



SUPPLEMENT ARTICLE

Access to fruit and vegetable markets and childhood obesity: A systematic review

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Funding information

Key Laboratory of Population Defects Intervention Technology of Henan Province, Grant/Award Number: ZD201905; State Key Laboratory of Urban and Regional Ecology, Grant/Award Number: SKLURE2018-2-5; The National Natural Science Foundation of China, Grant/Award Number: Grant No. 81703279

Summary

The lack of access to fruit/vegetable markets (FVMs) is thought to be a risk factor for childhood obesity by discouraging healthy dietary behaviours while encouraging access to venues that offer more unhealthy food (and thus the compensatory intake of those options). However, findings remain mixed, and there has not been a review of the association between FVM access and childhood obesity. A comprehensive and systematic understanding of this epidemiologic relationship is important to the design and implementation of relevant public health policies. In this study, a literature search was conducted in the Cochrane Library, PubMed, and Web of Science for articles published before 1 January 2019 that focused on the association between neighbourhood FVM access and weight-related behaviours and outcomes among children and adolescents. Eight cross-sectional studies, two longitudinal studies, and one ecological study conducted in five countries were identified. The median sample size was 2142 ± 1371 . Weight-related behaviours and outcomes were used as the outcome variable in two and eight studies, respectively, with one study using both weight-related behaviours and outcomes as outcome variables. We still found a negative association between access to FVMs in children's residential and school neighbourhoods and weight-related behaviours and an inconclusive association between FVM access and overweight or obesity. This conclusion should be regarded as provisional because of a limited amount of relevant evidence and may not be a strong guide for policymaking. Nonetheless, it points to an important research gap that needs to be filled if successful public health interventions are to be undertaken.

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KEYWORDS

access, child, food environment, fruit, obesity, vegetable

1 | INTRODUCTION

Obesity is a leading cause of morbidity and premature mortality, and the prevalence of overweight and obesity is increasing worldwide.¹ Their prevalence in childhood has also risen.^{2,3} From 1980 to 2013, the prevalence of overweight and obesity rose by 47.1% among children and adolescents worldwide.⁴ In particular, from 1975 to 2016, the global age-standardized mean body mass index (BMI) increased by 0.32 and 0.40 kg/m² per decade for girls and boys, respectively.⁵ Childhood obesity, if left unchecked, is associated throughout the life course with a greater risk and the earlier onset of chronic disorders, such as metabolic syndrome, cardiovascular disease, diabetes mellitus and its associated retinal and renal complications, nonalcoholic fatty liver disease, obstructive sleep apnea, polycystic ovarian syndrome, infertility, asthma, and orthopaedic complications.⁶ Also, childhood obesity results in adverse psychosocial consequences and lowers educational attainment.⁷⁻⁹ Since it is much more difficult to treat adulthood obesity, creating initiatives to prevent and mitigate childhood obesity is considered one of the major public health challenges of the 21st century.

The neighbourhood environment may interact with personal characteristics to affect individual weight status and, at times, even outweigh personal factors. Some studies have examined the influence of the neighbourhood food environment on health-related behaviours and weight gain, through the availability, accessibility, affordability, acceptability, and accommodation of food.¹⁰⁻¹³ Fruit and vegetable markets (FVMs) are among the most important venues providing healthy food, as fruit and vegetables have low energy density and high dietary fibre content. Increased consumption of fruit and vegetables has been associated with the increasing satiety effect, which may play a critical role in preventing overweight and obesity.^{14,15} Children and adolescents are more likely to be affected by their food environment and by marketing than adults,^{7,16} and hence, it is necessary to improve children's exposure to a healthy food environment to protect them from the risk of developing obesity.⁷ The World Health Organization (WHO) has also emphasized the need for initiatives to make fruit and vegetables more accessible in residential neighbourhoods.¹⁷

Some studies have suggested that greater availability and higher density of FVMs in the neighbourhood were associated with healthy eating habits and lower risk of overweight/obesity among children.^{10,18-21} However, other studies reported inconsistent results. For example, one study found that students living in neighbourhoods with higher densities of FVMs showed no association with the risk for obesity²²; a study conducted in the United States reported that the number of FVMs around children's homes was not associated with overweight/obesity.²³ Therefore, it is necessary to perform a systematic review to understand the role of FVM accessibility in childhood obesity. To the best of our knowledge, there has not been any study reviewing this association until this one.

This review contributes to the literature in the following respects: First, we expanded the concept of the access to FVMs to a full range of measurements (eg, number of FVMs, density of FVMs, and proximity to the nearest FVM) around multiple sites (eg, home, school, and workplace), for a comprehensive understanding of the influence of FVMs on children's weight-related outcomes. Second, we examined both body-weight status and weight-related behaviours (eg, diet, physical activity, and sedentary behaviours). We tested our hypothesis that better FVM accessibility may be associated with healthier eating behaviours and lower risk for overweight and obesity among children and adolescents.

2 | METHODS

A systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.²⁴

2.1 | Study selection criteria

Studies that met all the following criteria were included in the review: (a) They were peer-reviewed ecological, cross-sectional, or longitudinal studies (including prospective and retrospective cohort studies), rather than review or other types of nonoriginal research articles (eg, letters, editorials, and study/review protocols); (b) they examined the association between FVM accessibility and weight-related behaviours/outcomes among children and/or adolescents aged 18 years and below, rather than lacking the measures of either FVM accessibility or weight-related behaviours/outcomes or examining that association among adults aged above 18 years; (c) they were published in English and prior to 31 December 2018.

2.2 | Search strategy and data extraction

A keyword search was performed in three electronic bibliographic databases: Cochrane Library, PubMed, and Web of Science. The search strategy included all possible combinations of keywords from the three groups related to FVMs, children, and weight-related behaviours or outcomes. A full description of search strategies is provided in Appendix A.

Two reviewers (P.F. and R.T.) independently screened titles and abstracts of the articles identified through the keyword search against the study selection and excluded the irrelevant records. Interrater agreement was assessed by the Cohen kappa, which was 0.964, indicating a high agreement. Discrepancies were screened by a third reviewer (S.Y.), and the list of articles for the full-text review was jointly determined by three reviewers after discussion. Then, two reviewers (P.F. and R.T.) independently reviewed the full texts of all articles in the list and determined the final pool of articles included in the review. Interrater agreement was again assessed by the Cohen

kappa, which was 0.883. Discrepancies were resolved also by the third reviewer (S.Y.).

A standardized form of data extraction was used to collect key variables from each selected study whenever applicable, including (a) author(s) and year of publication, (b) study design, area, scale, and subject, (c) sample size, age, and characteristics, (d) statistical model used, (e) measures of FVM accessibility and weight-related behaviours and/or outcomes, and (f) the reported association between FVM accessibility and weight-related behaviours and/or outcomes. P.F. and R.T. independently extracted data from each included study, with discrepancies resolved by S.Y.

2.3 | 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.²⁵ This assessment tool rates each study based on 14 criteria (Table S1). For each criterion, a score of 1 was assigned if "yes" was the response, whereas a score of 0 was assigned otherwise (ie, an answer of "no," "not applicable," "not reported," or "cannot determine"). A study-specific global score ranging from 0 to 14 was calculated by summing up scores across all criteria. The study quality assessment was used to measure the strength of scientific evidence but not to determine the inclusion of studies.

3 | RESULTS

3.1 | Study selection

Figure 1 shows the study selection flowchart. We extracted 1732 articles through the keyword search. After excluding 522 repeated articles, we screened titles and abstracts and excluded 1045 articles. The full texts of the remaining 165 articles were reviewed against the study selection criteria, and 154 articles were further excluded. The remaining 11 studies that examined the relationship between

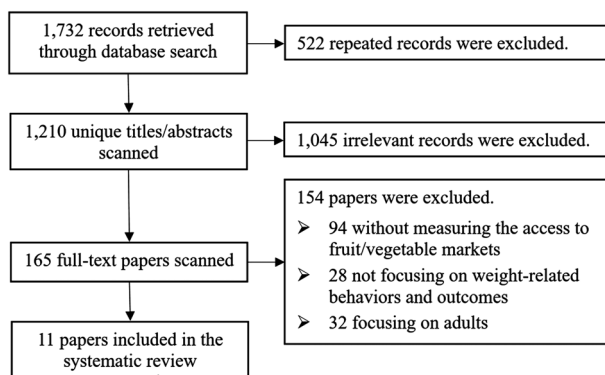


FIGURE 1 Study exclusion and inclusion flowchart

FVM access and children's weight-related behaviours and/or outcomes were included in this review.

3.2 | Study characteristics

Table 1 summarizes the basic characteristics of the 11 included studies, including eight cross-sectional studies, two longitudinal studies, and one ecological study. Most studies were conducted in the United States ($n = 6$), followed by Brazil ($n = 2$), Australia ($n = 1$), China ($n = 1$), and South Korea ($n = 1$). The sample size ranged from 120 to 12 954, with a mean of 2142 ± 1371 . The age of samples ranged from 4 to 19 years, with two studies not reporting the sample size and age. Seven studies focused on schoolchildren, two studies on urban children, one on both urban and rural children, and one on young girls alone. The statistical models used were composed of linear regression ($n = 5$), logistic regression ($n = 5$), and generalized estimating equation ($n = 2$).

Table 2 summarizes the measures of the access to FVMs and weight-related behaviours/outcomes in the included studies. The measures of FVM access included the number or density of FVMs ($n = 10$), the presence or availability of FVMs ($n = 3$), and the distance from home or school to the nearest FVM ($n = 3$). One study measured FVM access as the number of farmer's markets per county and per 10 000 persons.²³ One study measured the number of produce stands/farmer's markets within 0.4/0.8/1.6/8-km radii straight-line buffer around home.²⁸ Other studies created buffer zones with different radii and around either homes or schools: Two studies used a 0.4-km radius straight-line buffer around schools²² or homes,²⁸ and another two used a 0.4-km radius road-network buffer around schools³⁰ or homes¹⁰; three used a 0.8-km radius road-network³¹ or straight-line^{26,28} buffer around homes; two used a 1.0-km radius road-network²⁹ and straight-line³² buffer around homes; and two used a 1.6-km radius straight-line buffer around home,^{28,29} and another two used a 1.6-km radius road-network around home or school.^{10,21}

A variety of indicators were used to measure weight-related behaviours and outcomes. Two studies used fruit and vegetable consumption.^{29,31} Children's and adolescents' body-weight status was assessed by overweight or obesity in six studies,^{10,21-23,27,30} by BMI z score in three studies,^{10,26,30} by BMI in two studies,^{22,32} and by BMI percentile in one study.²⁸

3.3 | Associations between FVM access and weight-related behaviours/outcomes

Three studies reported an association between FVM access and weight-related behaviours.^{22,29,31} Two studies, conducted in South Korea²² and Australia,³¹ did not find a significant association with healthy eating habits, where FVM access was measured as the density of FVMs within a 0.5-km radius straight-line buffer around schools and the presence of FVMs within a 0.8-km road-network buffer around homes, respectively. Another study in Brazil showed that the presence of FVMs within a 0.5-km radius straight-line buffer around

TABLE 1 Basic characteristics of 11 included studies

First Author (y)	Study Area (scale) ^a	Sample Size	Sample Age (y, Range and/or Mean ± SD) ^b	Sample Characteristics (Follow-up Status for Longitudinal Studies)	Statistical Model
Longitudinal studies					
Leung (2011) ¹⁰	San Francisco Bay Area, USA (CT4)	353	6-7 (7.4 ± 0.4) in 2005	Girls (followed up from 2005 to 2008 with three repeated measures and an attrition rate of 20.5%)	General linear and logistic regression
Zhang (2016) ³²	China (N)	348	6-17 (10.9 ± 2.8) in 2009	Urban/rural children (followed up from 2009 to 2011)	Generalized Estimating Equation
Cross-sectional studies					
Bullock (2016) ²³	North Carolina, USA (S)	NA	NA	Preschool children	Linear regression
Burd (2013) ²⁶	New York, USA (C)	120	4-6 (5.2 ± 0.8) in 2005-2010	Urban children	Multilevel linear regression
Corrêa (2017) ²⁷	Florianópolis, Brazil (C)	2506	7-14 in 2010	Schoolchildren	Logistic regression
Jilcott (2011) ²⁸	Pitt County, USA (CT)	744	8-18 (12.9 ± 2.5) in 2007-2008	Schoolchildren	General linear regression
Nogueira (2018) ²⁹	São Paulo, Brazil (C)	521	12-19 (15.5 ± 2.29) in 2015	Urban children	Multilevel logistic regression
Park (2013) ²²	Seoul, South Korea (C)	939	12.1 ± 1.8 in 2011	Elementary and middle schoolchildren	Multilevel linear regression; generalized estimating equation
Tang (2014) ³⁰	New Jersey, USA (C4)	12 954	13.47 ± 3.46 in 2008-2009	Middle and high schoolchildren	Multivariate linear regression
Timperio (2008) ³¹	Victoria, Australia (C2)	801	5-6 and 10-12 in 2002-2003	Schoolchildren	Logistic regression
Ecological study					
Dwicaksono (2017) ²¹	New York, USA (S)	NA	NA	Schoolchildren	Multivariable logistic regression

Abbreviation: NA, not available.

^aStudy scale: [N] = National; [S] = State (eg, in the United States) or equivalent unit (eg, province in China, Canada); [Sn] = n states or equivalent units; [CT] = county or equivalent unit; [CTn] = n counties or equivalent units; [C] = City; [Cn] = n cities.

^bSample age: Age in baseline year for longitudinal studies or mean age in survey year for cross-sectional studies.

homes was associated with higher consumption of fruit and vegetables (OR = 1.73; 95% CI, 1.01-3.00).²⁹

Nine studies investigated the association between FVM access and weight-related outcomes. Three of these did not observe a significant association,^{10,23,27} where the weight-related outcome was described as overweight/obese (FVM access was measured as the presence of FVMs within a 0.4-km radius straight-line buffer around home),²⁷ county-level obesity rate (FVM access as the density of farmer's markets),²³ and change in the BMI z score and overweight/obese (FVM access as the presence of FVMs within 0.4-/1.6-km radii road-network buffer around homes).¹⁰ Three studies reported a negative association between the distance to the nearest FVM and BMI,³² between the density of FVMs within a 1.6-km road-network buffer around schools and obesity,²¹ and between the number of FVMs within a 0.8-km radius straight-line buffer around homes and BMI z scores.²⁶ One study reported that the presence of FVMs within a 0.4-km road-network buffer around homes was negatively associated

with BMI z scores but not with overweight/obese.³⁰ Another study revealed an inverse association between BMI percentiles and the coverage of FVMs within 0.4-/0.8-/1.6-km radii straight-line buffer around homes but not with the proximity to the nearest FVM and the number of FVMs within a 8-km road-network buffer around homes.²⁸ Only one study reported a positive association between the density of FVMs and BMI ($\beta = .19$; 95% CI, 0.04-0.34) and obesity (OR = 1.37; 95% CI, 1.12-1.54), while no association was reported between the density of FVMs within a 0.5-km radius straight-line buffer around schools and overweight/obese.²²

3.4 | Study quality assessment

Table S1 reports criterion-specific and global ratings from the study quality assessment. The eleven studies were scored 8.82 out of 11 on average, with a range from 5 to 12.

TABLE 2 Measures of access to fruit/vegetable markets, weight-related behaviours, and body-weight status in the included studies

First Author (year)	Measures of Access to Fruit/Vegetable Market	Other Environmental Factors Adjusted for in the Model	Measures of Weight-Related Behavior	Measures of Weight-Related Outcomes	Results of Weight-Related Behavior	Results of Weight-Related Outcomes
Longitudinal studies						
Leung (2011) ¹⁰	Number of FVMs (produce stands/farmers' markets) in 0.4/1.6-km home road-network buffer	Demographic features: baseline weight status, race/ethnicity, parent's/caregiver's highest education level, household income, county of residence	NA	Weight status (BMI for age) Normal (<85th percentile on the 2000 US CDC growth charts) Overweight (85th percentile- < 95th percentile on the 2000 US CDC growth charts); obese (\geq 95th percentile on the 2000 US CDC growth charts) BMI z scores	NA	Presence of FVMs within 0.4-km buffer was not associated with overweight/obesity (OR = 2.83; 95% CI, 0.62-12.85) and 3-y change in BMI z score (β = .10; 95% CI, -0.06 to 0.26) Availability of produce vendors/farmer's markets within a 1.6-km buffer was inversely associated with overweight/obesity (OR 0.22; 95% CI, 0.05-1.06), but not association with 3-y change in BMI z score (β = -.03; 95% CI, -0.10 to 0.15).
Zhang (2016) ³²	Density of FVMs (free markets) in 1.0-km home straight-line buffer Straight-line distance from home to the nearest FVM	SES features: household income per capita, and urbanicity index Density of food establishments	NA	BMI	NA	Distance to the nearest FVMs was negatively associated with the BMI for boys: Q1 (ref), Q2 (β = -2.10; 95% CI, -3.44 to -0.77), Q3 (β = 0.63; 95% CI, -0.96 to 2.22), and Q4 (β = -0.24; 95% CI, -2.22 to 1.73) Distance to the nearest FVMs was negatively associated with the BMI for girls: Q1 (ref), Q2 (β = -.36; 95% CI, -1.98, 1.27), Q3 (β = .08; 95% CI, -1.38 to 1.55), and Q4 (β = -1.57; 95% CI, -4.03 to 0.90)

(Continues)

TABLE 2 (Continued)

First Author (year)	Measures of Access to Fruit/ Vegetable Market	Other Environmental Factors Adjusted for in the Model	Measures of Weight- Related Behavior	Measures of Weight- Related Outcomes	Results of Weight-Related Behavior	Results of Weight- Related Outcomes
Cross-sectional studies						
Bullock (2016) ²³	Number of FVMs (farmers' markets) per county Number of farmers' markets per 10,000 persons in home country	Population density	NA	Children county-level obesity prevalence (obtained from the USDA Food Environment Atlas).	NA	No associations were found between obesity rate and the number of farmers' markets ($r = -0.00$, $P = .978$), obesity rate and farmers' markets per capita ($r = -0.04$, $P = .671$), obesity rate and farmers' markets accepting SNAP/EBT ($r = -0.05$, $P = .656$), and obesity rate and farmers' markets accepting SNAP/EBT per capita ($r = -0.06$, $P = .540$)
Burd (2013) ²⁶	Number of FVMs (farmers' markets) in 0.8-km home straight-line buffer	Family income, and population density	NA	BMI z-score (based on the 2000 US CDC growth charts)	NA	Food environment had association with child BMI z score [F (df) χ^2 4.6 (1,95); $P < .05$] Children in healthy food environments and unhealthy food environments had BMI z scores of 0.8 ± 1.2 and 1.3 ± 1.1 , respectively
Corréa (2017) ²⁷	Presence of FVMs (greengrocers/public markets) in 0.4-km home straight-line buffer	SES features: income in home census tract, type of school, mother's education level Presence/absence of restaurant, snack bars/FF outlets, street vendors, supermarkets, minimarkets, butchers, and bakeries	NA	Overweight/obesity (BMI $> z$ score + 1SD, equivalent to a BMI ≥ 25 kg/m ² at 19 y of age, based on the 2007 WHO growth reference)	NA	No association was found between presence of FVMs and overweight/obesity (OR = 0.92; 95% CI, 0.71-1.19) A child's family utilizing FVMs was positively associated with overweight/obesity (OR = 1.54; 95% CI, 1.06-2.24)
Jilcott (2011) ²⁸			NA		NA	

(Continues)

TABLE 2 (Continued)

First Author (year)	Measures of Access to Fruit/Vegetable Market	Other Environmental Factors Adjusted for in the Model	Measures of Weight-Related Behavior	Measures of Weight-Related Outcomes	Results of Weight-Related Behavior	Results of Weight-Related Outcomes
	Number of FVMs (produce stands/farmers' markets) in 0.4/0.8/1.6/8-km home straight-line buffer Straight-line distance from home to the nearest FVM	Rural/urban residence, race, and insurance status		BMI percentile (based on the 2000 US CDC growth charts)		No correlation was found between proximity to closest farmers' markets and BMI percentile ($r = 0.069$, $P = .059$) and between the number of farmers' markets and BMI percentile within 8-km buffer ($r = 0.018$, $P = .619$)
						Inverse associations were found between BMI percentile and coverage of farmers' markets/produce markets within 0.4-km ($r = -0.07$, $P = .0423$) and 0.8-km ($r = -0.11$, $P = .0036$) buffer, or within 0.8-km ($r = -0.08$, $P = .0308$) and 1.6-km buffers ($r = -0.10$, $P = .0086$)
Nogueira (2018) ²⁹	Density of FVMs (street markets) within a 0.5/1.0/1.5-km home straight-line buffer	Years of residence, health administrative areas, and HDI intramunicipal	Fruit and vegetable consumption. Adequacy of consumption of at least 400 g per day of FV FV consumption in grams, categorized as <75th percentile or >75th percentile	NA	The density of FVMs was positively associated with FV consumption (0.5-km buffer: street market density = 0 (ref); density = 1 (OR = 1.73; 95% CI, 1.01-3.00); density ≥ 2 (OR = 0.70; 95% CI, 0.35-1.42); 1-km buffer: density ≤ 1 (ref); street market density = 2-4 (OR = 1.33; 95% CI, 0.70-2.53)); street market density ≥ 5 (OR = 0.93; 95% CI, 0.41-2.12)); 1.5-km buffer: street density ≤ 2 (ref); street	NA

(Continues)

TABLE 2 (Continued)

First Author (year)	Measures of Access to Fruit/ Vegetable Market	Other Environmental Factors Adjusted for in the Model	Measures of Weight- Related Behavior	Measures of Weight- Related Outcomes	Results of Weight-Related Behavior	Results of Weight- Related Outcomes
Park (2013) ²²	Density of FVMs (supermarkets, traditional markets, FVMs) in 0.5-km school straight-line buffer	NA	NA	BMI based on measured weight and height, Ob and obese (≥ 85 th and ≥ 95 th percentile, respectively, based on the 2007 Korean National Growth Charts)	No association was found between high density of FVMs and healthy eating habits ($\beta = -0.06$, SE = 0.06).	Density of FVMs were positively associated with BMI ($\beta = .19$; 95% CI, 0.04-0.34), but no association with overweight/obese (OR = 1.05; 95% CI, 0.87-1.27), and obese (OR = 1.37; 95% CI, 1.12-1.54)
Tang (2014) ³⁰	Presence of FVMs (small grocery stores) in 0.4-km school road-network buffer Number of FVMs within a 0.4-km school road-network buffer	Number of convenience stores, limited-service restaurants, and supermarkets	NA	BMI z score (based on the 2000 US CDC growth charts) Overweight/obese (≥ 85 th percentile based on 2000 US CDC growth charts)	NA	Presence of FVMs was negatively associated with BMI Z-scores ($\beta = .12$; 95% CI, -0.24 to -0.01), but was not with overweight/obese ($\beta = -.02$; 95% CI, -0.06 to 0.02)
Timperio (2008) ³¹	Presence of FVMs (fruit, and vegetables grocers) in 0.8-km home road-network buffer Number of FVMs in 0.8-km home road-network buffer Straight-line distance from home to the nearest FVM	Maternal education Potential clustering by school	Frequency of FV consumption (collected by parents' answered) Fruit ≥ 2 times/d or vegetables ≥ 3 times/d	NA	No association was found between FV intake and presence or number of FVMs; no association was found between FV intake and straight-line distance from home to the nearest FVMs	Number of FVMs was associated with BMI z scores ($\beta = -.10$; 95% CI, -0.17 to -0.03) but was not with overweight/obese ($\beta = -.004$, 95% CI, -0.03 to 0.02)

Ecological study

(Continues)

TABLE 2 (Continued)

First Author (year)	Measures of Access to Fruit/Vegetable Market	Other Environmental Factors Adjusted for in the Model	Measures of Weight-Related Behavior	Measures of Weight-Related Outcomes	Results of Weight-Related Behavior	Results of Weight-Related Outcomes
Dwicaksono (2017) ²¹	Density of FVMs (farmers' market) in 1.6-km school road-network buffer	Poverty, racial and ethnic composition, urbanicity	NA	Obesity rate (≥ 95 th percentile)	NA	Density of FVMs was negatively associated with lower obesity rates ($\beta = -.116$, SE = 0.0027, $P < .01$)

Abbreviations: BMI, body mass index; CDC, Center for Disease Control and Prevention; CI, confidence interval; GIS, Geographic Information Systems; FV, fruit/vegetable; FVM, fruit/vegetable markets; OR, odd ratio; SES, socio-economic status; SNAP/EBT, Supplemental Nutrition Assistance Program/Electronic Benefit Transfer; WHO, World Health Organization; WHZ, weight-for-height z score; Straight-line buffer, a regular (eg, circular) zone with a certain radius around a given address/location or a street to represent a catchment or influential area of that address/location or street; road-network buffer, an irregular zone around a given address/location, where it covers the same distance (or takes the same time) to travel from any point on the boundary of the zone to that address/location along the shortest road network path.

4 | DISCUSSION

This is the first systematic review of the association between access to FVMs and the risk for childhood obesity. Some previous studies have reviewed the association between access to some commonly studied food outlets and childhood obesity, such as supermarkets,³³ convenience stores,³⁴ full-service restaurants,³⁵ and fast-food restaurants.³⁶ However, studies on the association between FVM access and childhood obesity have not yet been systematically reviewed. We found that, although some studies reported negative associations between FVM access and the consumption of fruit and vegetables,³⁷⁻⁴⁰ there was not a conclusive association between FVM access and overweight or obesity among children and adolescents, on the basis of the current literature.

Access to certain types of food stores has been widely considered to contribute to childhood obesity,^{41,42} as children do not always have significant control over their food choices during the transition to adolescence. However, there is no consensus regarding the access to food measure. Children and adolescents do not have unfettered access to private motorized travel, so a network buffer with a 0.8-km radius may better reflect a walkable distance for children,⁴³ and they are more likely to be exposed to or become aware of available FVMs on their way home or to school. Long-lasting exposure to healthy foods increases the visibility of those foods,⁴⁴ and as a result, children living in such environments may be more likely to accept and prefer healthy foods. However, results on the association between access to FVMs and childhood obesity are generally inconsistent. For example, six studies in the systematic review reported no association between FVM access and risk for overweight or obesity,^{10,22,23,27,30} five reported a negative association,^{21,26,28,30,32} and only one reported a positive association.²² Possible explanations include (a) access to fruit and vegetables is ubiquitous, and food shoppers are mobile, so measuring the density of FVMs and/or the distance to the nearest FVM in the neighbourhood may not reflect the actual accessibility of such healthy foods; and (b) other factors related to obesity in and food purchase choices by children may be not be considered in the analyses, such as cultural factors, mobility, and access to public transportation.

Although some studies reported a significant association between food environments and dietary behaviours and thus obesity, a critical pathway is purchasing behaviours. Children may eat meals at home and/or school, and they may not make the food purchase choices as often by themselves as do adults.^{45,46} Thus, the fresh fruit and vegetable environment around children's homes/schools may not affect their dietary behaviours and weight status. Instead, adolescents may be more likely to make food purchase choices. However, the data from all the included studies are insufficient to enable a good-quality meta-analysis for evaluating the association between FVM access and dietary behaviours and weight status. Another reason for not being able to conduct meta-analyses is a variety of definitions for dietary behaviours, even for weight-related outcomes.

The present study has several limitations. First, FVM was not examined as an independent factor in most included studies. Many studies evaluated the influence on weight-related behaviours and

outcomes of FVMs together with other types of food venues (eg, supermarkets) as one category. This may amplify or weaken the association detected, as supermarkets provide both fruit/vegetables and energy-dense and low-nutrient—ie, unhealthy—foods. To construct latent diet factors on the basis of intake categories of foods typically offered at each type of food outlets should be considered in future research.^{47,48} Second, FVM as a category was termed differently across studies, such as “greengrocer,” “farmers’ market,” “street market,” “free market,” and “healthy food outlets.” This has reduced the comparability among studies. This could happen because of low-quality reporting in studies or just different cultures or business registration systems (ie, points of interest) across countries/regions. Future studies should provide clearer definitions of FVM in their specific contexts, and this suggestion also applies to research on other types of food environments (eg, convenience stores). Third, FVM access was also defined differently across studies, for example, by using different buffer types (ie, straight-line and road-network) and/or radii and measuring the proximity to FVM from different destinations (eg, home and school). This further contributes to difficulties in comparing different studies, and a reporting guideline is needed to guide more multiscale studies or more comprehensive sensitivity tests in one study.^{49,50} Also, more spatial analysis methods should be used to examine FVM access, on the basis of the limited FVM data.^{51,52} Fourth, we only included studies written in English, and consequently, some relevant studies published in other languages may have been neglected. Lastly, more longitudinal studies that spatially and temporally match business registration data to diet, nutrition, and health survey data should be conducted to strengthen the causality of the association.⁵³

This study has important implications for future research and practice. First, given the differently termed FVMs and independently estimated FVM variables in most of the included studies, further studies should provide clearer and more standardized definitions of FVMs to more effectively evaluate the effect of FVMs on child obesity. Second, the food environment is one of the most important social determinants for child obesity and influences health and obesity disparities. Our study did not find a significant association between the accessibility of FVMs and weight-related outcomes in children and adolescents, which may be the result of the small number of relevant studies and low sample size. Therefore, further research should be carried out to understand the impact of the accessibility and availability of FVMs on childhood obesity.

5 | CONCLUSIONS

This systematic review revealed no relationship between the availability and accessibility of FVMs and weight-related behaviours and outcomes among children and adolescents. Nonetheless, the findings have important methodological implications for future research and practice. It can guide researchers in several relevant fields to collaborate on designing more spatial longitudinal studies in order to generate more high-quality research findings and, subsequently, evidence-based policies for building healthy and sustainable cities.

ACKNOWLEDGEMENTS

This study is supported by research grants from the National Natural Science Foundation of China (81703279), the State Key Laboratory of Urban and Regional Ecology of China (SKLURE2018-2-5), the National Health Commission Key Laboratory of Birth Defects Prevention, and the Key Laboratory of Population Defects Intervention Technology of Henan Province (ZD201905). Guo Cheng, Director of the Healthy Food Evaluation Research Center, thanks the research grant from the New Century Excellent Talents in University Program (NCET-12-0377) and Sichuan Outstanding Young Scholars Foundation (2014JQ0005). Peng Jia, Director of the International Initiative on Spatial Lifecourse Epidemiology (ISLE), thanks Lorentz Center, the Netherlands Organization for Scientific Research, the Royal Netherlands Academy of Arts and Sciences, the University of Twente, the Chinese Center for Disease Control and Prevention, the West China School of Public Health, and West China Fourth Hospital in Sichuan University for funding the ISLE and supporting ISLE's research activities.

CONFLICT OF INTEREST

We declare no conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

How to cite this article: Yang S, Zhang X, Feng P, et al. Access to fruit and vegetable markets and childhood obesity: A systematic review. *Obesity Reviews*. 2020;1-12. <https://doi.org/10.1111/obr.12980>