight status
17	Zhong (2018)[24]	For a unit increase of 100 m in the variable DTSM (distance to the nearest supermarket), the expected value of a household's HDDS decreases by a factor of 0·9994 or 0·1 %, which is a very small magnitude of change. Even for an increase of 10 units (1000 m) in the variable DTSM, the expected value of a household's HDDS decreases by a factor of only 0·9934, or less than 1 %.		1. Distance to wet markets is not a predictor or determinant of urban household dietary diversity. 2. Physical access to supermarkets has a limited influence on household dietary diversity. 3. The difference in the distance to wet markets or supermarkets makes no difference to urban household dietary diversity.	

Discussion

Findings from this review coincide with some of the documented relationships between neighbourhood food environment and diet in developed countries. For example, McInerney *et al.* found density of food outlets (e.g. fast-food restaurants, cafeterias, carry-out restaurants, full-service restaurants, supermarkets, grocery stores, convenience stores, multiproduct stores selling groceries, and single product specialty stores) to be positively associated with dietary diversity, nutrient adequacy, and diet quality among Canadian adults[34].Skidmore *et al.* reported proximity to convenience stores to be positively associated with high-calorie food intake[35]. Longacre *et al.* documented the number of fast-food outlets in a neighbourhood to be positively associated with fast-food consumption among urban adolescents and adults in the USA.[36]

The density and proximity of fast-food restaurants and convenience stores were found to be positively associated with local Chinese people's body weight status in some but not all studies included in the review. These inconsistencies in findings are also present among US-based studies. Cobb *et al.* found fast-food restaurant availability to be positively associated with obesity in the USA.[10] In contrast, Mejia *et al.* reported a null relationship between proximity to fast-food outlets and BMI among American adults[37]. In addition, Shier *et al.* reported a null relationship between the availability of fast-food restaurants and convenience stores and BMI percentile among children in the USA.[38]

Policies on SVFS were found to be associated with reduced intake frequency of SSB, snacks, and fast-food, as well as reduced risks of overweight, obesity and central obesity among schoolchildren[19]. This finding is consistent with two other reviews based on developed countries. Policies regulating the food environment in and/or surrounding schools hold the potential to promote healthy dietary behaviour[39], reduce junk food and SSB intake, and prevent childhood overweight/obesity among schoolchildren[13].

The neighbourhood food environment has received increasing attention from researchers, policy makers, and various stakeholders[40–42]. The existing literature predominantly investigated neighbourhood food environment in relation to diet and obesity in developed countries[35,37,43,44], whereas its potential influence among the Chinese population has been under-studied. This study serves as the first known attempt to systematically review and synthesize the relevant literature pertaining to the impact of the neighbourhood food environment on diet and adiposity in China. The strengths of the included studies include relatively large sample size and wide geographic coverage. However, several limitations remain. All studies are observational (i.e. either cross-sectional or longitudinal) that involve no controlled experiment, and thus are subject to confounding bias and should be interpreted with caution. Most of the studies used subjectively rather than objectively measured food environment and

Table 5 Study quality assessment

Study ID Criterion	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Was the research question or objective in this paper clearly stated?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2. Was the study population clearly specified and defined?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
3. Was the participation rate of eligible persons at least 50 %?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
4. Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study pre-specified and applied uniformly to all participants?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
5. Was a sample size justification, power description, or variance and effect estimates provided?	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
6. For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
7. Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?	N	N	N	Y	Y	Y	Y	N	N	Y	Y	N	Y	N	Y	N	N
8. For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g. categories of exposure, or exposure measured as continuous variable)?	N	Y	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	N	Y
9. Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Y	N	N	N	N	N	Y	Y	Y	N	Y	N	N	N	N	Y	Y
10. Was the exposure(s) assessed more than once over time?	N	N	N	Y	Y	Y	Y	N	N	Y	Y	N	Y	N	Y	N	N
11. Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	Y	N	N	Y	N
12. Were the outcome assessors blinded to the exposure status of participants?	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
13. Was loss to follow-up after baseline 20 % or less?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
14. Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N
Total score	8	8	6	8	10	10	11	9	8	10	11	7	9	6	9	7	7

Notes: This study quality assessment tool was adopted from the National Institutes of Health's Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies. For each criterion, a score of one was assigned if 'Y' was the response, whereas a score of zero was assigned otherwise. A study-specific global score, ranging from zero to fourteen, was calculated by summing up scores across all fourteen criteria. Study quality assessment helped measure strength of scientific evidence, but was not used to determine the inclusion of studies.

diet, which is prone to recall error and social desirability bias[17–21,23] No two studies included in the review reported quantitative estimates focusing on the same neighbourhood food environment, diet, and body weight measure, which precluded meta-analysis. Although the sample sizes of several included studies were large, they were not nationally or locally representative and the neighbourhoods covered within a study could be relatively homogeneous. The literature search was based on English only, and excluded Chinese and other languages (we identified four peer-reviewed publications in Chinese). This decision was made in part due to concern about the potential discrepancies in study quality and heterogeneities in food environment measures and study designs between English- and Chinese-based literature. This review only included published literature. There might be useful and relevant unpublished studies that were missed by this review. Future work could explore grey literature to see whether it could build on the findings from this review. Many questions remain unanswered, such as: whether and to what extent does the rapid urbanization in China impact the formation of diverse food retail markets that subsequently shape dietary habits among residents? Does the relationship between neighbourhood food environment and diet or obesity differ by city size (e.g. megacities *v.* provincial cities)? How do the food retail markets in China differ from those in other countries and what are the implications pertaining to their relationship with food purchase and consumption? Answers to these questions call for future research.

The findings of this review may shed light on China's urban design and zoning regulations. Convenient access to healthy food options such as fruit and vegetables through small- to mid-size grocery stores and large supermarkets may facilitate local residents adopting and maintaining a healthier diet. Urban design should pay attention to neighbourhood walkability and public transportation infrastructure so that people can easily reach grocery stores and supermarkets on a daily basis. Zoning regulations may restrict concentrations of fast food outlets and convenience stores surrounding schools and other places where children frequently gather to discourage fast food and sugar-sweetened beverage consumption. Besides accessibility, affordability also plays an essential role in determining purchase and

consumption. Therefore, in addition to modifying physical access to food stores, economic incentives such as junk food and soda tax and a healthy food subsidy could also be employed to jointly nudge people toward a healthier diet.

In conclusion, this study systematically reviewed literature pertaining to the impact of the neighbourhood food environment on diet and obesity in China. Seventeen studies met the selection criteria and were included in the review. Variety, density, and proximity of food outlets were found to be positively associated with local residents' dietary diversity, portion size, and daily energy intake. The density and proximity of fast-food restaurants and convenience stores were positively associated with local residents' body weight status in some but not all studies. Evidence linking a specific food outlet type to diet and obesity remains inconclusive owing to the small overall number of studies and heterogeneities in food environment measures, geographical locations, and populations under study. Two major limitations of this work pertain to the small number of studies identified and included in the review, which compromised the scope and generalizability of study findings, and a literature search based on English language only, which excluded articles written and published in Chinese and other languages. Future studies adopting an experimental study design and objective/validated environment and diet measures are warranted to advance research regarding the influence of the neighbourhood food environment on diet and adiposity in China.

Acknowledgements

Acknowledgments: None. *Financial support:* This research is partially funded by Guangzhou Sport University and National Natural Science Foundation of China (No. 81602869). *Conflict of interest:* The authors have no conflict of interests to declare. *Authorship:* R.A. is an Assistant Professor at Washington University in St. Louis. His research examines environmental influences and population-level interventions on weight-related behaviours and outcomes throughout the life course. R.A. designed the study, conducted the review, and wrote the manuscript. L.H. is an Assistant Professor at Beijing Normal University. Her research focuses on health behaviours among Chinese children and adolescents. L.H. contributed to literature review and manuscript drafting. J.S. is a PhD candidate at Beijing Sport University and a visiting scholar at University of Illinois at Urbana-Champaign. J.S. contributed to literature review and manuscript drafting. *Ethics of human subject participation:* NHANES was approved by the NCHS Research Ethics Review Board. This study is entirely based upon the de-identified public-use datasets from the NHANES, and thus is exempt from ethical approval.

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