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Access to public transport and childhood obesity: A systematic review

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Summary
The lack of access to public transport is generally considered to be a risk factor for childhood obesity by discouraging active transport and thus physical activity. To explore the association between access to public transport and childhood obesity, we have conducted a systematic literature search in the Cochrane Library, PubMed, and Web of Science for studies published before January 1, 2019. A total of 25 cross-sectional and two longitudinal studies conducted in 10 countries were identified. Inconsistent findings were identified arising from a great variety of sample characteristics, definitions of exposure (ie, access to public transport), and outcome variables (eg, obesity), and analysis methods. While over half of the studies showed null associations between access to public transport and childhood obesity, we have observed more positive than negative associations among the rest of the studies. These observations suggest that an increased level of access to public transport may have a health-promoting effect and hence prevent the development of childhood obesity. However, this conclusion needs to be further corroborated in future research on the

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basis of large-sample health surveys, in situ observations, and comparative analyses among different study areas.

KEYWORDS

built environment, obesity, physical activity, public transport

1 | INTRODUCTION

Obesity is a leading cause of morbidity and premature mortality worldwide. It increases the risk for diabetes, cardiovascular diseases, hypertension, stroke, and a range of cancers and has become the fifth leading risk for global deaths.[1-3] Over 340 million children and adolescents aged 5 to 19 years had overweight or obesity in 2016, and the prevalence is increasing in both developed and developing countries.[1] Combating childhood obesity has become a significant public health challenge and has received substantial public attention.[4]

The neighbourhood environment may shape children's lifestyles and interact with individual characteristics to affect their weight status.[5] Access to public transport in the neighbourhood is one such environmental factor and a form of active transport, also termed as public transit, mass transit, or urban transit. Public transport includes various transport services, such as metros, trams, trains, light rail, ferries, and buses.[6] The increased access to public transport provides additional opportunities for commuters to meet recommended physical activity (PA) levels while en route to transport stations.[7] To this end, we hypothesize that the lack of access to public transport would induce lower PA and higher levels of sedentary behaviours, eventually leading to weight gain among children and adolescents.

Several previous studies have confirmed this hypothesis. For example, residential proximity to subway stations was inversely associated with overweight and obesity among Massachusetts children.[8] It was also reported that the density of public transits had a positive effect on moderate to vigorous PA (MVPA) among pre-school and school children, although this association was not consistent across different statisticalmodels.[9,10] However, other studies reported conflicting health effects of public transport. For example, one study found that the density of bus stops was positively associated with the body mass index (BMI) z-score among white adolescents.[11] Another study reported that the density of public transport was negatively associated with the medium-intensity PA (MIPA) among boys.[12]

To date, there has been no review study specifically focusing on the association between public transport access and childhood obesity. To fill this gap, we conducted this review to test our hypothesis that access to public transport was associated with higher PA and lower risk for childhood overweight and obesity. This review contributes to the literature by examining a full range of measurements of public transport access (eg, the number of public transport stops/lines, the density of public transport stops, and the proximity to the nearest public transport stop) around multiple sites (eg, home, school, and workplace) and their associations with both body-weight status and weight-related behaviours (eg, PA, sedentary behaviour, and active commuting).

2 | METHODS

A systematic review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.[13]

2.1 | Study selection criteria

Studies that met all of the following criteria were included in the review: (a) study designs: longitudinal or cross-sectional studies (excluding letters, editorials, study/review protocols, or review articles); (b) study subjects: children and adolescents aged lees than 18 years; (c) exposures of interest: measures of access to public transport; (d) study outcomes: weight-related behaviours (eg, PA, sedentary behaviour, and diet) and/or weight outcomes (eg, BMI, overweight/obesity, waist circumference, waist-to-hip ratio, and body fat); (e) time of publication: from the inception of an electronic bibliographic database to December 31, 2018; and (f) language: written in English.

2.2 | Search strategy

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 three groups related to public transport, children, and weight-related behaviours or outcomes. The specific search strategy is provided in Appendix A.

Titles and abstracts of the studies identified through the keyword search were screened against the study selection criteria. Potentially relevant studies were retrieved for the evaluation of the full text. The reviewers LJ and JH independently conducted the title and abstract screening and identified potentially relevant studies for the full-text review. Interrater agreement was assessed by using the Cohen's kappa (κ = 0.88 for this study). Discrepancies were compiled by L.J. and screened by a third reviewer F.X. The three reviewers (L.J., J.H., and F.X.) jointly determined the list of studies for the full-text review through discussion. Then, L.J. and J.H. independently reviewed the full texts of all studies in the list and determined the final pool of studies included in the review. Interrater agreement was again assessed by the Cohen's kappa (κ = 0.85 for this study).

2.3 | Data extraction and preparation

A standardized data extraction form was used to collect methodological and outcome variables from each selected study, including authors, year of publication, country, sampling strategy, sample size, age at baseline, follow-up years, number of repeated measures, sample characteristics, statistical model, attrition rate, measures of access to public transport, measures of weight-related behaviours, measures of body-weight status, and key findings on the association between public transport and weight-related behaviours and/or outcomes. L.J. and J.H. independently extracted data from each study included in the review, and discrepancies were resolved by F.X.

2.4 | Study quality assessment

We used the National Institutes of Health's Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies to assess the quality of each included study. This assessment tool rates each study based on 14 criteria. For each criterion, a score of “1” 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 to measure the strength of scientific evidence but was not used to determine the inclusion of studies.

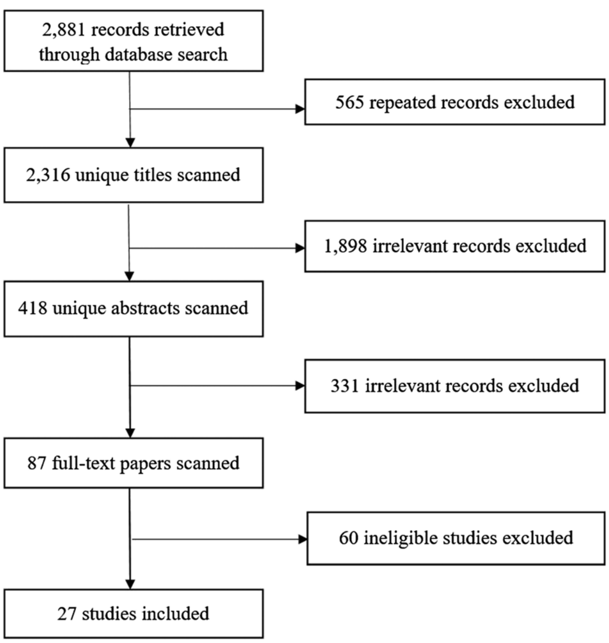

FIGURE 1 Flowchart of study inclusion and exclusion

3 | RESULTS

3.1 | Study selection

Figure 1 shows the flow chart of study selection. We identified a total of 2316 studies through the keyword search. They underwent title and abstract screening, and 2229 of them were excluded. The full texts of the remaining 87 studies were reviewed against the study selection criteria, and 60 studies were further excluded. The remaining 27 studies were included in this review that examined the 89 associations (27 significant and 62 null findings) between access to public transport and children's weight-related behaviours and/or outcomes.

3.2 | Study characteristics

The first eligible study was published in 2002, and 22 of the 27 included studies have been published since 2009 (Table 1). Twenty-five studies were cross-sectional, and only two were longitudinal. Ten studies were conducted in the United States, while four were conducted in Australia, three in Portugal, two studies each in China and Germany, and one study each in Cyprus, Iran, Ireland, New Zealand, Norway, and South Korea. Nearly half of the studies were based on datasets available to the public, whereas the other half were based on surveys conducted by authors. Additionally, 22 studies were conducted in one or more cities, with one study conducted at the provincial level and four at the national level. The statistical methods employed for estimating the association varied but predominantly utilized logistic regression (12/27), linear regression (6/27), and generalized estimating equation (3/27). The remaining six studies used the ordinary least squares and binary logit proportions regression, gamma log-regression, spatial error model estimation, cross-nested logit model, nominal group technique, and bivariate correlation analysis.

3.3 | Measures of access to public transport

Among 89 associations examined, both continuous (n = 60) and categorical variables (n = 29) were used to depict access to public transport (Table S1). The continuous variables included density of public transit stops (n = 19), density of bus stops (n = 13), distance between home and the nearest bus/subway station (n = 8), density of subway stations (n = 7), standardized measures such as Microscale Audit of Pedestrian Streetscapes (MAPS) scores (n = 6), the number of bus/train stops (n = 4), annual vehicle miles of the public transport supply (n = 2), and ease of walking to a bus station (n = 1). The categorical variables primarily included binary variables such as limited public transport (n = 10), ease of walking to a transit stop (n = 10), the presence of bus stops en route (n = 5), residence in Metro Seoul or non-Metro Seoul area (n = 2), the density of public transit stops is below or above the median (n = 1), and one trichotomous variable (the frequency of passing trucks or buses).

TABLE 1 Summary of basic characteristics of the 27 included studies

First Author (Year)	Study Design[a]	Study Area [Scale][b]	Sample Size	Sample Age (Years, Range, and/or Mean ± SD)[c]	Sample Characteristics (Follow-up Status for Longitudinal Studies)	Statistical Model
Buck (2015)[10]	C	Delmenhorst, Germany [C]	400	2-9 in 2007-2008	Preschool and primary school students from the baseline of preschool, and primary school students from the baseline of the Identification and prevention of Dietary- and lifestyle-induced health Effects in Children and infants (IDEFICS) study	Log-gamma regression
Buehler (2012)[14]	C	USA [C90]	90		From 90 of the 100 largest US cities in 2008	Ordinary least squares and binary logit proportions regressions
Cain (2014)[15]	C	San Diego, Seattle, Baltimore, metropolitan areas, USA [C4]	3,677	758 aged 9.1 ± 1.6, 897 aged 14.1 ± 1.4, 1655 aged 44.0 ± 27.0, and 367 aged 75.0 ± 6.6		Mixed linear regression
Crawford (2010)[16]	L	Melbourne, Australia [C]	301	10-12 in 2001	Primary school students from the Children Living in Active Neighbourhoods (CLAN) Study (followed up in 2001, 2004, and 2006 with three repeated measures and an attrition rate of 66.1%)	Generalized estimating equations
Duncan (2012)[11]	C	Boston, USA [C]	1,034	16.32 ± 1.26 in 2008	Public high school students from the 2008 Boston Youth Survey	Spatial error model estimation
Ermagun (2017)[17]	C	Tehran, Iran [C]	3,441	12-17 in 2011	Middle and high school students	Cross-nested logit model
Ferrao (2013)[18]	C	Porto, Portugal [C]	2,690	3-10 in 2009	From 27 preschools and 30 elementary schools	Logistic regression
Gose (2013)[19]	L	Kiel, Germany [C]	485	5-7 in 2006-2008	From the Kiel Obesity Prevention Study (KOPS) (followed up from 2006-2008 to 2010-2012 with two repeated measures and an attrition rate of 36.0%)	Generalized estimating equations (GEE)
Graziose (2016)[12]	C	New York, USA [C]	952	10.6 on average in 2012	From 20 primary schools mainly in low-resource	Multilevel linear regression

(Continues)

TABLE 1 (Continued)

First Author (Year)	Study Design[a]	Study Area [Scale][b]	Sample Size	Sample Age (Years, Range, and/or Mean ± SD)[c]	Sample Characteristics (Follow-up Status for Longitudinal Studies)	Statistical Model
					neighbourhoods, ie, the baseline of the Food, Health and Choices (FHC) obesity prevention trial	
He (2014)[20]	C	Hong Kong, China [C]	34	10-11	From three primary schools in four types of neighbourhoods with varying SES and walkability	Nominal group technique
Hinckson (2017)[21]	C	Auckland, Wellington, New Zealand [C2]	524	12-18 in 2013-2014	From eight high schools from the Adolescent New Zealanders (BEANZ) study	Generalized additive mixed models
Jago (2006)[22]	C	Greater Houston, USA [C]	210	10-14	From 36 Boy Scout troops from the baseline of a Boy Scout intervention trial	The hierarchical linear regression
Lee (2016)[23]	C	Korea [N]	638	12-18 in 2013	From the 2013 Korea National Health Examination and Nutrition Survey (KNHANES)	Logistic regression
Loucaides (2009)[24]	C	Cyprus [N]	676	13-15 in 2004	From 10 public middle schools (six urban and four rural)	Bivariate correlations
Lovasi (2011)[25]	C	New York, USA [C]	428	2-5 in 2003-2005	Preschool children of low-income families from Head Start programme	Generalized estimating equations
Machado-Rodrigues (2014)[26]	C	Portugal [N]	1,886	7-9 in 2009-2010	Girls from The Portuguese Prevalence Study of Obesity in Childhood (PPSOC)	Linear regression
Meng (2018)[27]	C	Shenzhen, China [C]	1,257	12 to 15 in May and June	From 3 middle schools	Logistic regression
Nelson (2010)[28]	C	Ireland [N]	2,159	15-17	Students living within 4 km of school from the Take PART study	Logistic regression
Oreskovic (2009)[8]	C	Massachusetts, USA [S]	21,008	2-18 in 2009	From the Partners Health Care database	Logistic regression
Santos (2009)[29]	C	I´lhavo, Portugal [C]	1,124	12-18	From three middle schools and two high schools in urban areas	Logistic regression
Sjolie (2002)[30]	C	Rendalen, Elverum, Norway [C2]	105	14-16	School students at grades 8 to 9 who had lived for ≥3	Linear regression

(Continues)

TABLE 1 (Continued)

First Author (Year)	Study Design[a]	Study Area [Scale][b]	Sample Size	Sample Age (Years, Range, and/or Mean ± SD)[c]	Sample Characteristics (Follow-up Status for Longitudinal Studies)	Statistical Model
					years in one rural and one urban area	
Timperio (2004)[31]	C	Melbourne, Australia [C]	1,210	291 aged 5-6 and 919 aged 10-12 in 2001	Primary school students in high (n = 10) and low (n = 9) SES areas	Logistic regression
Timperio (2005)[32]	C	Melbourne, Australia [C]	291	291 aged 5-6 and 919 aged 10-12 in 2001	From 19 state primary schools in high (n = 10) and low (n = 9) SES areas	Logistic regression
Timperio (2006)[33]	C	Melbourne, Australia [C]	912	235 aged 5-6 in 2001and 677 aged 10-12 in 2001	From 19 state primary schools in high (n = 10) and low (n = 9) SES areas	Logistic regression
Wall (2012)[34]	C	Minneapolis, USA [C]	2,682	14.5 ± 2.0 in 2009-2010	From 20 public middle and high schools from the Eating and Activity in Teens (EAT) 2010 study	Linear regression
Zhu (2008)[35]	C	Austin, USA [C]	1,281	NA	From eight elementary schools with low SES and high percentages of Hispanics	Logistic regression
Zhu (2009)[36]	C	Austin, USA [C]	2,695	5-18 in 2007	From 19 elementary schools	Logistic regression

Abbreviation: SES, socioeconomic status.
[a]Study design: [C], cross-sectional study; [L], longitudinal study.
[b]Study area: [N], national; [S], state (eg, in the United States) or equivalent unit (eg, province in China or Canada); [C], city; [Cn], n cities or equivalent units.
[c]Sample age: age in baseline year for longitudinal studies or mean age in survey year for cross-sectional studies.

In addition, network buffer (n = 28) and sausage buffer (n = 17) were mostly used to measure the area range. For network buffers, 0.32 km was the most common buffer distance (n = 6), followed by 1.6 and 0.4 km (both n = 4), and other network buffer distances included 0.5, 0.75, 0.8, 1, 1.25, 1.5, and 2 km (both n = 2). For sausage buffers, 0.5 km road buffers were the most common distance (n = 8), followed by 0.4 (n = 3), 0.25 (n = 2), 1.0 (n = 2), and 2.0 km (n = 2). Walking distance (n = 11) including ease of walking to destination (n = 4), general walking distance (n = 4), and 10-15 min/15 min walking distance (n = 3) were also used to describe the range of studies.

3.4 | Associations between public transport access and weight status

Nine studies examined a total of 25 associations between public transport access and obesity-related outcomes, among which BMI z-score (n = 8) was the most utilized measure of body weight status, followed by overweight (n = 6), obesity (n = 6), sum of skin-folds (n = 2), BMI (n = 1), BMI standard deviation score (n = 1), and overweight or obesity (n = 1) (Table S2).

Seven of eight studies assessing BMI z-score reported a null association between public transport access and BMI z-score, while only one study reported a negative association in whites. Other continuous weight status such as sum of skin-folds (n = 2) reported a positive and a null association, while BMI (n = 1) and BMI standard deviation scores (n = 1) reported a null and a negative association, respectively. The categorical measures such as overweight and obesity both reported five null associations and one positive association.

3.5 | Associations between public transport access and PA

Twenty-one studies examined 64 associations between public transport access and weight-related behaviours, primarily PA (n = 52) and travel modes (n = 12) (Table S2). Of the 52 associations with PA, the quantification of PA was considerably inconsistent, including the duration or frequency of low/medium/high intensity PA (n = 9), MVPA time (n = 22), sedentary time (n = 8), and other standardized PA metrics (n = 13), such as PA time (n = 2), PA frequency (n = 2), odds of meeting PA recommendations (n = 2), beneficial factors for PA (n = 2), PA counts (n = 2), PA index (n = 1), commuting distance (n = 1), and active or low-active PA (n = 1). Of the 12 associations with travel modes, different measures were used to quantify travel modes, including active/inactive commuting (n = 8), frequency of walking or biking (n = 2), and cycling levels (n = 2). Moreover, PA and travel modes in 34 of 64 associations for weight-related behaviours were measured by accelerometers, while 30 were self-, parent-, or guardian-reported.

When the duration or frequency of low/medium/high intensity PA were used as outcome variables, eight of nine associations reported null associations while one negative association was found in girls only. For MVPA time, 15 null associations and seven positive associations were observed while one positive association was reported in boys only. For sedentary time, there were seven null associations and one positive association. Moreover, six of 13 associations between the other standardized PA metric and public transport access were nonsignificant while three were negative association and four positive associations including one positive association observed only in boys. In terms of travel mode (n = 12), half of the associations were not significant and three positive and three negative associations were reported in the remaining half.

3.6 | Study quality assessment

Table S3 presents the quality assessment of the included studies according to different criteria and their global ratings. On average, the included studies scored seven out of 14, with a range from five to nine.

4 | DISCUSSION

This review summarizes 89 associations between public transport access and weight-related behaviours and/or outcomes from 27 original studies. Because of a wide variety of measures of variables, analysis methods, scales, and sampling population, we elected not to conduct a meta-analysis. If these discrepancies in the meta data were not accounted for, access of public transport was found to be health-promoting in 18 studies and health-damaging in nine studies.

The increase in public transport accessibility tended to reduce childhood obesity. This observation has also been evidenced in several environmental health reviews examining PA and childhood obesity. For example, Ferreira et al (2007) reviewed environmental correlates of PA in children/adolescents and identified several consistently positive factors, such as the father's PA, time spent outdoors, PA-related school policies, support from significant others, the mother's education level, family income, and nonvocational school attendance (in adolescents).[37] Dunton et al (2009) summarized characteristics of built and biophysical environmental factors that may influence childhood and adolescent obesity in a review study.[38] Only one study in their review had found no significant effect of public transport access/availability on the level of obesity. Other reviews evaluated previous literature that studied the association between the built environment and children's PA.[39-41] The built environmental variables in these reviews extend beyond the public transport system, such as recreational facilities.

In this review, we had mixed findings concerning the association of public transport accessibility with childhood obesity. This inconsistency may be induced by mode choice during every-day trips. Active travel, particularly walking and cycling, has confirmed health-promoting benefits in preventing and mitigating obesity and obesity-related commodities.[42-44] Public transport, referred to as the semi-active travel mode,[17] also has contingent health effects as it increases walking time en route to and from a public transit station.[42] However, easy access to public transport facilities does not indicate the use of public transport services, as commuters' mode choices vary. Additionally, other nonspatial factors may play a role in dictating the mode choice, such as time allowed for travel, travel cost, availability of bike paths and sidewalks, parking spaces, and weather conditions.[45,46]

Some reviews summarized a full range of factors in built environments affecting PA or sedentary behaviour but showed few consistent findings.[37,38,42] Rissel et al (2012) reviewed studies reporting the increased PA as a result of public transport use among adults.[42] This inconsistency was likely due to the substantial variability in parameter choice, methodological development, study area and scale, and sample population. A recent review published in 2017 suggested that increasing neighbourhood walkability, improving the quality of parks and playgrounds, and providing adequate transport infrastructure are likely to encourage PA among both children and adults.[47]

Furthermore, different results might be produced after controlling different variables even in the same study. Sjolie and Thuen (2009) showed that the distance of walked/cycled to school/bus stop (km) was associated with walked/cycled to weekly activities (km).[30] A study conducted by Nelson and Woods (2010) also reported that ease of walking to public transit was associated with active commuting to school in males and females after controlling for age and socioeconomic status, but this association only remained in females after adjustment for density (size of settlement), socio-demographics, density, or distance travelled to school.[28] An inverse association reported by Zhu and Lee (2013) was that the presence of bus stops en route reduced the likelihood of walking to or from school in 19 elementary school students,[36] but this scenario differed in elementary school students with low SES and of whom a high percentage were Hispanic.[35] This interesting phenomenon may suggest that different sample characteristics might account for the diverse travel mode and lead to the inconsistent association between public transport accessibility and obesity.[11,45,46]

We screened the studies that met the inclusion/exclusion criteria after systematically searching a variety of databases (eg, Cochrane Library, PubMed, and Web of Science). However, limitations remain as there exists a limited scope of studies having reported the association between public transport accessibility and childhood obesity whereas public transport accessibility has been considered a control variable rather than the independent variable in some of the multivariate analyses. Additionally, most of these studies adopt a cross-sectional design, which does not allow for an exploration of the causal relation between the two subjects. Finally, as demonstrated in the results of the quality assessment (Table 4), most included studies are of a moderate quality.

There are also some limitations of our review. First, we only summarize the major findings rather than adopting the meta-analysis, but this current review cannot calculate standardized effect sizes for the predictor variables owing to the great variety among the definitions of variables of interests, analysis methods, and sample characteristics. For example, public transportation accessibility could be defined by comprehensive (eg, public transit density) or component indices (eg, subway density), by objective (eg, GIS and MAPS) or subjective (eg, perception) measures, and by different distance criteria (eg, 500 m to 2 km buffers and 15-minute walking distance). A reporting guideline for spatial data and methods is being expected to mitigate this complexity.[48] Second, it is known that using different methods to examine the associations between two variables may result in different relationships. A variety of statistical techniques (eg, generalized estimating equations[19] and logistic regression, among others[18]) were used for such evaluations, which further introduced uncertainties. Most studies used multivariate analyses with socio-demographic and/or physical environmental correlates adjusted for, where we found a low level of consistency in controlled confounding variables. Third, the participants differed in household and regional characteristics, such as family income, educational attainment, race, and living conditions. This variety suggests directions for future exploration that (a) designs a universally acceptable standard for accessibility measurements, (b) reaches a consensus on obesity-related physical environmental features, and (c) consolidates a large number of studies and extracts consistent sample characteristics. Also, public transport accessibility, especially its utilization which is more associated with obesity, can be affected by climatic and weather factors. Therefore, the effect on obesity of public transport accessibility, or the underlying climatic and weather factors (through public transport utilization), may vary spatially and temporally.[49] This has not been considered in most, if not all, of the previous studies. Fourth, we failed to conduct subgroup analyses (ie, by gender, race, and age) because of the small number of studies included. Given that the health effects of public transport accessibility on subgroups may differ,[11,45] it is necessary to target different subgroups in future reviews once a sufficient number of studies have been accumulated. In addition, we grouped similar indicators together to describe results, but this may not be completely appropriate because of the differences between studies involving those indicators. For example, MVPA differs in measure (in minutes[15,16,21,22] or hours per day/week[12]), definition (using age-specific cut-points,[15] non-age-specific cut-offs,[21,22] or self-perception[16,23]) and monitoring time (3 days,[22] 7 days,[15] or other). Last, the majority of the included studies in this study are cross-sectional designs, which mainly show some correlation rather than revealing causal relationships between the public transport accessibility and obesity-related behaviours. Thus, additional longitudinal studies should be conducted in future efforts.

5 | CONCLUSIONS

In this study, we find more positive than negative findings when excluding the null findings regarding the association between access to public transport and childhood obesity. However, there are a great variety of measures, analyses, and samples among the included studies. Future research should reach a consensus on the definition of variables, analysis methods, and sample characteristics in order to better justify the health effects of public transport accessibility and convince multiple stakeholders to work together for improving the access to public transport.

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CONFLICT OF INTERESTS

We declare no conflicts of interest.

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REFERENCES

1. World Health Organization. Fact-sheets, obesity and overweight. Available at: //www.who.int/news-room/fact-sheets/detail/obesity-and-overweight. Accessed on: 12/03/2019.
2. Guh DP, Zhang W, Bansback N, Amarsi Z, Birmingham CL, Anis AH. The incidence of co-morbidities related to obesity and overweight: a systematic review and meta-analysis. *BMC public health*. 2009;9:88. //bmcpublichealth.biomedcentral.com/articles/10.1186/1471-2458-9-88#citeas
3. Ortega FB, Lavie CJ, Blair SN. Obesity and cardiovascular disease. *Circulation research*. 2016;118(11):1752-1770.
4. Karnik S, Kanekar A. Childhood obesity: a global public health crisis. *International Journal of Preventive Medicine*. 2012;3(1):1-7.
5. Jia P, Cheng X, Xue H, Wang Y. Applications of geographic information systems (GIS) data and methods in obesity-related research. *Obesity Reviews: An Official Journal Of The International Association for the Study of Obesity*. 2017;18(4):400-411.

6. Litman T. *Evaluating public transit benefits and costs: Victoria Transport Policy Institute British Columbia, Canada* 2015.
7. Besser LM, Dannenberg AL. Walking to public transit: steps to help meet physical activity recommendations. *American journal of preventive medicine*. 2005;29(4):273-280.
8. Oreskovic NM, Winickoff JP, Kuhlthau KA, Romm D, Perrin JM. Obesity and the built environment among Massachusetts children. *Clinical pediatrics*. 2009;48(9):904-912.
9. Buck C, Tkaczick T, Pitsiladis Y, et al. Objective measures of the built environment and physical activity in children: from walkability to moveability. *Journal of urban health: bulletin of the New York Academy of Medicine*. 2015;92(1):24-38.
10. Buck C, Kneib T, Tkaczick T, Konstabel K, Pigeot I. Assessing opportunities for physical activity in the built environment of children: interrelation between kernel density and neighborhood scale. *International journal of health geographics*. 2015;14:35.//ij-healthgeographics.biomedcentral.com/articles/10.1186/s12942-015-0027-3#citeas
11. Duncan DT, Castro MC, Gortmaker SL, Aldstadt J, Melly SJ, Bennett GG. Racial differences in the built environment—body mass index relationship? A geospatial analysis of adolescents in urban neighborhoods. *International journal of health geographics*. 2012;11:11. //ij-healthgeographics.biomedcentral.com/articles/10.1186/1476-072X-11-11#citeas
12. Graziose MM, Gray HL, Quinn J, Rundle AG, Contento IR, Koch PA. Association Between the Built Environment in School Neighborhoods With Physical Activity Among New York City Children, 2012. *Preventing chronic disease*. 2016;13:150581.https://www.cdc.gov/pcd/issues/2016/15_0581.htm
13. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of internal medicine*. 2009;151:264-269.
14. Buehler R, Pucher J. Cycling to work in 90 large American cities: new evidence on the role of bike paths and lanes. *Transportation*. 2012;39:409-432.
15. Cain KL, Millstein RA, Sallis JF, et al. Contribution of streetscape audits to explanation of physical activity in four age groups based on the Microscale Audit of Pedestrian Streetscapes (MAPS). *Social Science & Medicine*. 2014;116:82-92.
16. Crawford D, Cleland V, Timperio A, et al. The longitudinal influence of home and neighbourhood environments on children's body mass index and physical activity over 5 years: the CLAN study. *International Journal Of Obesity*. 2010;34(7):1177-1187.
17. Ermagun A, Levinson D. Public transit, active travel, and the journey to school: a cross-nested logit analysis. *Transportmetrica a-Transport Science*. 2017;13:24-37.
18. Ferrao MM, Gama A, Marques VR, et al. Association between parental perceptions of residential neighbourhood environments and childhood obesity in Porto, Portugal. *European Journal Of Public Health*. 2013;23(6):1027-1031.
19. Gose M, Plachta-Danielzik S, Willie B, Johannsen M, Landsberg B, Muller MJ. Longitudinal influences of neighbourhood built and social environment on children's weight status. *International Journal Of Environmental Research And Public Health*. 2013;10(10):5083-5096.
20. He G, Cerin E, Huang WY, Wong SH. Understanding Neighborhood Environment Related to HongKong Children's Physical Activity: A Qualitative Study Using Nominal Group Technique. *PloS ONE*. 2014;9(9):e106578.//journals.plos.org/plosone/article?id=10.1371/journal.pone.0106578
21. Hinckson E, Cerin E, Mavoa S, et al. Associations of the perceived and objective neighborhood environment with physical activity and sedentary time in New Zealand adolescents. *The International Journal Of Behavioral Nutrition And Physical Activity*. 2017;14:145.//ijbnpa.biomedcentral.com/articles/10.1186/s12966-017-0597-5#citeas
22. Jago R, Baranowski T, Harris M. Relationships between GIS environmental features and adolescent male physical activity: GIS Coding Differences. *Journal of Physical Activity & Health*. 2006;3(2):230-242.
23. Lee EY, Carson V, Jeon JY, Spence JC. Prevalence of physical activity and sitting time among South Korean adolescents: results from the Korean National Health and Nutrition Examination Survey, 2013. *Asia-Pacific Journal of Public Health*. 2016;28(6):498-506.
24. Loucaides CA. School location and gender differences in personal, social, and environmental correlates of physical activity in Cypriot middle school children. *Journal of Physical Activity & Health*. 2009;6(6):722-730.
25. Lovasi GS, Jacobson JS, Quinn JW, Neckerman KM, Ashby-Thompson MN, Rundle A. Is the environment near home and school associated with physical activity and adiposity of urban preschool children? *Journal of Urban Health: Bulletin of the New York Academy of Medicine*. 2011;88(6):1143-1157.
26. Machado-Rodrigues AM, Santana A, Gama A, et al. Parental perceptions of neighborhood environments, BMI, and active behaviors in girls aged 7-9 years. *American Journal of Human Biology: The Official Journal of the Human Biology Council*. 2014;26(5):670-675.
27. Meng S, Zacharias J, Han X. Longer afterschool active commutes and the travel environment of middle schools in Shenzhen, China. *Prev Med Rep*. 2018;12:170-175.
28. Nelson NM, Woods CB. Neighborhood perceptions and active commuting to school among adolescent boys and girls. *Journal of physical activity & health*. 2010;7(2):257-266.
29. Santos MP, Page AS, Cooper AR, Ribeiro JC, Mota J. Perceptions of the built environment in relation to physical activity in Portuguese adolescents. *Health & Place*. 2009;15(2):548-552.
30. Sjolie AN, Thuen F. School journeys and leisure activities in rural and urban adolescents in Norway. *Health promotion international*. 2002;17(1):21-30.
31. Timperio A, Crawford D, Telford A, Salmon J. Perceptions about the local neighborhood and walking and cycling among children. *Preventive Medicine*. 2004;38(1):39-47.
32. Timperio A, Salmon J, Telford A, Crawford D. Perceptions of local neighbourhood environments and their relationship to childhood overweight and obesity. *International Journal of Obesity*. 2005;29(2):170-175.
33. Timperio A, Ball K, Salmon J, et al. Personal, family, social, and environmental correlates of active commuting to school. *American Journal of Preventive Medicine*. 2006;30(1):45-51.
34. Wall MM, Larson NI, Forsyth A, et al. Patterns of obesogenic neighborhood features and adolescent weight: a comparison of statistical approaches. *American Journal of Preventive Medicine*. 2012;42(5):e65-e75.
35. Zhu X, Arch B, Lee C. Personal, social, and environmental correlates of walking to school behaviors: case study in Austin, Texas. *The Scientific World Journal*. 2008;8:859-872.
36. Zhu X, Lee C. Correlates of walking to school and implications for public policies: survey results from parents of elementary school children in Austin, Texas. *J Public Health Policy*. 2009;30(Suppl 1):S177-S202.
37. Ferreira I, Van Der Horst K, Wendel-Vos W, Kremers S, Van Lenthe FJ, Brug J. Environmental correlates of physical activity in youth—a review and update. *Obesity reviews*. 2007;8(2):129-154.
38. Dunton GF, Kaplan J, Wolch J, Jerrett M, Reynolds KD. Physical environmental correlates of childhood obesity: a systematic review. *Obesity reviews*. 2009;10(4):393-402.
39. Masoumi HE. Associations of built environment and children's physical activity: a narrative review. *Rev Environ Health*. 2017;32(4):315-331.
40. McGrath LJ, Hopkins WG, Hinckson EA. Associations of objectively measured built-environment attributes with youth moderate-vigorous

physical activity: a systematic review and meta-analysis. *Sports Medicine*. 2015;45(6):841-865.
41. An R, Shen J, Yang Q, Yang Y. Impact of built environment on physical activity and obesity among children and adolescents in China: a narrative systematic review. *Journal of sport and health science*. 2019;8(2):153-169.
42. Rissel C, Curac N, Greenaway M, Bauman A. Physical activity associated with public transport use—a review and modelling of potential benefits. *International journal of environmental research and public health*. 2012;9(7):2454-2478.
43. Sadarangani KP, Von Oetinger A, Cristi-Montero C, Cortinez-O'Ryan A, Aguilar-Farias N, Martinez-Gomez D. Beneficial association between active travel and metabolic syndrome in Latin-America: a cross-sectional analysis from the Chilean National Health Survey 2009-2010. *Preventive medicine*. 2018;107:8-13.
44. Saunders LE, Green JM, Petticrew MP, Steinbach R, Roberts H. What Are the Health Benefits of Active Travel? A Systematic Review of Trials and Cohort Studies. *PloS ONE*. 2013;8(8):e69912.//journals.plos.org/plosone/article?id=10.1371/journal.pone.0069912
45. Kamargianni M, Polydoropoulou A. Hybrid choice model to investigate effects of teenagers' attitudes toward walking and cycling on mode choice behavior. *Transportation Research Record*. 2013;151-161.
46. Kamargianni M, Dubey S, Polydoropoulou A, Bhat C. Investigating the subjective and objective factors influencing teenagers' school travel mode choice—an integrated choice and latent variable model. *Transportation Research Part a-Policy and Practice*. 2015;78:473-488.
47. Smith M, Hosking J, Woodward A, et al. Systematic literature review of built environment effects on physical activity and active transport—an update and new findings on health equity. *Int J Behav Nutr Phys Act*. 2017;14:158.//ijbnpa.biomedcentral.com/articles/10.1186/s12966-017-0613-9#citeas
48. Jia P, Yu C, Remais J, et al. Spatial Lifecourse Epidemiology Reporting Standards (ISLE-ReSt) Statement. *Health & Place*. 2019. Published online: //www.sciencedirect.com/science/article/pii/S1353829219306355
49. Zhang X, Zhang M, Zhao Z, et al. Obesogenic environmental factors of adult obesity in China: a nationally representative cross-sectional study. *Environmental Research Letters*. 2019.https://doi.org/10.1088/1748-9326/ab6614

SUPPORTING INFORMATION

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

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