Received: 5 May 2020 | Accepted: 7 May 2020

DOI: 10.1111/obr.13052

SUPPLEMENT ARTICLE

OBESITY Reviews WILEY

Neighbourhood speed limit and childhood obesity

Miyang Luo[1,2,3] | Hanqi Li[4,2] | Xiongfeng Pan[1,2] | Teng Fei[4,2] | Shaoqing Dai[5,2] | Ge Qiu[2] | Yuxuan Zou[6,2] | Heleen Vos[5] | Jiayou Luo[1,2] | Peng Jia[5,7,2]

[1]Xiangya School of Public Health, Central South University, Changsha, China

[2]International Initiative on Spatial Lifecourse Epidemiology (ISLE), Hong Kong, China

[3]Saw Swee Hock School of Public Health, National University of Singapore, Singapore

[4]School of Resources and Environmental Science, Wuhan University, Wuhan, China

[5]Faculty of Geo-information Science and Earth Observation, University of Twente, Enschede, The Netherlands

[6]School of Geographical Sciences, Guangzhou University, Guangzhou, China

[7]Department of Land Surveying and Geo-Informatics, The Hong Kong Polytechnic University, Hong Kong, China

Correspondence
Jiayou Luo, Department of Maternal and Child Health, Xiangya School of Public Health, Central South University, 110 Xiangya Road, Changsha 410078, China.
Email: jiayouluo@csu.edu.cn

Peng Jia, PhD, Director, International Initiative on Spatial Lifecourse Epidemiology (ISLE); Faculty of Geo-information Science and Earth Observation, University of Twente, Enschede, the Netherlands.
Email: p.jia@utwente.nl; jiapengff@hotmail.com

Funding information
State Key Laboratory of Urban and Regional Ecology of China, Grant/Award Number: SKLURE2018-2-5; National Natural Science Foundation of China, Grant/Award Number: 81872641

Summary

As an important factor for neighbourhood walkability, the speed limit in the neighbourhood may influence children's physical activity (PA) outdoors, especially active transport, and further their weight status. This review aimed to systematically evaluate the association between neighbourhood speed limit and obesity-related behaviours and outcomes among children and adolescents. PubMed, Embase and Web of Science were systematically searched for relevant studies published from the inception of the database to 1 January 2019. Sixteen studies were included, with 13 cross-sectional studies and three longitudinal studies. Speed limit was measured as the percentage/number of high-speed roads, perception of safe driving speed, perception of speeding and use of traffic-calming tools in the neighbourhood. Eleven studies measured the use of active transport as the outcome of interest, and seven studies measured PA directly. Eleven studies revealed an association between a lower speed limit and increased PA, whereas one study showed a negative association, and three studies reported non-significant associations. Only one study associated speed limit with weight status, which reported a non-significant association. This review generally supported a negative association between speed limit and PA among children and adolescents. More studies are needed to examine their causality, as well as the association between speed limit and weight status, in order to increase the impact of this research area on public health policy making.

KEYWORDS

built environment, child, obesity, speed limit

1 | INTRODUCTION

Childhood obesity remains a global public health problem, and the prevalence of obesity has been steadily increasing over the past few decades.[1–3] Obesity is a leading cause of several chronic diseases, including cardiovascular diseases, diabetes, musculoskeletal disorders and certain types of cancers. Therefore, the major consequences of childhood obesity include an increased risk of obesity and chronic diseases in adulthood, premature death and disability in adulthood. Apart from these long-term effects, children with obesity may also experience breathing difficulties and psychological problems.[4]

It is widely reported that the neighbourhood-built environment may shape individual behaviours and interacts with individual characteristics to affect their weight status.[5–9] The speed limit of traffic in the neighbourhood is one of such environmental factors, whose primary objective is to prevent traffic accidents caused by speeding. The perception of parents on traffic safety hazards may impede the mobility of their children, and thus, a high speed limit is considered a physical barrier.[10,11] Previous studies revealed that a reduced speed limit in residential neighbourhoods may increase the walkability of a neighbourhood and improve the actual or perceived safety of walking and cycling, thereby decreasing the likelihood of childhood obesity.[12–14] However, speed limit has been measured differently in previous studies, which may cause us to draw robust conclusions from them.[15] To date, no review has been made regarding the association between speed limit and weight-related behaviours or weight status among children and adolescents.

This study aimed to conduct a systematic review of the association between speed limit and weight-related behaviours or weight status among children and adolescents. Characteristics of all relevant studies have been analysed and summarized, such as study design and area, measures of speed limit and weight-related behaviours and outcomes, in order to demonstrate the strengths and weaknesses of the current evidence. Such information may provide important suggestions for urban planning practitioners and policy makers when designing urban environment to curb obesity.

2 | METHODS

2.1 | Literature search and study selection

The PubMed, Embase and Web of Science databases were searched for potentially relevant articles published from the inception of the database to 1 January 2019. The search terms included various expressions of speed limit, children or adolescents and weight-related behaviours and outcomes in the title or abstract (Appendix A).

Titles and abstracts were evaluated in the first round, and the eligibility of the studies for inclusion was confirmed by full-text reviews using the following inclusion criteria: (1) study designs: longitudinal studies, including prospective and retrospective cohort studies, cross-sectional studies, case–control studies, ecological studies or intervention studies; (2) study subjects: children or adolescents, aged younger than 18 years; (3) exposure of interest: speed limit in the neighbourhood; (4) study outcome: weight-related behaviour (e.g., physical activity [PA], sedentary behaviour and active transport) or outcome (e.g., weight, body mass index [BMI], overweight status and obesity status); and (5) language: full texts written in English. Studies were excluded if they failed to meet any of the inclusion criteria (i.e., inappropriate study design or study population, not having speed limit as the exposure of interest, not having weight-related behaviour or outcome as the study outcome or not written in English). The study selection was independently conducted by two reviewers (ML and XP), with discrepancies resolved by a third author on the basis of full-text reviews (PJ).

2.2 | Data extraction and quality assessment

A standardized data extraction form was used to collect methodological and outcome variables from each selected study, including first author, year of publication, study area and country, sample size, age at baseline, follow-up years, sample characteristics, statistical model, measure(s) of speed limit, measure(s) of weight-related behaviours and/or status and key findings on the association between speed limit and weight-related behaviours and/or outcomes. Two reviewers (ML and HL) independently extracted data from each study included in the review, with discrepancies resolved by a third reviewer (PJ).

The quality of the studies was assessed using the National Institutes of Health's Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies (NIHQAT). This assessment tool rates each study on the basis of 14 criteria (Table S1). For each criterion, a score of 1 was assigned if 'yes' was the response, whereas a score of 0 was assigned otherwise (i.e., an answer of 'no', 'not applicable', 'not reported' or 'cannot determine'). A study-specific global score ranging from 0 to 14 was calculated by summing up the scores of all criteria.

3 | RESULTS

3.1 | Study characteristics

After the literature search, 16 studies from 1684 unique records were included in this review (Figure 1). The study characteristics of all included studies were summarized in Table 1. The included studies were published from 2008 to 2018, with 13 cross-sectional studies and three longitudinal studies. The median sample size was 715, ranging from 184 to 180 346. Five studies were conducted in Canada; two studies each in Australia, Belgium and the United States; and one study each in Denmark, Ireland, Mexico, New Zealand and the Netherlands. The majority of the included studies were conducted at city level (n = 10), and the other studies were conducted at state (n = 5) or national level (n = 1). Participants in most studies were students (n = 12), followed by children and their parents (n = 2), young park users (n = 1) and children recruited from communities (n = 1).

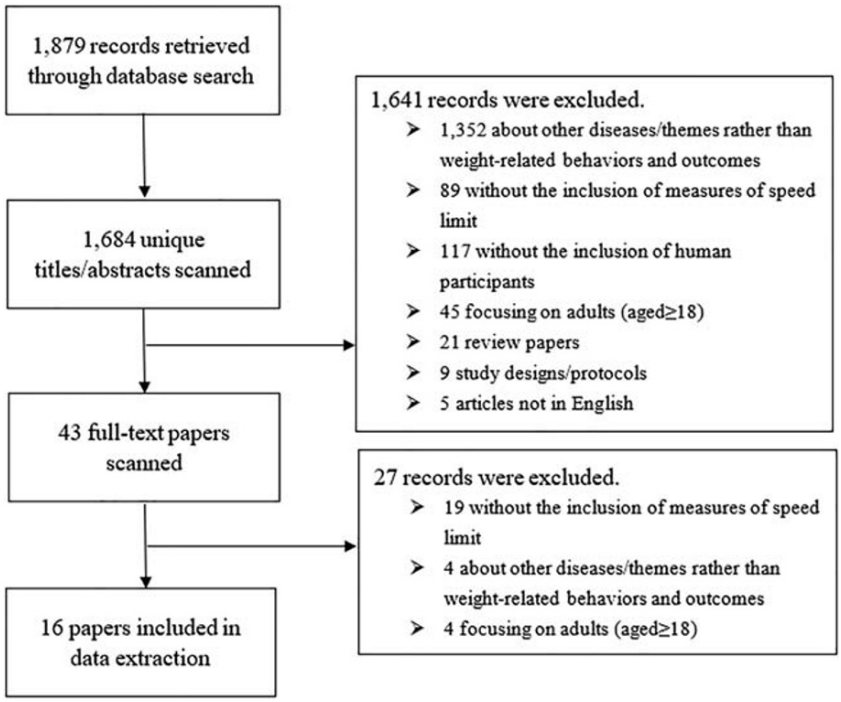

FIGURE 1 Study exclusion and inclusion flowchart

The quality assessment of the included studies was reported in Table S1. Based on the NIHQAT, the 16 studies scored between 6 and 12, with an average of 8.4.

3.2 | Measurements of speed limit and weight-related behaviours/outcomes

Various measures were used for speed limit in the neighbourhood, which can be grouped in four major categories: percentage/number of roads with a high speed limit (n = 5), perceived safe traffic speed (n = 5), perceived speeding (n = 3) and the use of traffic-calming tools (n = 7) (Table 2). More specifically, the percentage/number of high-speed roads was objectively measured, in which a high speed was usually defined as a speed limit greater than 50–60 km h^{-1} (n = 4), whereas one study used 30 km h^{-1} as the cut-off value. The perception of safe traffic speed was measured by asking questions such as whether the traffic usually drives slowly. A slow traffic speed was defined as less than or equal to 50 km h^{-1} in two studies, less than or equal to 30 km h^{-1} in one study and as subjective perceptions such as 'slow' or 'fast' in the other two studies. The perceived traffic speeding was measured by asking whether there were drivers exceeding the maximum speed limit. Measures regarding these perceptions were reported by adolescents (n = 3), parents (n = 2) or both (n = 1). The use of traffic-calming tools was objectively measured by the number (n = 4) or presence (n = 3) of traffic-calming factors, such as speed humps and traffic lights. In addition, three studies focused on the school neighbourhood, eight studies focused on the home neighbourhood, three studies analysed the neighbourhood en route to school and one study analysed the park neighbourhood. Various definitions of neighbourhood were observed: four studies used straight-line buffer zones as boundaries; three studies used road network buffer zones; and one study used the postal zone. The 0.8-km straight-line buffer zone (n = 4) and 1.0-km road network buffer zone (n = 2) were most commonly used.

The study outcomes were behaviours in most studies (n = 15) and BMI z score in only one study (Table 2). The behaviours measured included active transport (n = 11), PA (n = 7) and screen time (n = 1). Active transport was commonly measured by using the self- or parent-reported usual mode of transport, which was divided into two categories (n = 6): active mode, including walking or cycling, and passive mode, including by bus or by car. Other measures of active transport included frequency of using active transport (n = 2), choice of active transport route (n = 1), intention to cycle (n = 1), and time spent in active transport without accompaniment, namely, active independent mobility (n = 1). The accelerometer was used in seven studies measuring PA to measure the average duration of moderate-to-vigorous physical activity (MVPA) per day (n = 3), percentage of time spent in MVPA (n = 1) and outdoor play z score (n = 1), whereas one study used the parent-reported PA score determined by duration and frequency, and one study used the observed active level (i.e., sedentary, waking and active) by trained researchers.

3.3 | Association between speed limit and weight-related behaviours/outcomes

Of three longitudinal studies, one study revealed that the number of speed humps in the home neighbourhood was associated with a greater increase in duration of MVPA outside school among the overall population; the number of traffic/pedestrian lights was associated with a positive change in active transport frequency and a negative

TABLE 1 Basic characteristics of the 16 studies included in this study

First author (year)	Study area [scale][a]	Sample size	Sample age (years) in the survey year	Study design[b]	Sample characteristics	Statistical model
Alejandra (2016)[16]	Puerto Vallarta, Guadalajara and Mexico City, Mexico [C3]	1191	NA	C	Students in Grades 3–5	Multilevel logistic regression
Carson (2014)[17]	Kingston, Canada [C]	800	0–5 in 2011	C	Children and their parents from licensed child care centres and public health/community programmes	Multilevel linear regression
Carver (2008)[18]	Melbourne, Australia [C]	180 346	8–9 in 2004 and 13–15 in 2006	C	Students from 19 primary schools	Linear regression and logistic regression
Carver (2010)[19]	Melbourne, Australia [C]	446	8–9 in 2004 and 13–15 in 2006	L	Students from 19 primary schools	Linear regression
Christiansen (2014)[20]	Southern Denmark [S]	1250	11–13 in 2010	C	Students in Grade 5 or 6 from 14 schools	Multilevel logistic regression
Coughenour (2014)[21]	Las Vegas, USA [C]	1423	<18 in 2012	C	Youth park users	Multinomial logistic regression
Dessing (2016)[22]	Zaanstad, Haarlemmermeer and Edam-Volendam, the Netherlands [C3]	184	8–12 in 2014	C	Students from seven schools	Conditional logistic regression
Ghenadenik (2018)[23]	Montreal, Canada [C]	391	8–10 in 2005–2008	L	Caucasian children in Grades 2–5 from elementary schools with at least one obese biological parent and their parents	Linear regression
Huertas-Delgado (2018)[24]	Ghent, Belgium [C]	291	12–15 in 2014–2016	L	Children recruited from neighbourhoods across the city and suburbs	Multilevel linear regression
Larouche (2014)[25]	The Ottawa-Gatineau region, Canada [S]	567	9–11, 10 average in 2012–2013	C	Students in Grade 5 from 26 schools	Generalized linear mixed model
Nguyen (2018)[26]	Kingston, Canada [C]	458	10–13 in 2015–2016	C	Local students	General linear model
Norah (2010)[27]	Ireland [N]	4,720	15–17	C	Adolescents living within 2.5 miles of their school	Logistic regression
Oliver (2015)[28]	Auckland, New Zealand [C]	253	9–13 in 2011–2012	C	Students in Grades 5–8 from nine schools	Generalized estimating equation model
Oluyomi (2014)[29]	Texas, USA [S]	830	NA	C	Students in Grade 4 from 81 schools and their parents	Logistic regression
van Loon (2014)[30]	Vancouver, British Columbia and the surrounding lower mainland region, Canada [S]	629	8–11 in 2005–2006	C	Students in Grades 4–6 from nine schools	Generalized estimating equation model
Verhoeven (2017)[31]	Flanders, Belgium [S]	882	13.9 ± 1.6 in 2016	C	Students in first to fourth year from 12 secondary schools	Logistic regression

Abbreviation: NA, not available.

[a]Study scale: [N], national; [S], state (US) or equivalent unit (e.g., province); [C], city; [C*n*], *n* cities.

[b]Study design: C, cross-sectional; L, longitudinal.

TABLE 2 Measures of speed limit and weighted-related behaviours and weight status in 16 included studies

First author (year)	Measures of speed limit	Other variables adjusted for in the model	Measures of weight-related behaviour/outcomes
Alejandra (2016)[16]	• Presence of posted speed limits in 0.4-/0.8-km school buffer	• Individual variables: age, gender, number of adults in the household, number of children in the household, income and parental perceived school safety • Environment variables: walkability index, street segments with sidewalks, street cleanliness, street segments with path obstructions, street segments with low-volume roads, path condition and neighbourhood socio-economic status	• Parent-reported mode of AT (walking and cycling)
Carson (2014)[17]	• Proportion of roads <61 km h^{-1} in home postal zone	• Individual variables: age and sex of children, sex and education of parents, child care status and family structure • Environment variables: neighbourhood SES, walkability, streetscape, outdoor play/activity space, recreation facilities, distance to closest park, yard space at home and recreation facilities	• Parent-reported PA score of children and PA score of parents assessed using questionnaire based on duration and frequency of PA • Parent-reported screen time of children and parents assessed using questionnaire
Carver (2008)[18]	• Number of speed humps in 0.8-km home buffer (in tertiles) • Number of traffic/pedestrian lights in 0.8-km home buffer (in tertiles)	• Individual variables: NA • Environment variables: local road length/index, total length of walking tracks, living in cul-de-sac, number of intersections, gates/barriers and 'slow points'/road narrowing	• AT frequency (walking and cycling, parent-reported for children and self-reported for adolescents), in two categories: ≥7 times per week and <7 times per week • PA (average duration of MVPA outside school hours) measured using accelerometer
Carver (2010)[19]	• Number of speed humps in 0.8-km home buffer (in tertiles) • Number of traffic/pedestrian lights in 0.8-km home buffer (in tertiles)	• Individual variables: NA • Environment variables: local road length/index, total length of walking tracks, number of intersections, gates/barriers and 'slow points'/road narrowing	• Change in AT frequency (walking and cycling, parent-reported for children and self-reported for adolescents) • Change in PA (average duration of MVPA outside school hours) measured using accelerometer
Christiansen (2014)[20]	• Adolescent's perception of traffic speeding en route to school (using a 5-point scale from strongly disagree to strongly agree)	• Individual variables: age, gender, household income, parent nativity and distance to school, perceived friends' cycle, perceived parents' cycle and parents' support • Environment variables: school walkability index, route safety, number of paths and safe crossings	• Self-reported ATS mode (in two categories: active transport [walking or cycling] and passive transport)
Coughenour (2014)[21]	• Number of high-speed streets (≥56 km h^{-1}) in 0.4-km park buffer	• Individual variables: gender, percent minority and Hispanic and income • Environment variables: amenities, incivilities, size, sidewalk condition and temperature	• PA levels observed by researchers (in three categories: sedentary, walking or very active)
Dessing (2016)[22]	• Number of speed bumps en route to school • Number of traffic lights en route to school	• Individual variables: NA • Environment variables: type of area (residential, commercial, recreational or traffic areas), presence of greenery/natural waterways along the route and type of street (pedestrian, cycling, residential streets or arterial roads)	• Choice of ATS route assessed by GPS (actual route vs. shortest route)

(Continues)

TABLE 2 (Continued)

First author (year)	Measures of speed limit	Other variables adjusted for in the model	Measures of weight-related behaviour/outcomes
Ghenadenik (2018)[23]	• Presence of traffic-calming features (i.e., speed bumps, midstreet section stop signs, 30 km h^{-1} speed limit signs, traffic obstacles and traffic lights) in 0.2- to 0.4-km home road network buffer	• Individual variables: age, gender, maternal and paternal BMI, parental education and material deprivation • Environment variables: residential density, presence of pedestrian aids, disorder indicator, PA facilities, convenience stores and fast-food restaurants	• **BMI *z* score and waist-height ratio based on measured waist, height and weight**
Huertas-Delgado (2018)[24]	• Parents' and adolescents' perception of traffic speed (≤50 km h^{-1}) and speeding (>maximum speed limit) in home neighbourhood (using a four-point scale from strongly disagree to strongly agree)	• Individual variables: adolescents' gender, parents' highest educational level	• Self-reported and parent-reported independent mobility (average time spent travelling without accompaniment) and active independent mobility (average time walking and cycling without adult accompaniment)
Larouche (2014)[25]	• Presence of traffic-calming measures in school neighbourhood	• Individual variables: gender, school travel time, school language and school board • Environment variables: identification of safe routes to school, providing crossing guards and perceived crime safety	• Self-reported ATS mode (in two categories: active commuting [walking and cycling] and inactive commuting)
Nguyen (2018)[26]	• Parents' perception of traffic speed (≤50 km h^{-1}) and traffic slowing devices in home neighbourhood (in three categories: low, moderate and high) • Traffic speed index (based on % of high-speed roads) in 1-km home road network buffer • Traffic-calming indexes (based on number of traffic-calming factors per km of road) in 1-km home road network buffer	• Individual variables: age, gender, race and annual household income • Environment variables: traffic volume indexes, pedestrian infrastructure indexes, average daily temperature and precipitation, season of participation and walk score	• Outdoor active play *z* score measured using accelerometers, GPS watch and log
Norah (2010)[27]	• Adolescent's perception of traffic speed (slow or fast) in home neighbourhood • Adolescent's perception of presence of speeding in home neighbourhood	• Individual variables: age, gender and SES • Environment variables: NA	• Self-reported ATS mode (in two categories: active commuting [walking and cycling] and inactive commuting)
Oliver (2015)[28]	• Ratio of high-speed roads (>60 km h^{-1}) to low speed roads in 1-km school road network buffer	• Individual variables: age, ethnicity, gender • Environment variables: street connectivity, net residential density, distance to school, neighbourhood destination accessibility index, area-level SES, New Zealand Systematic Pedestrian and Cycling Environmental Scale	• PA (% of out-of-school time spent in MVPA) measured using accelerometers each day for 7 days • Self-reported AT (% of trips made by active mode [walking or cycling]) each day for 7 days
Oluyomi (2014)[29]	• Parents' perceived traffic speed concerns en route to school (in three categories: always a problem, sometimes a problem and no problem)	• Individual variables: ethnicity, any type of public assistance in family and car ownership in family • Environment variables: NA	• Parent-reported AT mode (walking to school)
van Loon (2014)[30]	• Proportion of low speed limit streets (≤30 km h^{-1}) in 0.2-/0.4-/0.8-/1.6-km home buffer	• Individual variables: age, gender, ethnicity and median household income • Environment variables: neighbourhood environment index, cul-de-sac density and distance to closest nonpark recreation site	• PA (average minutes of MVPA per day) measured using accelerometers

TABLE 2 (Continued)

First author (year)	Measures of speed limit	Other variables adjusted for in the model	Measures of weight-related behaviour/outcomes
Verhoeven (2017)[31]	• Adolescents' perception of speed limit (30 vs. 50 km h^{-1}) • Presence of speed bumps	• Individual variables: NA • Environment variables: NA	• Intention to cycle for transport

Abbreviations: AT, active transport or active travel; ATS, active transportation to school; BMI, body mass index; MVPA, moderate-to-vigorous physical activity; NA, not available; PA, physical activity; SES, socio-economic status.

change in duration of MVPA among girls (Table 3). The other two longitudinal studies reported non-significant associations between the presence of traffic-calming features and the BMI *z* score, as well as between the perceived safety traffic speed and children's active independent mobility.

Of 13 cross-sectional studies, six studies reported a significant association between speed limit measures in the neighbourhood and active transportation, whereas two studies reported non-significant associations for this outcome. More specifically, three studies found that the presence of traffic-calming measures was associated with an increased use of active transport, three studies reported that a perceived high speed limit/speeding was associated with a decreased use of active transport, and one study found that the presence of speed bumps was associated with a lower intention to cycle. Of six studies that analysed PA, three studies found that the percentage/number of high-speed roads was associated with a decreased PA, one study found that a perceived high traffic speed is positively associated with outdoor PA, and only one study reported a non-significant association. Two studies reported opposite findings regarding the presence of traffic-calming measures and PA, with one having reported a positive association between the number of speed humps and the duration of MVPA in the evening, and one having reported a negative association between the traffic-calming index and outdoor play *z* score. One study also reported a non-significant association between the percentage of high-speed roads and screen time.

Differences in such associations between genders were observed in three studies: one study found an association between the number of traffic lights and the use of active transport frequency among girls only; one study found an association between the proportion of high-speed roads and the duration of MVPA among girls only; and one study found an association between the number of speed humps and the duration of MVPA among boys only. In addition, one study reported a significant interaction between a safe route to school and traffic-calming measures, where only the coexistence of both factors was associated with increased active transport to school.

4 | DISCUSSION

We identified and systematically reviewed 16 studies on the association between speed limit and weight-related behaviours and outcomes among children and adolescents. Speed limit was measured as the road speed limit or the use of traffic-calming segments in most studies, and active transport and level of PA were commonly used as the outcome measures. We found a protective effect for children's weight-related behaviours within the lower speed limits in most of the studies, whereas fewer studies reported negative or non-significant relationships.

Active transport is an important form of PA for children. Studies have suggested that active transport is associated with a healthier lifestyle and reduced levels of obesity.[32,33] It is hypothesized that the speed limit of the street may influence children's intention to use active transport, like walking and cycling, by improving pedestrian safety. This association was supported to some extent in this review, though it is important to note that active transport is also determined by a combination of multiple environmental factors, including residential density, land use mix and transportation infrastructure.[34] For instance, one study reported that the coexistence of both a safe route to school and traffic-calming measures was associated with increased active transport to school, whereas the association was non-significant for each factor alone.[25] Moreover, individual factors also played an important role in this association, including gender and attitudes towards active transport among both parents and children. In this review, three studies reported gender differences for the association between speed limit and PA, in which significant associations were more commonly reported among girls. This gender difference may partly be explained by parental factors, as evidence suggested that fewer parental restrictions concerning independent play are placed on boys than on girls, while parents are in general more concerned about environmental safety than children.[35,36]

In this review, different measures were used for speed limit and behaviour outcomes, which may lead to inconsistent findings. Many studies adopted subjective measurements for speed limit, which may vary per individual. Moreover, we cannot exclude inverse causations when interpreting the results, as subjects who are involved in outdoor activity or use active transport may be more likely to perceive the existence of speed limit factors in the neighbourhood. The increasing applications of advanced geospatial and big data technologies may contribute to a more accurate and frequent measurement of the built environment, including speed limit, in future studies.[37–40] We also noticed that the definition of neighbourhood varied across the included studies. Studies have suggested that the choice of different neighbourhood boundaries can influence whether an association is detected.[41] In this review, one study examined four straight-line buffers (i.e., 0.2/0.4/0.8/1.6 km) for the measurement of speed limit and reported that using neighbourhoods defined by a 1.6-km buffer zone explained MVPA better than the smaller buffer sizes.[30] However, a previous study also reported that using the 800-m and

TABLE 3 Associations of speed limit and children's weight-related behaviours and weight status in 16 included studies

First author (year)	Associations of speed limit with weight-related behaviours/outcomes	Main findings of weight-related behaviours/outcomes
Alejandra (2016)[16]	• At the 0.4-km buffer, AT was associated with the presence of posted speed limits (<6% vs. >12%: OR = 0.36). Similar relationships were observed at the 0.8-km buffer.	• The presence of posted speed limits was associated with increased AT.
Carson (2014)[17]	NA	• No association was observed between percentage of low speed roads and PA among children and parents. • No association was observed between percentage of low speed roads and screen time among children and parents.
Carver (2008)[18]	• Total number of speed humps was positively associated with adolescent boys' MVPA during evenings (β = 0.25, p < 0.01). • Adolescent girls residing in neighbourhoods with a medium number (i.e., two or three sets) of traffic/pedestrian lights were more likely to make seven or more walking/cycling trips per week than those whose neighbourhoods had fewer traffic lights (OR = 2.7, 95% CI [1.2, 6.2]).	• The number of speed humps was associated with increased PA during evenings among boys. • A median number of traffic lights were associated with increased AT compared with a low number among girls.
Carver (2010)[19]	• The number of speed humps was positively associated with ΔMVPA among adolescent boys (β = 0.23, p = 0.015) and girls (β = 0.33, p = 0.02) after school. • The number of traffic/pedestrian lights was associated with ΔAT (β = 0.45, p = 0.004) and negatively associated with ΔMVPA (β = −0.88, 95% CI [−1.41, −0.35]) during evenings among younger girls.	• The number of speed humps was associated with a greater change in MVPA. • The number of traffic/pedestrian lights was associated with a positive change in AT and a negative change in MVPA among girls.
Christiansen (2014)[20]	• Perceiving high-speed traffic in the neighbourhood was associated with significantly fewer ATS (OR = 0.50, 95% CI [0.40, 0.61]).	• Perceived high-speed traffic was associated with fewer ATS.
Coughenour (2014)[21]	• The number of high-speed streets was associated with decreased odds of doing vigorous activity in the park (OR = 0.76, p = 0.05).	• The number of high-speed traffic was associated with decreased odds of doing vigorous activity.
Dessing (2016)[22]	• The number of traffic lights was positively associated with route choice during ATS ($OR_{walking}$ = 1.07, 95% CI [1.07, 4.15]; $OR_{cycling}$ = 1.75, 95% CI [1.04, 2.95]).	• No association was observed between street bumps and choice of ATS route. • The number of traffic lights was associated with choice of ATS route.
Ghenadenik (2018)[23]	**NA**	• **No association was observed between presence of traffic-calming features and BMI *z* score.** • **No association was observed between presence of traffic-calming features and waist-to-height ratio.**
Huertas-Delgado (2018)[24]	NA	• No association was observed between perceived traffic speed/speeding and perceived independent mobility/active independent morbidity.
Larouche (2014)[25]	• At schools that identified safe routes to school and where traffic-calming measures were observed, children were	• An interaction was observed for a safe route to school and traffic-calming measures, and the coexistence of both

TABLE 3 (Continued)

First author (year)	Associations of speed limit with weight-related behaviours/outcomes	Main findings of weight-related behaviours/outcomes
	much more likely to engage in ATS compared with schools without these features (OR = 7.87, 95% CI [2.85, 21.76]). If only one of these features was present, the association with ATS was not significant.	factors was associated with increased ATS.
Nguyen (2018)[26]	• Children whose parents perceived moderate or high traffic speeds had higher outdoor active play *z* scores ($\beta_{moderate}$ = 0.35, SE = 0.15; β_{high} = 0.20, SE = 0.10) than children whose parents perceived a low traffic speed. • Neighbourhoods with a moderate traffic-calming index were associated with a lower outdoor play *z* score (β = −0.28, SE = 0.11) than those with low traffic-calming index.	• Perceived traffic speed was positively associated with outdoor activity play. • A moderate traffic-calming index was associated with lower outdoor activity play compared with neighbourhood with low traffic-calming index.
Norah (2010)[27]	NA	• No association was observed between perceived traffic speed/speeding and ATS.
Oliver (2015)[28]	• An increased ratio of high-speed roads around the school was associated with reduced %MVPA during out of school hours on weekdays (β = −2.54, 95% CI [−4.91, −0.16], p = 0.036).	• An increased ratio of high-speed roads around school was negatively associated with out-of-school %MVPA. • Ratio of high-speed roads was not associated with AT.
Oluyomi (2014)[29]	• Children whose parents perceived traffic speed as 'sometimes a problem' or 'not a problem' had higher odds of walking to school compared with those who perceived traffic speed as 'always a problem' ($OR_{sometimes}$ = 1.84, 95% CI [1.03, 3.28]; OR_{not} = 2.86, 95% CI [1.64, 4.99]).	• Perceived traffic speed was negatively associated with ATS.
van Loon (2014)[30]	• The proportion of low speed streets was associated with higher MVPA among girls (β = 7.68, p < 0.05).	• The proportion of low speed streets was positively associated with MVPA among girls but not among boys.
Verhoeven (2017)[31]	• A lower speed limit was associated with a higher intention to cycle (OR = 1.2, 95% CI [1.0, 1.4]). • The presence of speed bumps was associated with a lower intention to cycle (OR = 0.9, 95% CI [0.7, 1.1]).	• The speed limit was negatively associated with the intention to cycle. • The presence of speed bumps was negatively associated with the intention to cycle.

Abbreviations: AT, active transport or active travel; ATS, active transportation to school; BMI, body mass index; MVPA, moderate-to-vigorous physical activity; NA, not available; PA, physical activity.

1000-m road network buffers made it more likely to observe significant associations between built environment and PA than using smaller scales.[41] As inconsistent results were reported for the optimal choice of buffer zone areas, it is therefore necessary for future studies to examine a different range of buffer zone areas and determine the definition of neighbourhood based on real local context when measuring environmental exposures.

This review has some limitations. First, it was limited by the number of available studies, especially the small number of longitudinal studies. Only one included study evaluated the BMI *z* score as an outcome of interest, which has limited our analyses on the association between speed limit and weight-related outcomes. More studies are needed to focus on evaluating not only the associations but also the effects of speed limit on weight-related outcomes. Also, the mediating effects of various types of PA on those (causal) associations are worthy of investigation, so pathways from speed limit in the neighbourhood to children's weight status could be elucidated. Second, it was limited by the reporting quality of most, if not all, included studies.[42] Measures of speed limit varied a lot in the included studies, which has influenced the comparability between studies. Third, the effects of various confounding factors (both individual and environmental) in different studies on our findings, also due to the lack of a

consistent reporting style, could not be fully considered. To better synthesize findings of different studies for supporting evidence-based policy making, confounding factors should be better considered and reported not only in review studies but also in original research. For example, areas with a lower speed limit may be in populated areas with more food outlet destinations, which might be the true reason for higher levels of PA; furthermore, destinations usually include both healthful and unhealthful food outlets, which would pose opposite effects on individuals' weight status.[43–46] Such complexities need to be untangled by using increasingly available novel types of ancillary data (e.g., retail purchasing data and social media data).

5 | CONCLUSIONS

This review suggested a negative association between speed limit and children's PA, especially the use of active transport. More studies are needed to evaluate the association between speed limit and children's weight status, as well as the causality of this association in a longitudinal study design. A more consistent reporting style should be adopted in this type of cross-disciplinary studies, so findings from different studies can be better summarized to form solid evidence for public health policy making.

ACKNOWLEDGEMENTS

This study is supported by research grants from the State Key Laboratory of Urban and Regional Ecology of China (SKLURE2018-2-5) and the National Natural Science Foundation of China (81872641). Peng Jia, Director of the International Initiative on Spatial Lifecourse Epidemiology (ISLE), thanks the Netherlands Organization for Scientific Research, the Royal Netherlands Academy of Arts and Sciences, the Chinese Center for Disease Control and Prevention, and the West China School of Public Health/West China Fourth Hospital in Sichuan University for funding the ISLE and supporting ISLE's research activities.

CONFLICT OF INTEREST

No conflict of interest was declared.

ORCID

Shaoqing Dai https://orcid.org/0000-0003-0858-4728
Peng Jia https://orcid.org/0000-0003-0110-3637

REFERENCES

1. Lobstein T, Baur L, Uauy R. Obesity in children and young people: a crisis in public health. *Obes Rev*. 2004;5(s1):4-85.
2. Ng M, Fleming T, Robinson M, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the global burden of disease study 2013. *Lancet*. 2014;384(9945):766-781.
3. Jia P, Ma S, Qi X, Wang Y. Spatial and temporal changes in prevalence of obesity among Chinese children and adolescents, 1985–2005. *Prev Chronic Dis*. 2019;16:E160.
4. Wabitsch M. Overweight and obesity in European children: definition and diagnostic procedures, risk factors and consequences for later health outcome. *Eur J Pediatr*. 2000;159(1):S8-S13.
5. Jia P. Spatial lifecourse epidemiology. *Lancet Planet Health*. 2019;3(2):e57-e59.
6. Xu F, Jin L, Qin Z, et al. Access to public transport and childhood obesity: A systematic review. *Obesity Reviews*. 2020. https://doi.org/10.1111/obr.12987
7. Wang Z, Zhao L, Huang Q, et al. Traffic-related environmental factors and childhood obesity: A systematic review and meta-analysis. *Obesity Reviews*. 2020. https://doi.org/10.1111/obr.12995
8. Jia P, Zou Y, Wu Z, et al. Street connectivity, physical activity, and childhood obesity: a systematic review and meta-analysis. *Obes Rev*. 2019.
9. Zhang X, Zhang M, Zhao Z, et al. Obesogenic environmental factors of adult obesity in China: a nationally representative cross-sectional study. *Environ Res Lett*. 2020;15(4):044009.
10. Duncan DT, Sharifi M, Melly SJ, et al. Characteristics of walkable built environments and BMI *z*-scores in children: evidence from a large electronic health record database. *Environ Health Perspect*. 2014;122(12):1359-1365.
11. Jerrett M, McConnell R, Chang CCR, et al. Automobile traffic around the home and attained body mass index: a longitudinal cohort study of children aged 10–18 years. *Prev Med*. 2010;50:S50-S58.
12. de Nazelle A, Nieuwenhuijsen MJ, Antó JM, et al. Improving health through policies that promote active travel: a review of evidence to support integrated health impact assessment. *Environ Int*. 2011;37(4):766-777.
13. Jia P, Xue H, Cheng X, Wang Y, Wang Y. Association of neighborhood built environments with childhood obesity: evidence from a 9-year longitudinal, nationally representative survey in the US. *Environ Int*. 2019;128:158-164.
14. Ding D, Sallis JF, Kerr J, Lee S, Rosenberg DE. Neighborhood environment and physical activity among youth: a review. *Am J Prev Med*. 2011;41(4):442-455.
15. Jia P, Cheng X, Xue H, Wang Y. Applications of geographic information systems (GIS) data and methods in obesity-related research. *Obes Rev*. 2017;18(4):400-411.
16. Alejandra J, Erica S, René S-L, et al. A multisite study of environmental correlates of active commuting to school in Mexican children. *J Phys Act Health*. 2016;13(3):325-332.
17. Carson V, Rosu A, Janssen I. A cross-sectional study of the environment, physical activity, and screen time among young children and their parents. *BMC Public Health*. 2014;14(1):61.
18. Carver A, Timperio AF, Crawford DA. Neighborhood road environments and physical activity among youth: the CLAN study. *J Urban Health*. 2008;85(4):532-544.
19. Carver A, Timperio A, Hesketh K, Crawford D. Are safety-related features of the road environment associated with smaller declines in physical activity among youth? *J Urban Health*. 2010;87(1):29-43.
20. Christiansen LB, Toftager M, Schipperijn J, Ersbøll AK, Giles-Corti B, Troelsen J. School site walkability and active school transport—association, mediation and moderation. *J Transport Geogr*. 2014;34:7-15.
21. Coughenour C, Coker L, Bungum TJ. Environmental and social determinants of youth physical activity intensity levels at neighborhood parks in Las Vegas, NV. *J Community Health*. 2014;39(6):1092-1096.
22. Dessing D, de Vries SI, Hegeman G, Verhagen E, van Mechelen W, Pierik FH. Children's route choice during active transportation to school: difference between shortest and actual route. *Int J Behav Nutr Phys Act*. 2016;13(1):48.
23. Ghenadenik AE, Kakinami L, Van Hulst A, Henderson M, Barnett TA. Neighbourhoods and obesity: a prospective study of characteristics of the built environment and their association with adiposity outcomes in children in Montreal, Canada. *Prev Med*. 2018;111:35-40.
24. Huertas-Delgado FJ, Mertens L, Chillon P, Van Dyck D. Parents' and adolescents' perception of traffic- and crime-related safety as

correlates of independent mobility among Belgian adolescents. *PLoS ONE*. 2018;13(9):e0204454.
25. Larouche R, Chaput J-P, Leduc G, et al. A cross-sectional examination of socio-demographic and school-level correlates of children's school travel mode in Ottawa, Canada. *BMC Public Health*. 2014; 14(1):497.
26. Nguyen A, Borghese MM, Janssen I. Pedestrian traffic safety and outdoor active play among 10–13 year olds living in a mid-sized city. *Prev Med Rep*. 2018;10:304-309.
27. Norah MN, Catherine BW. Neighborhood perceptions and active commuting to school among adolescent boys and girls. *J Phys Act Health*. 2010;7(2):257-266.
28. Oliver M, Mavoa S, Badland H, et al. Associations between the neighbourhood built environment and out of school physical activity and active travel: an examination from the kids in the city study. *Health Place*. 2015;36:57-64.
29. Oluyomi AO, Lee C, Nehme E, Dowdy D, Ory MG, Hoelscher DM. Parental safety concerns and active school commute: correlates across multiple domains in the home-to-school journey. *Int J Behav Nutr Phys Act*. 2014;11(1):32.
30. van Loon J, Frank LD, Nettlefold L, Naylor P-J. Youth physical activity and the neighbourhood environment: examining correlates and the role of neighbourhood definition. *Soc Sci Med*. 2014;104:107-115.
31. Verhoeven H, Ghekiere A, Van Cauwenberg J, et al. Which physical and social environmental factors are most important for adolescents' cycling for transport? An experimental study using manipulated photographs. *Int J Behav Nutr Phys Act*. 2017;14(1):108.
32. Pucher J, Buehler R, Bassett DR, Dannenberg AL. Walking and cycling to health: a comparative analysis of city, state, and international data. *Am J Public Health*. 2010;100(10):1986-1992.
33. Brown V, Moodie M, Mantilla Herrera AM, Veerman JL, Carter R. Active transport and obesity prevention—a transportation sector obesity impact scoping review and assessment for Melbourne, Australia. *Prev Med*. 2017;96:49-66.
34. Ewing R, Cervero R. Travel and the built environment: a synthesis. *Transport Res Rec*. 2001;1780(1):87-114.
35. Carver A, Timperio A, Crawford D. Playing it safe: the influence of neighbourhood safety on children's physical activity—a review. *Health Place*. 2008;14(2):217-227.
36. O'Brien M, Jones D, Sloan D, Rustin M. Children's independent spatial mobility in the urban public realm. *Childhood*. 2000;7(3):257-277.
37. Jia P. Integrating kindergartener-specific questionnaires with citizen science to improve child health. *Front Public Health*. 2018;6:236.
38. Jia P, Stein A. Using remote sensing technology to measure environmental determinants of non-communicable diseases. *Int J Epidemiol*. 2017;46(4):1343-1344.
39. Jia P, Stein A, James P, et al. Earth observation: investigating non-communicable diseases from space. *Annu Rev Public Health*. 2019; 40(1):85-104.
40. Jia P, Xue H, Yin L, Stein A, Wang M, Wang Y. Spatial Technologies in Obesity Research: current applications and future promise. *Trends Endocrinol Metab*. 2019;30(3):211-223.
41. Mavoa S, Bagheri N, Koohsari MJ, et al. How do neighbourhood definitions influence the associations between built environment and physical activity? *Int J Environ Res Public Health*. 2019;16(9): 1501.
42. Jia P, Yu C, Remais JV, et al. Spatial lifecourse epidemiology reporting standards (ISLE-ReSt) statement. *Health Place*. 2020;61:102243.
43. Zhou Q, Zhao L, Zhang L, et al. Neighborhood supermarket access and childhood obesity: A systematic review. *Obesity Reviews*. 2019; https://doi.org/10.1111/obr.12937
44. Xin J, Zhao L, Wu T, et al. Association between access to convenience stores and childhood obesity: A systematic review. *Obesity Reviews*. 2019;https://doi.org/10.1111/obr.12908
45. Jia P, Luo M, Li Y, Zheng JS, Xiao Q, Luo J. Fast-food restaurant, unhealthy eating, and childhood obesity: a systematic review and meta-analysis. *Obes Rev*. 2019.
46. Li Y, Luo M, Wu X, et al. Grocery store access and childhood obesity: A systematic review and meta-analysis. *Obesity Reviews*. 2019. https://doi.org/10.1111/obr.12945

SUPPORTING INFORMATION

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

How to cite this article: Luo M, Li H, Pan X, et al. Neighbourhood speed limit and childhood obesity. *Obesity Reviews*. 2020;1–11. https://doi.org/10.1111/obr.13052

APPENDIX A: SEARCH STRATEGY

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

1 'speed limit*' OR 'traffic speed*' OR 'speed bump*' OR 'speed hump*' OR 'speeding traffic' OR 'limit of speed' OR 'speed of traffic' OR 'maximum speed*' OR 'limit speed*' OR 'maximal speed*' OR 'vehicle speed*' OR 'road speed*' OR 'street speed*' OR 'traffic calming' OR 'stop sign*' OR 'traffic obstacle*' OR 'speed zone sign*' OR 'chicane*' OR 'traffic choker*' OR 'children playing sign*' OR 'school zone sign*' OR 'pedestrian walking sign*' OR 'speed restriction*' OR 'high-speed street*' OR 'high-speed road*' OR 'speed road*' OR 'speed street*'
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'.