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SUPPLEMENT ARTICLE

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Fast-food restaurant, unhealthy eating, and childhood obesity: A systematic review and meta-analysis

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Summary

Excessive access to fast-food restaurants (FFRs) in the neighbourhood is thought to be a risk factor for childhood obesity by discouraging healthful dietary behaviours while encouraging the exposure to unhealthful food venues and hence the compensatory intake of unhealthy food option. A literature search was conducted in the PubMed, Web of Science, and Embase for articles published until 1 January 2019 that analysed the association between access to FFRs and weight-related behaviours and outcomes among children aged younger than 18. Sixteen cohort studies and 71 cross-sectional studies conducted in 14 countries were identified. While higher FFR access was not associated with weight-related behaviours (eg, dietary quality score and frequency of food consumption) in most studies, it was commonly associated with more fast-food consumption. Despite that, insignificant results were observed for all meta-analyses conducted by different measures of FFR access in the neighbourhood and weight-related outcomes, although 17 of 39 studies reported positive associations when using overweight/obesity as the outcome. This systematic review and meta-analysis revealed a rather mixed relationship between FFR access and weight-related behaviours/outcomes among children and adolescents.

KEYWORDS
dietary behaviour, fast food, food environment, obesity

Peng Jia and Miyang Luo have equal contribution.

1 | INTRODUCTION

Obesity is a major risk factor for global mortality, with an estimated 2.8 million people died of obesity-related causes each year.[1] Obesity can lead to a variety of health consequences, including heart disease, stroke, diabetes mellitus, hypertension, dyslipidaemia, breathing disorders, and certain types of cancer.[2] In 2016, the World Health Organization (WHO) reported that 39% of adults had obesity, whereas the obesity rate in 1975 was only around 3% in men and 6% in women.[1] However, a considerable proportion of adult obesity stem from childhood, which, therefore, is a critical period to prevent obesity.[3,4] Childhood obesity is one of the most serious global public health problems in the 21st century. The prevalence of overweight and obesity in children and adolescents has risen dramatically from 4% in 1975 to over 18% in 2016.[5] Childhood obesity can also lead to a range of health problems, including high blood pressure, high total cholesterol, and impaired glucose tolerance. Prevention of childhood obesity requires high priority in public health practices.

It is widely accepted that some environmental factors in the neighbourhood may interact with personal characteristics to affect individual weight status.[6,7] Fast-food restaurants (FFRs) are one of such environmental factors, which are defined as food venues primarily engaged in providing food services (except snack and non-alcoholic beverage bars) where patrons generally order or select items and pay before eating. They allow convenient consumption of fast food that typically contains high levels of calories, saturated fat, trans-fat, sugar, simple carbohydrates, and sodium, sold at a relatively low price. FFRs can be categorized using Standard Industrial Classification (SIC) code (5812002) or North America Industry Classification System (NAICS) code (722513) under the category of limited-service restaurants.[8] With the rapid development of international fast-food chains, the consumption of fast food has risen dramatically over the past few decades along with the increasing obesity rates globally.[9,10] Moreover, fast food has been more popular among children and adolescents, partly due to easy availability, taste, and marketing strategies.[11] Some studies showed that FFR access may potentially lead to greater risk of being overweight and obesity, especially in children and adolescents.[12] However, compared with the evidence suggesting an association between fast-food consumption and weight gain,[13] the association between FFR access and childhood obesity was less clear.

This systematic review comprehensively investigated the association between FFR access and weight-related behaviours and weight status. We tested our hypothesis that the greater FFR access was associated with higher levels of unhealthful food intake and weight gains among children and adolescents. Studies that use a full range of measures of FFR access in the neighbourhood and examine multiple weight-related behaviours and outcomes were included. Furthermore, meta-analyses were conducted to quantify the association between FFR access and childhood obesity.

2 | METHODS

A systematic review and meta-analysis were conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

2.1 | Study selection criteria

Studies that met all of the following criteria were included in the review: (a) study subjects (children and adolescents aged younger than 18); (b) study outcomes (weight-related behaviours [eg, diet, physical activity, and sedentary behaviour] and/or outcomes [eg, overweight and obesity measured by body mass index (BMI, kg/m^2), waist circumference, waist-to-hip ratio, and body fat]); (c) article types (peer-reviewed original research); (d) time of publication (earlier than 1 January 2019); and (5) language (articles written in English).

Studies that met any of the following criteria were excluded from the review: (1) studies that incorporated no measures of FFR access or weight-related behaviours/outcomes; (2) computer-based simulation studies without the inclusion of human participants; (3) controlled experiments conducted in manipulated rather than naturalistic settings; (4) articles not written in English; or (5) letters, editorials, study/review protocols, or review articles.

2.2 | Search strategy

A keyword search was performed in three electronic bibliographic databases: PubMed, Web of Science, and Embase. The search strategy included all possible combinations of keywords from the three groups related to fast-food restaurant, children, and weight-related behaviours or outcomes. The specific search strategy is provided in Appendix A.

Two reviewers (M.L. and Y.L.) independently conducted the title and abstract screening and identified potentially relevant articles for the full-text review. Inter-rater agreement was assessed by using the Cohen kappa (κ = 0.8). Discrepancies were compiled by M.L. and screened by a third reviewer (P.J.). M.L., Y.L., and PJ. jointly determined the list of articles for the full-text review through discussion. Then M.L. and Y.L. independently reviewed the full texts of all articles in the list and determined the final pool of articles included in the review. Inter-rater agreement was again assessed by the Cohen kappa (κ = 0.9). [Correction added on 14 January 2021, after first online publication: the title of Section 2.2 has been amended to 'Search Strategy'.]

2.3 | Data extraction

Two reviewers (M.L. and Y.L.) independently extracted data from each included study, and discrepancies were resolved by the third reviewer (P.J.). A standardized data extraction form was used to collect methodological and outcome variables from each selected study, including authors, year of publication, study area and scale, sample size and characteristics, statistical models, and age at baseline, follow-up years, number of repeated measures, and attrition rate for cohort studies, as well as measures of FFR access, weight-related behaviours/outcomes, and their association.

2.4 | Meta-analysis

A meta-analysis was performed to estimate the pooled effect size of FFR access on each weight-related behaviour and outcomes. Weight-related outcomes included BMI, BMI percentile, BMI *z*-score, overweight, and obesity. Overweight was defined as BMI at or above the 85th percentile, and obesity was defined as BMI at or above the 95th percentile based on references mentioned in each article. Several studies were excluded from the meta-analysis due to the following reasons: neither standard error nor confidence interval (CI) was reported; effect size was unable to be transformed into a standardized coefficient (ie, beta coefficient) due to limited information reported; the unit of effect size was inconsistent with others; and less than two studies reported the same outcome variable.

Effect sizes were reported by mean differences for continuous outcomes (ie, BMI and BMI percentile) and odds ratios for categorical variables (ie, overweight and obesity). Study heterogeneity was assessed by using the I^2 index. The level of heterogeneity represented by I^2 was interpreted as modest ($I^2 \leq 25\%$), moderate ($25\% < I^2 \leq 50\%$), substantial ($50\% < I^2 \leq 75\%$), or considerable ($I^2 > 75\%$). Q tests were also conducted, where $P < .1$ indicates the presence of heterogeneity across studies. A random-effect model was used to pool the estimates from individual studies because of the varying population and criteria used to define outcomes. Publication bias was assessed by a visual inspection of the funnel plot and Begg's and Egger's tests. All meta-analyses were performed by the "meta" and "metagen" packages using R version 4.3-2.[14] All analyses used two-sided tests, and $P < .05$ was considered statistically significant except for the evaluation of heterogeneity ($P < .1$).

2.5 | Study quality assessment

The quality of included studies was assessed using the National Institutes of Health's Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies.[15] This assessment tool rates each study based on 14 criteria (Table S2). For each criterion, a score of one was assigned if "yes" was the response, whereas a score of zero was assigned otherwise (ie, an answer of "no," "not applicable," "not reported," or "cannot determine"). A study-specific global score ranging from zero to 14 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.

3 | RESULTS

3.1 | Study selection

A total of 1441 articles were identified through the keyword search, of which 66 were non-duplicated articles (Figure 1). After title and abstract screening, 575 articles were excluded. The full texts of the remaining 111 articles were reviewed against the study selection criteria, and 24 articles were further excluded. The remaining 87 studies that examined the association between FFR access and children's weight-related behaviours and/or outcomes were included in this review.

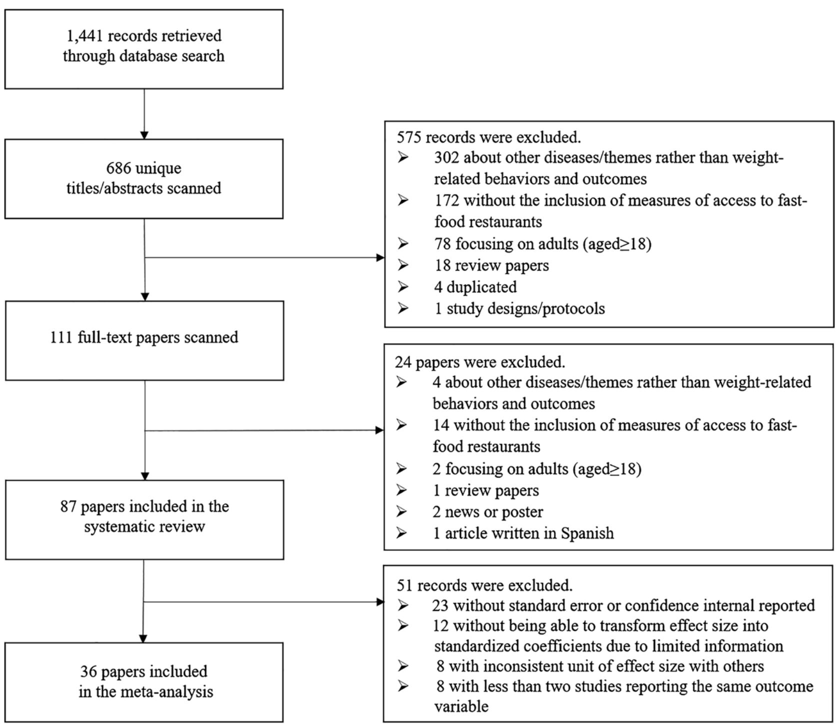

FIGURE 1 Flowchart of study inclusion and exclusion

TABLE 1 Basic characteristics of 87 included studies

Author (Year)[ref]a	Study Area [Scale]b	Sample Size	Sample Age (Years, range, and/or mean ± SD)c	Sample Characteristics	Statistical Models
Longitudinal studies					
Chen (2016)[27]	Arkansas, USA [S]	21 639	in 2003–2004	School children (followed up from academic year 2003/2004 to 2009/2010 with seven repeated measures)	Growth curve model and cox regression
Chen (2016)[28]	USA [N]	7090	11 in 2004	School children (followed up from 2004 to 2007 with two repeated measures)	Multilevel linear regression
Fraser (2012)[29]	Avon, UK [CT]	4022	13 y	Adolescents (followed up from 13 to 15 y with two repeated measures and an attrition rate of 21.2%)	Linear and logistic regression
Ghenadenik (2018)[30]	Montreal, Canada [C]	391	8-10 in 2005-2008	Children with a parental history of obesity (followed up from 2005-2008 to 2008-2011 with two repeated measures and an attrition rate of 37.9%)	Multivariate linear regression
Green (2018)[31]	Leeds, UK [C]	746	11-12 in 2005	Secondary school students (followed up from 2005 to 2010 with three repeated measures)	Multilevel linear regression
Hamano (2017)[32]	Sweden [N]	944 487	0-14 in 2005	Entire Swedish population (followed up from 2005 to 2010 with two repeated measures)	Multilevel logistic regression
Khan (2012)[33]	USA [N]	11 700	in 2004	School children (followed up from 2004 to 2007 with two repeated measures)	Multilevel linear regression
Lee (2012)[34]	USA [N]	7710	6.2 ± 0.4 in 1999	School children (follow up from 1999 to 2004 with four repeated measures and an attrition rate of 43.0%)	Multilevel linear regression
Leung (2011)[35]	California, USA [CT4]	353	6-7 in 2005	Girls (followed up from 2005 to 2008 with three repeated measures and an attrition rate of 20.5%)	Generalized linear and logistic regression
Pearce (2018)[36]	Gloucestershire, UK [CT]	1577	in 2006-2007	School children (followed up from 2006/2007 to 2012/2013 with two repeated measures and an attrition rate of 34.4%)	Multivariate logistic regression
Powell (2009)[37]	USA [N]	5215	12-17 (15.5 ± 1.7) in 1997	Adolescents living at home (followed up from 1997 to 2000 with four repeated measures)	Multilevel linear regression

(Continues)

TABLE 1 (Continued)

Author (Year)[ref]a	Study Area [Scale]b	Sample Size	Sample Age (Years, range, and/or mean ± SD)c	Sample Characteristics	Statistical Models
Shier (2012)[38]	USA [N]	6260	in 2004	School children (followed up from 2004 to 2007 with two repeated measures)	Multilevel linear regression
Smith (2013)[39]	London, UK [C]	757	11-12 in 2001	Secondary school students (followed up from 2001 to 2005 with two repeated measures and an attrition rate of 45.2%)	Generalized linear regression
Sturm (2005)[40]	USA [N]	6918	6.2 ± 0.4 in 1999	Elementary school children (followed up from 1999 to 2002 with three repeated measures and an attrition rate of 42.4%)	Multilevel linear regression
Van Hulst (2015)[41]	Quebec, Canada [S]	512	8-10 in 2005-2008	Children with a parental history of obesity (followed up from 2005-2008 to 2008-2011 with two repeated measures and an attrition rate of 9.8%)	Multivariate linear regression
Wang (2012)[42]	China [N]	185	6-18 in 2004	School-age children (followed up from 2004 to 2006 with two repeated measures and an attrition rate of 19%)	Multilevel linear regression
Cross-sectional studies					
Alviola (2014)[43]	Arkansas, USA [S]	942 public schools	in 2008-2009	Children in kindergarten, grades 2, 4, 6, 8, and 10	Multivariate linear regression
An (2012)[44]	California, USA [S]	13 462	8226 aged 5-11 and 5236 aged 12-17 in 2005 and 2007	Measured in 2005 and 2007	Negative binomial regression
Bader (2013)[45]	New York City, USA [C]	94 348	≥13 y in 2007-2008	Public high school students	Generalized multilevel linear regression
Baek (2014)[46]	California, USA [S]	926 018	in 2007	Grades 5, 7, and 9 students	Multilevel linear regression
Barrett (2017)[47]	Hampshire, UK [CT]	1173	6 y between 2007 and 2014	NA	Multilevel linear regression
Burdette (2004)[48]	Cincinnati, Ohio, USA [C]	7020	36-59 months in 1998-2001	Low-income preschool children	Multivariate logistic regression
Carroll-Scott (2013)[49]	New Haven, USA [C]	1048	10.9 ± 0.8 in 2009	Grades 5 and 6 students	Multilevel linear regression

(Continues)

TABLE 1 (Continued)

Author (Year)[ref]a	Study Area [Scale]b	Sample Size	Sample Age (Years, range, and/or mean ± SD)c	Sample Characteristics	Statistical Models
Casey (2012)[50]	Bas-Rhin, France [S]	3327	12.0 ± 0.6 in 2001	Middle-school first-level students	Multilevel logistic regression
Cetateanu (2014)[51]	UK [N]	3 003 288	4-5 and 10-11 in 2007-2010	School Reception and Grade 6 children	Multivariate linear regression
Chiang (2011)[52]	Taiwan [S]	2283	6-13 in 2001-2002	Elementary school children	Multivariate linear regression
Choo (2017)[20]	Seoul, South Korea [C]	126	9-12 in 2015	Elementary school children at Grades 4 to 6	Multivariate logistic regression
Clark (2014)[53]	Otago, New Zealand [S]	664	15-18 in 2011	Grades 11-13 adolescents	Generalized estimating equation
Correa (2018)[54]	Florianopolis, Brazil [C]	2195	7-14 in 2012-2013	School children	Multivariate logistic regression
Crawford (2008)[55]	Melbourne, Australia [C]	380	137 aged 8-9 and 243 aged 13-15 in 2004	Schoolchildren	Linear and logistic regression
Cutumisu (2017)[56]	Quebec, Canada [S]	26 655	in 2010-2011	Secondary school children	Multilevel logistic regression
Davis (2009)[57]	California, USA [S]	529 367	in 2002-2005	Middle and high school students	Linear and logistic regression
Dwicaksono (2018)[58]	New York, USA [S]	680 school districts	in 2010-2012	School-aged children	Multivariate linear regression
Fiechtner (2013)[59]	Massachusetts, USA [S]	438	2-6.9 in 2006-2009	Overweight and obese preschool-age children	Multivariate linear regression
Fiechtner (2015)[60]	Massachusetts, USA [S]	49 770	4-18 in 2011-2012	Paediatric patients	Multivariate linear regression
Forsyth (2012)[61]	Minneapolis/St. Paul, USA [C]	2724	14.5 ± 2.0 in 2009-2010	Adolescents in secondary schools	Multilevel linear regression
Fraser (2010)[62]	Leeds, West Yorkshire, UK [C]	33 594	3-14 in 1998-2006	NA	Generalized estimating equation
Galvez (2009)[63]	New York, USA [C]	323	6-8 in 2004	NA	Multivariate logistic regression
Gilliland (2012)[64]	London, UK [C]	891	10-14 y	Grades 6-8 students	Multilevel linear regression
Gorski Findling (2018)[65]	USA [N]	3748	2-18 in 2012-2013	NA	Logistic regression

(Continues)

TABLE 1 (Continued)

Author (Year)[ref]a	Study Area [Scale]b	Sample Size	Sample Age (Years, range, and/or mean ± SD)c	Sample Characteristics	Statistical Models
He (2012)[66]	London, Ontario, Canada [C]	782	11-13 in 2006-2007	Grades 7 and 8 students	Multilevel logistic regression
He (2012)[67]	London, Ontario, Canada [C]	632	11-14 in 2006-2007	Grades 7 and 8 students	Multilevel linear regression
Hearst (2012)[68]	Minneapolis and St Paul, MN, USA [C2]	634	10.8-17.7 in 2007-2008	Adolescents	Multilevel linear regression
Heroux (2012)[69]	Canada, Scotland, and the USA [N3]	26 778	13-15 in 2009-2010	Students	Multilevel logistic regression
Ho (2010)[70]	Hong Kong, China [S]	24 796	14.5 ± 0.11 in 2006-2007	Secondary school students	Logistic regression
Hobin (2013)[71]	Ontario, Canada [S]	21 754	in 2005-2006	Grades 9 to 12 students in secondary schools	Multilevel linear regression
Howard (2011)[72]	California, USA [S]	879 public schools	in 2007	Grade 9 students in public schools	Multivariate linear regression
Jago (2007)[73]	Houston, USA [C]	204	10-14 in 2003	Boy scouts	Multivariate linear regression
Jilcott (2011)[74]	Pitt County, USA [CT]	744	8-18 (12.9 ± 2.5) in 2007-2008	Paediatric patients	Generalized linear regression
Joo (2015)[75]	Suwon, Hwaseong, and Osan, Korea [C3]	243	in 2012	Grades 6 and 8 students	Chi-square test and *t* test
Kelly (2018)[76]	Ireland [N]	5344	in 2010	Post-primary school students	Logistic regression
Kepper (2016)[77]	Louisiana, USA [S]	78	2-5 (2.9 ± 0.7) y	Pre-school children	Multivariate linear regression
Koleilat (2012)[78]	Los Angeles, USA [CT]	266 ZIP codes	3-4 in 2008	Children who participated in the WIC programme	ANOVA
Lakes (2016)[79]	Berlin, Germany [C]	28 159	5-6 in 2012	Preschool children	Multivariate linear regression
Lamichhane (2012)[80]	South Carolina, USA [S]	359	14.5 ± 2.9 in 2001-2005	Youth with diabetes	Generalized estimating equation
Lamichhane (2012)[81]	South Carolina, USA [S]	845	11.7 ± 4.7 in 2001-2006	Youth with diabetes	Generalized estimating equation
Langellier (2012)[82]	Los Angeles, USA [CT]	1694 schools	in 2008-2009	Grades 5, 7, and 9 students	Multilevel linear regression
Larsen (2015)[83]	Toronto, Canada [C]	943	11.02 ± 9.63 in 2010-2011	Grades 5 and 6 students	Logistic regression

(Continues)

TABLE 1 (Continued)

Author (Year)[ref]a	Study Area [Scale]b	Sample Size	Sample Age (Years, range, and/or mean ± SD)c	Sample Characteristics	Statistical Models
Laska (2010)[84]	Minneapolis, USA [C]	349	11-18 (15.4 ± 1.7) in 2006-2007	Adolescents	Multilevel linear regression
Laxer (2014)[85]	Canada [N]	6099	11-15 in 2009-2010	Grades 6-10 students	Multilevel logistic regression
Le (2016)[86]	Saskatoon, Canada [C]	1221	10-14 in 2011	Elementary school students	Logistic regression
Leatherdale (2011)[87]	Ontario, Canada [S]	1207	Grades 5-8 in 2007-2008	School children at grades 5-8	Multilevel logistic regression
Li (2011)[88]	Xi'an, China [C]	1792	11-17 in 2004	Junior high students	Multilevel linear regression
Liu (2007)[89]	Marion, Indiana, USA [CT]	7334	3-18 in 2000	Children for routine well-child care	Logistic regression
Longacre (2012)[90]	New Hampshire and Vermont, USA [S2]	1547	12-18 in 2007-2008	Grades 7-11 students	Poisson regression
Mellor (2011)[91]	Virginia, USA [S]	2023	11.4 ± 1.7 in 2006	Grades 3, 6, and 7 students	Linear and logistic regression
Miller (2014)[92]	Perth, Australia [C]	1850	5-15 in 2005-2010	NA	Logistic regression
Ohri-Vachaspati (2015)[93]	New Jersey, USA [S]	560	3-18 years in 2009-2010	NA	Multivariate logistic regression
Oreskovic (2009)[94]	Massachusetts, USA [S]	6680	2-18 in 2006	Children from a Partners HealthCare outpatient affiliate	Multilevel logistic regression
Oreskovic (2009)[95]	Massachusetts, USA [S]	21 008	2-18 in 2006	Children from a Partners HealthCare outpatient affiliate	Multilevel logistic regression
Pabayo (2012)[96]	Edmonton, Canada [C]	1760	4-5 in 2005-2007	Pre-school children	Multivariate logistic regression
Park (2013)[97]	Seoul, South Korea [C]	939	12.1 ± 1.8 in 2011	Grades 4-9 students	Generalized estimating equation
Powell (2009)[98]	USA [N]	6594	6-17 (12.0 ± 3.2) in 1998, 2000, and 2002	NA	Multilevel linear regression
Powell (2011)[99]	USA [N]	1134	12-18 (14.8 ± 1.9) in 1997 and 2002-2003	(measured in 1997 and 2002-2003)	Multivariate linear regression
Salois (2012)[100]	USA [N]	2192 counties	2-4 in 2007-2009	Low-income preschool children	Multivariate linear regression
Sanchez (2012)[101]	California, USA [S]	926 018	in 2007	Grades 5, 7, and 9 students	Multilevel logistic regression
Seliske (2009)[102]	Canada [N]	7281	11-16 in 2005-2006	Grades 6-10 students	Multilevel logistic regression

(Continues)

TABLE 1 (Continued)

Author (Year)[ref]a	Study Area [Scale]b	Sample Size	Sample Age (Years, range, and/or mean ± SD)c	Sample Characteristics	Statistical Models
Shareck (2018)[103]	London, UK [C]	3089	13-15 in 2014	Year 9 students in secondary schools	Poisson regression
Shier (2016)[104]	USA [N]	903	12-13 in 2013	Children in military families	Multivariate linear regression
Svastisalee (2012)[105]	Denmark [N]	6034	11-15 in 2006	Grades 5, 7, and 9 students	Multilevel logistic regression
Svastisalee (2016)[106]	Denmark [N]	4642	11-15 in 2010	Grades 5, 7, and 9 students	Multilevel logistic regression
Tang (2014)[107]	New Jersey, USA [C4]	12 954	13.5 ± 3.5 in 2008-2009	Middle and high school students in low-income communities	Multilevel linear regression
Timperio (2008)[108]	Melbourne and Geelong, Australia [C2]	801	340 aged 5-6 and 461 aged 10-12 in 2002-2003	School children	Logistic regression
Van Hulst (2012)[109]	Quebec, Canada [C]	512	8-10 in 2005-2008	Grades 2-5 students	Logistic regression and generalized estimating equation
Wall (2012)[110]	Minneapolis/St. Paul, USA [C]	2682	14.5 ± 2.0 in 2009-2010	Public middle and high school students	Multivariate linear regression
Wasserman (2014)[111]	Kansas, USA [C2]	12 118	4-12 in 2008-2009	Elementary school children	Multilevel linear regression
Williams (2015)[112]	Berkshire, UK [CT]	16 956	4-5 y and 10-11 y in 2010-2011	Primary school children	Multilevel linear and logistic regression

Abbreviation: NA, not available.

[a]Studies included in meta-analyses are in bold.

[b]Study area: [N], national; [S], state (eg, in the United States) or equivalent unit (eg, province in China and Canada); [S*n*], *n* states or equivalent units; [CT], county or equivalent unit; [CT*n*], *n* counties or equivalent units; [C], city; [C*n*], *n* cities.

[c]Sample age: age in baseline year for longitudinal studies or mean age in survey year for cross-sectional studies.

TABLE 2 Meta-analyses of associations between access to fast-food restaurants (FFRs) and weight status

Author (Year)[ref]	Study Design[1]	Study Area [Scale][2]	Sample Size	FFR Measures	Weight-related Outcomes	Estimated Effect	Pooled Effect Size (95% CI)	I^2 Index
Presence of FFRs and overweight/obesity (N = 13)								
Hamano (2017)[32]	LO	Sweden [N]	944 487	Presence of FFRs within 1-km straight-line buffer around home	Hospital or out-patient diagnosis of childhood obesity	OR (95% CI) 0.99 (0.94-1.05)	OR (95% CI) 1.01 (0.97-1.05) random	50%
Leung (2011)[35]	LO	California, USA [CT4]	353	Presence of FFRs within 0.4-km road-network buffers around home	Overweight/obesity (BMI percentile ≥85th on the 2000 US CDC growth charts)	OR (95% CI) 0.82 (0.28-2.44)		
Correa (2018)[54]	CS	Florianopolis, Brazil [C]	2195	Presence of FFRs within 0.4-km straight-line buffer around home	Overweight/Obesity (BMI *z*-score > +1SD based on the 2007 WHO growth reference, equivalent to BMI ≥25 kg/m^2 in adults)	OR (95% CI) 1.00 (0.75-1.34)		
Crawford (2008)[55]	CS	Melbourne, Australia [C]	380	Presence of FFRs within 2-km straight-line buffer around home	Overweight/obesity based on IOTF cut-offs, equivalent to BMI ≥25 kg/m^2 in adults	OR (95% CI) 8- to 9-year-old boys: 1.52 (0.84-2.76); 8- to 9-year-old girls: 0.48 (0.06-3.60); 13- to 15-year-old boys: 0.63 (0.19-2.10); 13- to 15-year-old girls: 0.19 (0.09-0.41) 0.56 (0.17-1.84) random		
Davis (2009)[57]	CS	California, USA [S]	529 367	Presence of FFRs within 0.8 km from school	Overweight/obesity (BMI ≥85th percentile) based on the US CDC growth charts	OR (95% CI) 1.06 (1.02-1.10)		
Heroux (2012)[69]	CS	Canada, Scotland, and the USA [N3]	26 778	Presence of FFRs within 1-km straight-line buffer around school	Overweight/obesity based on IOTF cut-offs, equivalent to BMI ≥25 kg/m^2 in adults	OR (95% CI) Canadian youth (n = 11 945): 0.92 (0.83-1.03); Scottish youth (n = 4697): 0.94 (0.74-1.20); US youth (n = 4928): 1.08 (0.96-1.21) 0.98 (0.88-1.10) random		
Mellor (2011)[91]	CS	Virginia, USA [S]	2023	Presence of FFRs within 0.16-/0.4-/0.8-/1.6-km road-network buffers around home	Obesity (BMI ≥95th percentile) based on the 2000 US CDC growth charts	OR (95% CI) 0.16-km buffer zone: 3.83 (0.94-15.63); 0.4-km buffer zone: 1.05 (0.67-		

(Continues)

TABLE 2 (Continued)

Author (Year)[ref]	Study Design[1]	Study Area [Scale][2]	Sample Size	FFR Measures	Weight-related Outcomes	Estimated Effect	Pooled Effect Size (95% CI)	I^2 Index
						1.65); 0.8-km buffer zone: 1.19 (0.80-1.77); 1.6-km buffer zone: 0.94 (0.64-1.39) 1.09 (0.86-1.38) fixed		
Miller (2014)[92]	CS	Perth, Australia [C]	1850	Presence of FFRs within 0.8-km road-network buffer around home	Overweight/obesity (BMI ≥85th percentile) based on the 2000 US CDC growth charts	OR (95% CI) 0.691 (0.529-0.903)		
Ohri-Vachaspati (2015)[93]	CS	New Jersey, USA [S]	560	Presence of FFRs within 0.4-km road-network buffer around home	Overweight/obesity (BMI ≥85th percentile) based on the 2000 US CDC growth charts	OR (95% CI) 0.67 (0.38-1.20)		
Oreskovic (2009)[95]	CS	Massachusetts, USA [S]	21 008	Presence of FFRs within 0.4-km road-network buffer around home	Overweight/obesity (BMI ≥85th percentile) based on the 2000 US CDC growth charts	OR (95% CI) 1.05 (0.98-1.12)		
Seliske (2009)[102]	CS	Canada [N]	7281	Presence of FFRs within 1-km straight-line buffer around school	Overweight/obesity based on IOTF cut-offs, equivalent to BMI ≥25 kg/m^2 in adults	OR (95% CI) 0.83 (0.70-0.98)		
Shier (2016)[104]	CS	USA [N]	903	Parent-perceived presence of FFRs within 20-min walk from home	Overweight/obesity (BMI ≥85th percentile)	β (SE) 0.020 (0.030) OR (95% CI) 1.02 (0.96-1.08)		
Tang (2014)[107]	CS	New Jersey, USA [C4]	12 954	Presence of FFRs within 0.4-km road-network buffer around school	Overweight/obesity (BMI percentile ≥85th)	β (95% CI) 0.03 (−0.004 to 0.06) OR (95% CI) 1.03 (1.00-1.07)		
Presence of FFRs and obesity (N = 4)								
Hamano (2017)[32]	LO	Sweden [N]	944 487	Presence of FFRs within 1-km straight-line buffer around home	Hospital or out-patient diagnosis of childhood obesity	OR (95% CI) 0.99 (0.94-1.05)	OR (95% CI) 1.04 (0.99-1.09) random	42%
Davis (2009)[57]	CS	California, USA [S]	529 367	Presence of FFRs within 0.8 km from school		OR (95% CI) 1.07 (1.02-1.12)		

(Continues)

TABLE 2 (Continued)

Author (Year)[ref]	Study Design[1]	Study Area [Scale][2]	Sample Size	FFR Measures	Weight-related Outcomes	Estimated Effect	Pooled Effect Size (95% CI)	I^2 Index
					Obesity (BMI ≥95th percentile) based on the US CDC growth charts			
Mellor (2011)[91]	CS	Virginia, USA [S]	2023	Presence of FFRs within 0.16/0.4/0.8/1.6-km road-network buffers around home	Obesity (BMI ≥95th percentile) based on the 2000 US CDC growth charts	OR (95% CI) 0.16-km buffer zone: 3.83 (0.94-15.63); 0.4-km buffer zone: 1.05 (0.67-1.65); 0.8-km buffer zone: 1.19 (0.80-1.77); 1.6-km buffer zone: 0.94 (0.64-1.39) 1.09 (0.86-1.38) fixed		
Oreskovic (2009)[95]	CS	Massachusetts, USA [S]	21 008	Presence of FFRs within 0.4-km road-network buffer around home	Obesity (BMI ≥95th percentile) based on the 2000 US CDC growth charts	OR (95% CI) 1.06 (0.98-1.14)		
Number of FFRs and overweight/obesity (N = 15)								
Bader (2013)[45]	CS	New York, USA [C]	94 348	Number of FFRs in the residential census tract	Overweight/obesity (BMI ≥85th percentile) based on the 2011 US CDC growth charts	OR (95% CI) 0.972 (0.957-0.988)	OR (95% CI) 1.00 (0.99-1.01) random	89%
Choo (2017)[20]	CS	Seoul, South Korea [C]	126	Number of Western FFRs within 0.2-km straight-line buffer around community child centre	Obesity (BMI ≥95th percentile or BMI >25 kg/m^2) based on the 2012 guidelines of Korea Centers for Disease Control and Prevention	OR (95% CI) 0.87 (0.608-1.245)		
Crawford (2008)[55]	CS	Melbourne, Australia [C]	380	Number of FFRs within 2-km straight-line buffer around home	Overweight/obesity based on IOTF cut-offs, equivalent to BMI ≥25 kg/m^2 in adults	OR (95% CI) 8- to 9-year-old boys: 0.96 (0.84-1.10); 8- to 9-year-old girls: 0.82 (0.63-1.08); 13- to 15-year-old boys: 0.91 (0.78-1.06); 13- to 15-year-old girls: 0.86 (0.74-0.99)		

(Continues)

TABLE 2 (Continued)

Author (Year)[ref]	Study Design[1]	Study Area [Scale][2]	Sample Size	FFR Measures	Weight-related Outcomes	Estimated Effect	Pooled Effect Size (95% CI)	I^2 Index
Fraser (2010)[62]	CS	Leeds, West Yorkshire, UK [C]	33 594	Number of FFRs in residential super-output area (SOA)	Overweight/obesity (BMI ≥85th percentile)	OR (95% CI) 0.90 (0.83-0.98) fixed 1.01 (1.002-1.02)		
Gorski Findling (2018)[65]	CS	USA [N]	3748	Number of FFRs within 1.6-km straight-line buffer around home	Overweight/obesity (BMI ≥85th percentile) based on the 2000 US CDC growth charts	OR (95% CI) 0.99 (0.96-1.02)		
Larsen (2015)[83]	CS	Toronto, Canada [C]	943	Number of FFRs within 1-km road-network buffer around home	Overweight and obesity based on IOTF cut-offs, equivalent to BMI ≥25 kg/m^2 in adults	OR (95% CI) 0.978 (0.953-1.003)		
Leatherdale (2011)[87]	CS	Ontario, Canada [S]	1207	Number of FFRs within 1-km straight-line buffer around school	Obesity (BMI percentile ≥95th based on the 2000 US CDC growth charts)	OR (95% CI) 0.96 (0.82-1.13)		
Mellor (2011)[91]	CS	Virginia, USA [S]	2023	Number of FFRs within 0.16-/0.4-/0.8-/1.6-km road-network buffer around home	Obesity (BMI ≥95th percentile) based on the 2000 US CDC growth charts	OR (95% CI) 0.16-km buffer zone: 3.07 (0.75-12.59); 0.4-km buffer zone: 1.04 (0.92-1.19); 0.8-km buffer zone: 0.97 (0.89-1.06); 1.6-km buffer zone: 0.98 (0.94-1.03) 0.98 (0.95-1.02) fixed		
Miller (2014)[92]	CS	Perth, Australia [C]	1850	Number of FFRs within 0.8-/3-km road-network buffer around home	Overweight/obesity (BMI ≥85th percentile) based on the 2000 US CDC growth charts	OR (95% CI) 0.8-km buffer zone: 0.961 (0.919-1.006); 3-km buffer zone: 0.993 (0.988-0.999) 0.98 (0.96-1.01) random		
Oreskovic (2009)[94]	CS	Massachusetts, USA [S]	6680	Number of FFRs within 0.4-km road-network buffer around home	Overweight (BMI ≥85th percentile) based on the 2000 US CDC growth charts	OR (95% CI) high-income towns: 1.09 (0.82-1.26) low-income towns: 1.09 (1.07-1.11) 1.09 (1.07-1.11) fixed		
Oreskovic (2009)[95]	CS	Massachusetts, USA [S]	21 008	Number of FFRs within 0.4-km road-network buffer around home	Overweight/obesity (BMI ≥85th percentile) based on the 2000 US CDC growth charts	OR (95% CI) 0.98 (0.96-1.01)		

(Continues)

TABLE 2 (Continued)

Author (Year)[ref]	Study Design[1]	Study Area [Scale][2]	Sample Size	FFR Measures	Weight-related Outcomes	Estimated Effect	Pooled Effect Size (95% CI)	I^2 Index
Park (2013)[97]	CS	Seoul, South Korea [C]	939	Number of FFRs within 0.5-km straight-line buffer around school	Overweight/obesity (BMI ≥85th percentile) based on the 2007 Korean National Growth Charts	OR (95% CI) 0.83 (0.72-0.96)		
Shier (2016)[104]	CS	USA [N]	903	Number of FFRs within 3.2-km straight-line buffer around home	Overweight/obesity (BMI ≥85th percentile)	β (SE) 0.000 (0.002) OR (95% CI) 1.00 (0.9961-1.0039)		
Tang (2014)[107]	CS	New Jersey, USA [C4]	12 954	Number of FFRs within 0.4-km straight-line buffer around school	Overweight/obesity (BMI percentile ≥85th)	β (95% CI) 0.0001 (−0.004 to 0.005) OR (95% CI) 1.0001 (0.9960-1.0042)		
Wasserman (2014)[111]	CS	Kansas, USA [C2]	12 118	Number of FFRs within 0.8-km straight-line buffer around school	Overweight (BMI ≥85th percentile)	OR (95% CI) 1.02 (0.98-1.08)		
Number of FFRs and obesity (N = 8)								
Choo (2017)[20]	CS	Seoul, South Korea [C]	126	Number of Western FFRs within 0.2-km straight-line buffer around community child centre	Obesity (BMI ≥95th percentile or BMI >25 kg/m^2) based on the 2012 guidelines of Korea Centers for Disease Control and Prevention	OR (95% CI) 0.87 (0.608-1.245)	OR (95% CI) 1.02 (0.98-1.07) random	90%
Fraser (2010)[62]	CS	Leeds, West Yorkshire, UK [C]	33 594	Number of FFRs in residential super-output area (SOA)	Obesity (BMI ≥95th percentile)	OR (95% CI) 1.01 (1.002-1.02)		
Leatherdale (2011)[87]	CS	Ontario, Canada [S]	1207	Number of FFRs within 1-km straight-line buffer around school	Obesity (BMI percentile ≥95th based on the 2000 US CDC growth charts)	OR (95% CI) 0.96 (0.82-1.13)		
Mellor (2011)[91]	CS	Virginia, USA [S]	2023	Number of FFRs within 0.16-/0.4-/0.8-/1.6-km road-network buffer around home	Obesity (BMI ≥95th percentile) based on the 2000 US CDC growth charts	OR (95% CI) 0.16-km buffer zone: 3.07 (0.75-12.59); 0.4-km buffer zone: 1.04 (0.92-1.19); 0.8-km buffer zone: 0.97 (0.89-1.06); 1.6-km buffer zone: 0.98 (0.94-1.03) 0.98 (0.95-1.02) fixed		

(Continues)

TABLE 2 (Continued)

Author (Year)[ref]	Study Design[1]	Study Area [Scale][2]	Sample Size	FFR Measures	Weight-related Outcomes	Estimated Effect	Pooled Effect Size (95% CI)	I^2 Index
Oreskovic (2009)[94]	CS	Massachusetts, USA [S]	6680	Number of FFRs within 0.4-km road-network buffer around home	Obesity (BMI ≥95th percentile) based on the 2000 US CDC growth charts	OR (95% CI) high-income towns: 0.95 (0.72-1.25); low-income towns: 1.13 (1.10-1.16) 1.13 (1.10-1.16) fixed		
Oreskovic (2009)[95]	CS	Massachusetts, USA [S]	21 008	Number of FFRs within 0.4-km road-network buffer around home	Obesity (BMI ≥95th percentile) based on the 2000 US CDC growth charts	OR (95% CI) 0.99 (0.96-1.02)		
Park (2013)[97]	CS	Seoul, South Korea [C]	939	Number of FFRs within 0.5-km straight-line buffer around school	Obesity (BMI ≥95th percentile) based on the 2007 Korean National Growth Charts	OR (95% CI) 1.15 (0.94-1.39)		
Wasserman (2014)[111]	CS	Kansas, USA [C2]	12 118	Number of FFRs within 0.8-km straight-line buffer around school	Obesity (BMI ≥95th percentile)	OR (95% CI) 1.02 (0.97-1.08)		
Distance (km) to the nearest FFR and overweight/obesity (N = 6)								
Choo (2017)[20]	CS	Seoul, South Korea [C]	126	Road-network distance (m) to the closest Western FFR around community child centre	Obesity (BMI ≥95th percentile or BMI >25 kg/m^2) based on the 2012 guidelines of Korea Centers for Disease Control and Prevention	OR (95% CI) 1.00 (0.984-1.008)	OR (95% CI) 0.98 (0.95-1.01) random	19%
Crawford (2008)[55]	CS	Melbourne, Australia [C]	380	Road-network distance (km) to the nearest FFR from home	Overweight/obesity based on IOTF cut-offs, equivalent to BMI ≥25 kg/m^2 in adults	OR (95% CI) 8- to 9-year-old boys: 0.99 (0.86-1.15); 8- to 9-year-old girls: 1.02 (0.83-1.25); 13- to 15-year-old boys: 1.08 (0.89-1.30); 13- to 15-year-old girls: 1.18 (0.96-1.45) 1.05 (0.96-1.15) fixed		
Larsen (2015)[83]	CS	Toronto, Canada [C]	943	Road-network distance (km) to the nearest FFR from home	Overweight and obesity based on IOTF cut-offs, equivalent to BMI ≥25 kg/m^2 in adults	OR (95% CI) 1.261 (0.871-1.825)		

(Continues)

TABLE 2 (Continued)

Author (Year)[ref]	Study Design[1]	Study Area [Scale][2]	Sample Size	FFR Measures	Weight-related Outcomes	Estimated Effect	Pooled Effect Size (95% CI)	I^2 Index
Miller (2014)[92]	CS	Perth, Australia [C]	1850	Road-network distance (m) to the nearest FFR from home	Overweight/obesity (BMI ≥85th percentile) based on the 2000 US CDC growth charts	OR (95% CI) 1.000 (1.000-1.000)		
Oreskovic (2009)[94]	CS	Massachusetts, USA [S]	6680	Road-network distance (km) to the nearest FFR from home	Overweight (BMI ≥85th percentile) based on the 2000 US CDC growth charts	OR (95% CI) high-income towns: 0.93 (0.86-1.00); low-income towns: 0.97 (0.92-1.03) 0.96 (0.92-1.00) fixed		
Oreskovic (2009)[95]	CS	Massachusetts, USA [S]	21 008	Road-network distance (km) to the nearest FFR from home	Overweight (BMI ≥85th percentile) based on the 2000 US CDC growth charts	OR (95% CI) 0.98 (0.95-1.00)		
Distance (km) to the nearest FFR and obesity (N = 3)								
Choo (2017)[20]	CS	Seoul, South Korea [C]	126	Road-network distance (m) to the closest Western FFR around community child centre	Obesity (BMI ≥95th percentile or BMI >25 kg/m^2) based on the 2012 guidelines of Korea Centers for Disease Control and Prevention	OR (95% CI) 1.00 (0.984-1.008)	OR (95% CI) 0.93 (0.84-1.02) random	65%
Oreskovic (2009)[94]	CS	Massachusetts, USA [S]	6680	Road-network distance (km) to the nearest FFR from home	Obesity (BMI ≥95th percentile) based on the 2000 US CDC growth charts	OR (95% CI) high-income towns: 0.93 (0.82-1.04); low-income towns: 0.83 (0.75-0.91) 0.87 (0.80-0.94) fixed		
Oreskovic (2009)[95]	CS	Massachusetts, USA [S]	21 008	Road-network distance (km) to the nearest FFR from home	Obesity (BMI ≥95th percentile) based on the 2000 US CDC growth charts	OR (95% CI) 0.97 (0.94-1.01)		
Number of FFRs and BMI percentile (N = 2)								
An (2012)[44]	CS	California, USA [S]	13 462	Number of FFRs within 0.8-km straight-line buffer around school	Parent-reported BMI percentile based on the 2000 US CDC growth charts	β (SE) 5-11 y: −0.0009 (0.0019); 12-17 y: −0.0025 (0.0022) −0.0016 (0.0014) fixed	β (95% CI) 0.0990 (-0.2124, 0.4104) Random	57%
Wasserman (2014)[111]	CS	Kansas, USA [C2]	12 118	Number of FFRs within 0.8-km straight-line buffer around school	Measured BMI percentile based on the 2000 US CDC growth charts	β (SE) 0.35 (0.23)		

(Continues)

TABLE 2 (Continued)

Author (Year)[ref]	Study Design[1]	Study Area [Scale][2]	Sample Size	FFR Measures	Weight-related Outcomes	Estimated Effect	Pooled Effect Size (95% CI)	I^2 Index
Distance to nearest FFR and BMI *z*-score (N = 2)								
Crawford (2008)[55]	CS	Melbourne, Australia [C]	380	Road-network distance (km) to the nearest FFR from home	Measured BMI *z*-score based on the 2000 US CDC growth charts	β (95% CI) 8- to 9-year-old boys: 0.05 (0.00-0.10); 8- to 9-year-old girls: −0.04 (−0.13 to 0.05); 13- to 15-year-old boys: 0.04 (−0.06 to 0.13); 13- to 15-year-old girls: 0.03 (−0.03 to 0.09) 0.0304 (−0.0029 to 0.0637) fixed	β (95% CI) 0.0316 (0.0098-0.0534) fixed/random	0
Lamichhane (2012)[81]	CS	South Carolina, USA [S]	845	Road-network distance (mile) to the nearest FFR from home	Measured BMI *z*-score based on the 2000 US CDC growth charts	β (95% CI) 0.052 (0.007-0.098) km: 0.0325 (0.0044-0.0613)		
Presence of FFRs and BMI *z*-score (N = 6)								
Ghenadenik (2018)[30]	LO	Montreal, Canada [C]	391	Presence of FFRs in residential street segment	Measured BMI *z*-score based on the 2010 US CDC growth charts	β (SE) 0.105 (0.185)	β (95% CI) 0.0276 (−0.0205 to 0.0757) random	27%
Crawford (2008)[55]	CS	Melbourne, Australia [C]	380	Presence of FFRs within 2-km straight-line buffer around home	Measured BMI *z*-score based on the 2000 US CDC growth charts	β (95% CI) 8- to 9-year-old boys: −0.02 (−0.23 to 0.25); 8- to 9-year-old girls: −0.01 (−1.11 to 1.09); 13- to 15-year-old boys: −0.49 (−0.95 to −0.03); 13- to 15-year-old girls: −0.35 (−0.69 to −0.02) −0.1573 (−0.3220 to 0.0073) fixed		
Gilliland (2012)[64]	CS	London, UK [C]	891	Presence of FFRs within 0.5-km road-network buffer around home	Self-reported BMI *z*-score based on the WHO growth charts	β (SE) 0.012 (0.121)		
Tang (2014)[107]	CS	New Jersey, USA [C4]	12 954	Presence of FFRs within 0.4-km road-network buffer around school	BMI *z*-score based on the 2000 US CDC growth charts	β (95% CI) 0.07 (−0.01 to 0.15)		
Wall (2012)[110]	CS	Minneapolis/St Paul, USA [C]	2682	Presence of FFRs within 1.2-km road-network buffer around home	Measured BMI *z*-score based on the 2000 US CDC growth charts	β (SE) boys: 0.095 (0.078); girls: 0.045 (0.060) 0.0636 (0.0476) fixed		

(Continues)

TABLE 2 (Continued)

Author (Year)[ref]	Study Design[1]	Study Area [Scale][2]	Sample Size	FFR Measures	Weight-related Outcomes	Estimated Effect	Pooled Effect Size (95% CI)	I^2 Index
Williams (2015)[112]	CS	Berkshire, UK [CT]	16 956	Presence of FFRs within 0.8-km road-network buffer around school	Measured BMI *z*-score based on the IOTF reference curves	β (95% CI) 0.02 (−0.02 to 0.06)		
Number of FFRs and BMI *z*-score (N = 8)								
Chen (2016)[27]	LO	Arkansas, USA [S]	21 639	Number of FFRs along the most direct street route from home to school within 50-m buffer on either side of the street	Measured BMI *z*-score based on the 2000 US CDC growth charts	β (95% CI) 0.0001 (−0.0004 to 0.0007)	β (95% CI) 0.0006 (−0.0015 to 0.0027) random	41%
Green (2018)[31]	LO	Leeds, UK [C]	746	Number of FFRs within 1-km straight-line buffer around home	Measured BMI SDS based on the UK 1990 growth charts	β (95% CI) −0.017 (−0.035 to 0.002)		
Baek (2014)[46]	CS	California, USA [S]	926 018	Number of FFRs within 0.4-/0.8-/1.2-km straight-line buffer around school	Measured BMI *z*-score based on the 2000 US CDC growth charts	β (SE) 0.4-km buffer zone: 1.14×10^{-3} (3.73×10^{-3}); 0.8-km buffer zone: 1.12×10^{-3} (1.97×10^{-3}); 1.2-km buffer zone: 1.72×10^{-3} (1.15×10^{-3}) 0.0015 (0.0010) fixed		
Crawford (2008)[55]	CS	Melbourne, Australia [C]	380	Number of FFRs within 2-km straight-line buffer around home	Measured BMI *z*-score based on the 2000 US CDC growth charts	β (95% CI) 8- to 9-year-old boys: −0.01 (−0.05 to 0.04); 8- to 9-year-old girls: −0.02 (−0.15 to 0.11); 13- to 15-year-old boys: −0.07 (−0.14 to 0.01); 13- to 15-year-old girls: −0.03 (−0.08 to 0.02) −0.0262 (−0.0540 to 0.0017) fixed		
Fraser (2010)[62]	CS	Leeds, West Yorkshire, UK [C]	33 594	Number of FFRs in residential super-output area (SOA)	Measured BMI SDS based on the UK1990 BMI reference	β (95% CI) 0.004 (−0.007 to 0.01)		
Lamichhane (2012)[81]	CS	South Carolina, USA [S]	845	Number of FFRs within 1.6-km road-network buffer around home	Measured BMI *z*-score based on the 2000 US CDC growth charts	β (95% CI) 0.002 (−0.027 to 0.031)		

(Continues)

TABLE 2 (Continued)

Author (Year)[ref]	Study Design[1]	Study Area [Scale][2]	Sample Size	FFR Measures	Weight-related Outcomes	Estimated Effect	Pooled Effect Size (95% CI)	I^2 Index
Shier (2016)[104]	CS	USA [N]	903	Number of FFRs within 3.2-km straight-line buffer around home	BMI *z*-score based on the 2000 US CDC growth charts	β (SE) −0.001 (0.004)		
Tang (2014)[107]	CS	New Jersey, USA [C4]	12 954	Number of FFRs within 0.4-km straight-line buffer around school	BMI *z*-score based on the 2000 US CDC growth charts	β (95% CI) 0.01 (−0.002 to 0.02)		
Presence of FFRs and BMI (N = 3)								
Davis (2009)[57]	CS	California, USA [S]	529 367	Presence of FFRs within 0.8 km from school	BMI	β (95% CI) 0.10 (0.03-0.16)	β (95% CI) 0.2888 (−0.0942 to 0.6719) random	52%
Li (2011)[88]	CS	Xi'an, China [C]	1792	Presence of FFRs within 10-min walk around school reported by school doctors	Measured BMI	β (95% CI) 0.7 (0.1-1.2)		
Mellor (2011)[91]	CS	Virginia, USA [S]	2023	Presence of FFRs within 0.8-km road-network buffer around home	Measured BMI	β (95% CI) 0.35 (−0.42 to 1.13)		
Presence of FFRs and BMI (N = 2)								
Davis (2009)[57]	CS	California, USA [S]	529 367	Presence of FFRs within 0.4 km from school	BMI	β (95% CI) 0.12 (0.04-0.20)	β (95% CI) 0.2420 (−0.2555 to 0.7395) random	37%
Mellor (2011)[91]	CS	Virginia, USA [S]	2023	Presence of FFRs within 0.4-km road-network buffer around home	Measured BMI	β (95% CI) 0.77 (−0.24 to 1.78)		
Density of FFRs and BMI (N = 2)								
Powell (2009)[37]	LO	USA [N]	5215	Density of FFRs per 10 000 capita	Self-reported BMI	β (SE) 0.1215 (0.1164)	β (95% CI) −0.0275 (−0.3132 to 0.2582) random	70%
Powell (2009)[98]	CS	USA [N]	6594	Density of FFRs per 10 000 capita	Mother-reported BMI	β (SE) −0.1701 (0.1081)		
Number of FFRs and BMI (N = 2)								
Davis (2009)[57]	CS	California, USA [S]	529 367	Number of FFRs within 0.8-km road-network buffer around school	BMI	β (95% CI) 0.00 (0.00-0.00)	β (95% CI) 0.004 (−0.15 to 0.16)	NA
Mellor (2011)[91]	CS	Virginia, USA [S]	2023	Number of FFRs within 0.8-km road-network buffer around home	Measured BMI	β (95% CI) 0.004 (−0.15 to 0.16)		

(Continues)

TABLE 2 (Continued)

Author (Year)[ref]	Study Design[1]	Study Area [Scale][2]	Sample Size	FFR Measures	Weight-related Outcomes	Estimated Effect	Pooled Effect Size (95% CI)	I^2 Index
Presence of FFRs and school overweight rates (N = 2)								
Howard (2011)[72]	CS	California, USA [S]	879 public schools	Presence of FFRs within 0.8-km road-network buffer around school	School overweight rates based on criterion-referenced gender-, age-, and test-specific cut-offs established by a national advisory panel	β (95% CI) −0.04 (−1.18 to 1.10)	β (95% CI) 0.1767 (−0.5830 to 0.9365) fixed/random	0
Langellier (2012)[82]	CS	Los Angeles, USA [CT]	1694 schools	Presence of FFRs within 0.8-km road-network buffer around school	School overweight rates based on the sex- and age-specific cut-offs defined by the Physical Fitness Testing programme in 2009	β (SE) 0.35 (0.52)		

[1]Study design: LO, longitudinal; CS, cross-sectional; [2]Study area: [N], national; [S], state (eg, in the United States) or equivalent unit (eg, province in China and Canada); [Sn], *n* states or equivalent units; [CT], county or equivalent unit; [CTn], *n* counties or equivalent units; [C], city; [Cn], *n* cities.

3.2 | Study characteristics

Eighty-seven included studies consisted of 16 cohort studies and 71 cross-sectional studies and were published during 2004 to 2018 (Table 1). Most of these studies were conducted in the United States (n = 45); one international comparison study was conducted in the United States, Canada, and Scotland; the remaining studies were conducted in Canada (n = 13), the United Kingdom (n = 10), China (n = 4), Australia (n = 3), South Korea (n = 3), Denmark (n = 2), Brazil (n = 1), France (n = 1), Germany (n = 1), Ireland (n = 1), New Zealand (n = 1), and Sweden (n = 1). Twenty of these studies were conducted at a national level, and 26, 32, and nine studies were conducted at state, city, and county levels, respectively. The sample size of included studies ranged widely from 78 to 3 003 288, and school children/adolescents were the most common study population (n = 54).

3.3 | Measures of FFR access

Access to FFRs was usually measured by the presence (n = 20), number (n = 50), and density (n = 23) of FFRs within various types of buffer zones and the distance to the nearest FFR (n = 28; Table S1). Other measures included the proportion of FFRs over all restaurants or food venues (n = 4) and weighted accessibility score (n = 3), which was calculated from measures of number and distance in the neighbourhood. Most of these measures used road-network (n = 36) or straight-line distance (n = 34) around the centroid of home (n = 56) and/or school (n = 34). Some studies also focused on home-school travel route (n = 4) and community child centre (n = 1). Among studies that used measures within road-network–based buffer zones, the radii of buffer zones ranged from 0.16 to 3.0 km, and the most commonly used ones were 0.8 (n = 13), 0.4 (n = 9), and 1.6 km (n = 7). In contrast, among studies that measured FFR access within straight-line buffer zones, a greater range of radii, from 0.16 to 8.0 km, was observed, and the commonly used ones included 1.0 (n = 13), 0.8 (n = 8), and 1.6 km (n = 6). Other measures of buffer zones included 5 to 20 minutes' walking time (n = 3), postal zone (n = 4), and census tract (n = 5).

3.4 | Measures of weight-related behaviours and outcomes

Of the 87 included studies, 35 studies have used weight-related behaviours as outcome variables, which were usually measured by food consumption (n = 33) and physical activity (n = 3). Measures of food consumption varied a lot across studies, including food consumption frequency (n = 23), dietary quality scores calculated based on food frequency questionnaire (n = 8), average daily nutrition intake (n = 2), food purchasing frequency (n = 2), and place having lunch (n = 1). Measures of physical activity included the time of exercise and time of sedentary behaviours.

Weight-related outcomes were used in 61 studies, where measures included overweight/obesity (n = 37), BMI *z*-score (n = 15), BMI (n = 10), BMI percentile (n = 6), BMI standard deviation score

(SDS) (n = 2), waist circumference SDS (n = 1), height z-score (n = 1), weight z-score (n = 1), waist circumference z-score (n = 1), waist circumference (n = 1), triceps skinfold thickness (TSF) z-score (n = 1), waist-height ratio (n = 1), weight gain (n = 1), and body fat percentage (n = 1). The BMI references used included the US Centers for Disease Control and Prevention (CDC) growth charts (n = 32), WHO growth reference (n = 3), UK BMI reference (n = 2), 2012 guidelines of Korea CDC (n = 1), and reference values of Kromeyer-Haushild (n = 1). Most of weight-related outcomes were objectively measured (n = 49), while some were self- or parent-reported (n = 12).

3.5 | FFR access and weight-related behaviours

In terms of dietary behaviours related to FFR access, the most commonly studied types of food included fast food, fruit and vegetable, juice, and sugar-sweetened beverages. Of the 14 studies analysing the frequency of fast-food consumption, 11 studies reported a positive association between FFR access and fast-food consumption, with this association observed only among boys in two studies; such association varied in rural (positive) and urban (negative) areas in one study, and the other two studies reported a null association. Nine of 14 studies examining FFR access and fruit/vegetable consumption reported a null association between them, while three reported a negative association and two reported a positive association. Two of five studies focusing on FFR access and juice consumption reported a negative association and the other three studies reported a null association. For the consumption of sugar-sweetened beverages, five of eight studies reported null associations while three reported a positive association. Seven studies using a dietary quality score as the outcome variable reported positive (n = 2), negative (n = 3), and null (n = 2) associations with FFR access. No associations were found between FFR access and nutritional intake. In terms of physical (in)activity, most associations were not significant for both exercise (n = 2) and sedentary behaviours (n = 2), whereas one study reported a positive association for exercise.

3.6 | FFR access and weight status

When using continuous weight measures as outcome variables (ie, BMI and BMI percentile/z-score/SDS), the majority of the included cohort studies reported non-significant associations with FFR access and weight-related outcomes (n = 9), with only one study reporting a positive association. Half of the cohort studies using overweight/obesity as outcome variables reported a positive association (n = 3), while the other half reported non-significant associations (n = 3). Twenty-four cross-sectional studies used BMI-related continuous measures as weight-related outcomes, where 19 studies reported null associations, nine studies reported a positive association, and two studies reported a negative association. Overweight/obesity was used as outcome variables in 33 cross-sectional studies, where 26 studies reported null associations, and positive and negative associations were reported in 11 and four studies, respectively. In addition, the majority of the studies (n = 8) conducting stratified analyses showed different associations with FFR access among stratified subgroups, including gender (n = 5), age (n = 4), income (n = 1), ethnicity (n = 1), and grades (n = 1).

3.7 | Meta-analyses between FFR access and weight status

We conducted separate meta-analyses for different measures of FFR access (i.e., presence of FFRs, density of FFRs, and distance to the nearest FFR) and outcomes (i.e., overweight/obesity, obesity, BMI, BMI percentile, and BMI z-score) (Table 2). Although most studies suggested a positive association between FFR access and weight-related outcomes, none of the meta-analyses demonstrated significant results. For instance, the pooled odds ratio for the presence of FFRs and overweight/obesity was 1.01 (95% CI, 0.97-1.05) based on 13 included studies (Figure 2). The pooled odds ratio for the number of FFRs and overweight/obesity was 1.00 (95%CI, 0.99-1.01) based on 15 included studies (Figure 3). The pooled beta coefficient for the density of FFRs and BMI z-score was 0.0006 (95% CI, −0.0015 to 0.0027) based on eight included studies. The meta-analysis for the density of FFRs and BMI showed a negative but not significant association (β = −0.0275; 95% CI, −0.3132 to 0.2582)3.

3.8 | Study quality assessment

Table S2 reported criterion-specific and global ratings from the study quality assessment. The included studies scored 10.1 of 14 on average, with a range from seven to 14.

4 | DISCUSSION

In this review, 87 studies focusing on FFR access and childhood obesity were selected and based on which meta-analyses were conducted. This pool was composed of studies with various study designs (ie, 16 cohort studies and 71 cross-sectional studies) and study locations (ie, 14 different countries). Weight-related behaviours and outcomes were used as outcome variables in 35 and 61 studies, respectively. Although FFR access was positively associated with fast-food consumption in the majority of studies focusing on that relationship, its associations with other weight-related behaviours, including frequency of food consumption, dietary quality score, and physical activity, were either mixed or not significant. For the association between FFR access and weight-related outcomes, no associations were reported in most studies when using BMI-related continuous measures; when using overweight/obesity measures, about half of cohort studies and one-third of cross-sectional studies reported a positive association. No significant results were observed in separate meta-analyses between various measures of FFR access and body weight.

One previous review on local food environment and obesity in North America has covered the association between FFR access and

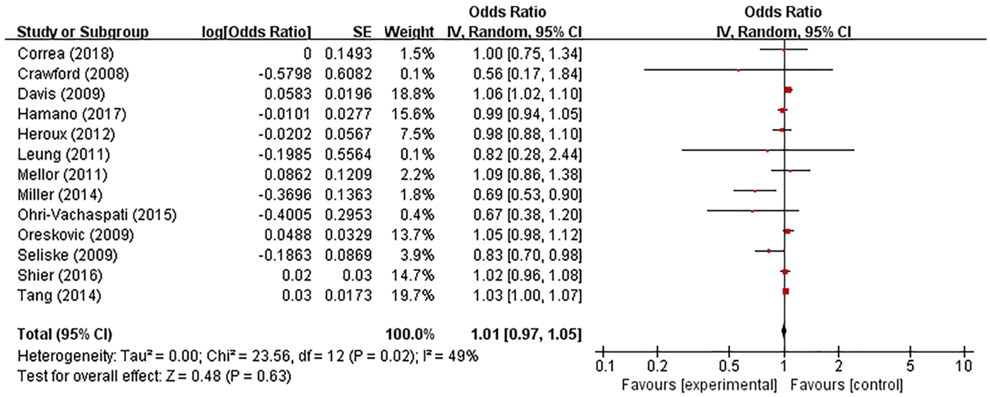

FIGURE 2 Meta-analysis of associations between presence of fast-food restaurants in the neighbourhood and childhood overweight/obesity

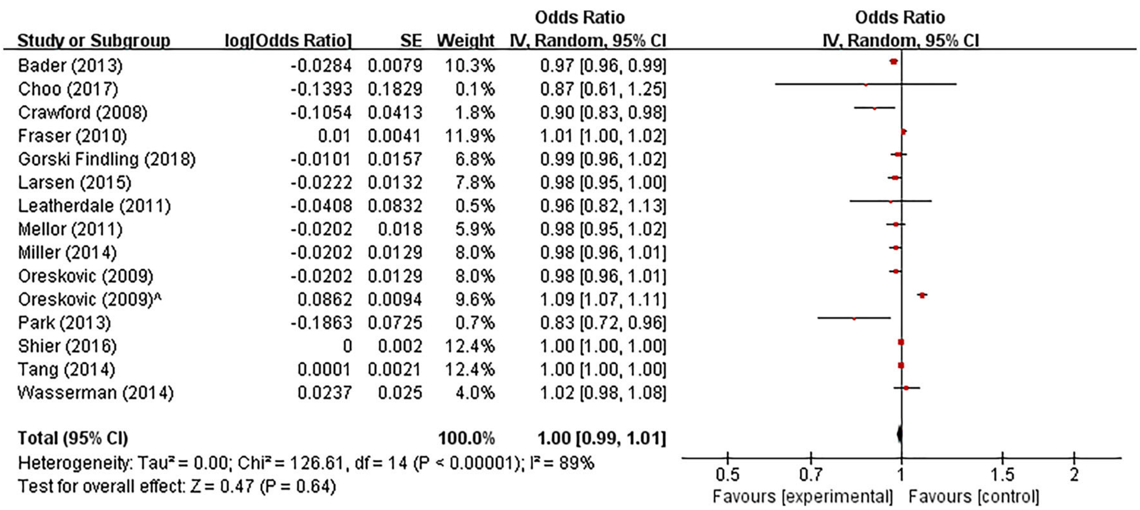

FIGURE 3 Meta-analysis of associations between density of fast-food restaurants in the neighbourhood and childhood overweight/obesity

childhood obesity, where the majority of studies found no associations, with half of the remaining studies reporting a positive association and the other half reporting a negative association.[16] Also, the availability of fast food was more consistently associated with higher risk of obesity in low-income populations. Likewise, with mixed findings from the included studies (some evidence supporting a positive association but others suggesting a null association), this review also cannot provide a clear-cut answer for the association between FFR access and childhood obesity.[16] Some parts of our hypothesis on the association between FFR access, unhealthy food consumption, and childhood obesity have been supported. For example, 10 of 14 included studies supported the link between FFR access and increased fast-food consumption; a systematic review also supported the association between fast-food consumption and increased caloric intake.[13] However, the association between fast-food consumption and childhood obesity may be subject to many confounding factors, especially at the population level, as childhood obesity may be attributed to other factors including genetic susceptibility, prenatal and early life factors, consumption of other unhealthy or healthy food, physical activity, and family factors.[17] Therefore, the association between fast-food consumption and childhood obesity is less easier to access without careful control for confounders.[18] More modern technologies used in spatial lifecourse epidemiologic research, such as location-based mobile services, ecological momentary assessment, and things of Internet, need to be applied to collect more data on food acquisition and consumption and other behaviours that may result in and prevent obesity.[6,19] In addition, many studies have reported different associations when stratified by factors including age, gender, ethnicity, and income. Thus, it is also possible that the association between FFR access and childhood obesity only applies to certain subgroups and is not significant at the population level.

The results of the included studies may be influenced by several factors. First, the variation of food served in different FFRs may to some extent affect study results. For instance, one study analysed both Korean and western FFRs and reported that fast-food consumption was significantly associated with access to Korean FFRs instead of access to western FFRs, which may be explained by the higher density of Korean FFRs than of western FFRs in the study area.[20] It is also important to note that many FFRs have started to change its unhealthy public image by providing relatively healthy food choices, like salad and sugar-free beverages. Furthermore, some countries have taken measures to control excessive fast-food eating by providing nutrition information (ie, calorie intake) on the menu. The actual effects of these measures on obesity prevention among children and adolescents are expected to be examined and adjusted in future studies. This also implies that definitions of the FFR and the fast food sold in those venues need to be made clear in each specific context. Second, variations in measures of FFR access were observed among the included studies. Although the measures used were either the number of FFRs or the distance to the nearest FFR, the definition of the neighbourhood area based on which measures were taken can be quite different, where the radii of buffer zones could range from 0.16 to 8 km. The administrative or postal zone boundaries were used where individual addresses were not available.[21] We suggested that the measurement in one study should be conducted at multiple scales for better comparability with other studies,[8] also to better present the results with the Modifiable Areal Unit Problem overcome.[22,23] Moreover, measuring the access to FFRs has been more challenging and complicated with the development of transportation and communication. Nowadays, it becomes increasingly convenient to commute in different parts of a city, and an increasing number of people, especially the young, have started to choose ordering food online. Thus, the definition and delineation of the area in which people have convenient access to certain food venues may need to change accordingly.[24] The advanced spatial and location-based applications may aid in measuring the realistic access to fast food.[25] Third, different from most types of food venues, FFRs appear more frequently along the highways (eg, in rest areas and near gas stations), so fast-food purchasing may happen in neither residential areas nor school neighbourhoods. Therefore, to comprehensively examine the effects of FFRs on childhood obesity needs the coordination of multiple stakeholders in the real world to track movement patterns of patrons and flows of fast food.

This systematic review, especially meta-analyses, was limited by the number of studies available. We need to analyse separately for different combinations of exposure and outcomes, as it is not feasible to seamlessly synthesize different measures of access to FFR, as well as different measures of weight-related behaviours and outcomes. Also, it is not feasible to conduct meta-analyses for combinations with insufficient studies. We also noticed that the majority of the included studies were cross-sectional studies, which has prevented us from examining effects of FFR access on individual weight status over time. Future studies were needed to focus on longitudinal associations to investigate their causality.[26]

5 | CONCLUSIONS

This systematic review revealed a rather mixed association between FFR access and weight-related behaviours/outcomes among children and adolescents. Methods of defining and measuring FFR access need to be improved to better estimate individuals' exposure to FFRs. Also, research on pathways from FFR access to childhood obesity is needed to allow multiple stakeholders to design effective interventions and policies for prevention of childhood obesity.

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CONFLICT OF INTEREST

No conflict of interest was declared.

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SUPPORTING INFORMATION

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

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APPENDIX A

SEARCH STRATEGY

The search strategy includes all possible combinations of keywords in the title/abstract from the following three groups:

1. "fast-food restaurant*," "fast-food restaurant*," "fastfood restaurant*," "fast food outlet*," "fast-food outlet*," "fastfood outlet*," "takeaway restaurant*," "take-away restaurant*," "take away restaurant*," "takeaway outlet*," "take-away outlet*," "take away outlet*," "takeout restaurant*," "take-out restaurant*," "take out restaurant*," "takeout outlet*," "take-out outlet*," "take out outlet*," "limited-service restaurant*," "limited service restaurant," "quick-service restaurant," "quick service restaurant*";
2. "child*," "juvenile*," "pubescent*," "pubert*," "adolescen*," "youth*," "teen*," "kid*," "young*," "youngster*," "minor*," "student*," "pupil*," "pediatric*," "preschooler*," "pre-schooler*," "schoolchild*," "school-child*," "school child*," "schoolage*," "school-age*," "school age*";
3. "diet*," "diet behavio*," "dietary behavio*," "eating*," "eating behavio*," "food*," "food intak*," "food consum*," "energy intak*," "energy consum*," "energy balance," "calorie*," "caloric intak*," "physical activit*," "physical exercis*," "exercis*," "body activit*," "body mass index," "BMI," "weight," "weight status," "weight-related behavio*," "weight-related health," "overweight," "obese," "obesity," "adiposity," "abdominal overweight," "abdominal obesity," "central overweight," "central obesity," "central adiposity," "waist circumference," "waist to hip," "waist-to-hip," "waist to height," "waist-to-height," "waist to stature," "waist-to-stature," "fatness," "body fat," "excess fat," "excess weight," "overnutrition," "over-nutrition," "over nutrition."