Neighbourhood speed limit and childhood obesity

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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

Received: 5 May 2020 Accepted: 7 May 2020
DOI: 10.1111/obr.13052

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1 | INTRODUCTION

Childhood obesity remains a global public health problem, and the prevalence of obesity has been steadily increasing over the past few decades. 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.

It is widely reported that the neighbourhood-built environment may shape individual behaviours and interacts with individual characteristics to affect their weight status. 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. 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. However, speed limit has been measured differently in previous studies, which may cause us to draw robust conclusions from them. 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).
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>
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<tr>
<th>First author (year)</th>
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<tr>
<td>Alejandra (2016)&lt;sup&gt;16&lt;/sup&gt;</td>
<td>Puerto Vallarta, Guadalajara and Mexico City, Mexico [C3]</td>
<td>1191</td>
<td>NA</td>
<td>C</td>
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<td>Carson (2014)&lt;sup&gt;17&lt;/sup&gt;</td>
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<td>Carver (2008)&lt;sup&gt;18&lt;/sup&gt;</td>
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<td>8–9 in 2004 and 13–15 in 2006</td>
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<td>Carver (2010)&lt;sup&gt;19&lt;/sup&gt;</td>
<td>Melbourne, Australia [C]</td>
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<td>8–9 in 2004 and 13–15 in 2006</td>
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<td>Christiansen (2014)&lt;sup&gt;20&lt;/sup&gt;</td>
<td>Southern Denmark [S]</td>
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<td>Ghenadenik (2018)&lt;sup&gt;23&lt;/sup&gt;</td>
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<td>Larouche (2014)&lt;sup&gt;25&lt;/sup&gt;</td>
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<td>567</td>
<td>9–11, 10 average in 2012–2013</td>
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<td>Students in Grade 5 from 26 schools</td>
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<tr>
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<td>Flanders, Belgium [S]</td>
<td>882</td>
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<td>Students in first to fourth year from 12 secondary schools</td>
<td>Logistic regression</td>
</tr>
</tbody>
</table>

Abbreviation: NA, not available.

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

<sup>b</sup>Study design: C, cross-sectional; L, longitudinal.
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<td>Carson (2014)</td>
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<td>Carver (2008)</td>
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<td>AT frequency (walking and cycling, parent-reported for children and self-reported for adolescents), in two categories: ≥ 7 times per week and &lt;7 times per week. PA (average duration of MVPA outside school hours) measured using accelerometer.</td>
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<tr>
<td>Carver (2010)</td>
<td>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)</td>
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<td>Choice of ATS route assessed by GPS (actual route vs. shortest route).</td>
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<td>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</td>
<td>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</td>
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<td>Huertas-Delgado (2018)</td>
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<tr>
<td>Oluyomi (2014)</td>
<td>Parents' perceived traffic speed concerns en route to school (in three categories: always a problem, sometimes a problem and no problem)</td>
<td>Individual variables: ethnicity, any type of public assistance in family and car ownership in family Environment variables: NA</td>
<td>Parent-reported AT mode (walking to school)</td>
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<tr>
<td>van Loon (2014)</td>
<td>Proportion of low speed limit streets (≤30 km h⁻¹) in 0.2-/0.4-/0.8-/1.6-km home buffer</td>
<td>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</td>
<td>PA (average minutes of MVPA per day) measured using accelerometers</td>
</tr>
</tbody>
</table>
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. 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.

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. 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.

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. 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. 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. However, a previous study also reported that using the 800-m and

### TABLE 2 (Continued)

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<td>• Adolescents’ perception of speed limit (30 vs. 50 km h⁻¹) • Presence of speed bumps</td>
<td>• Individual variables: NA • Environment variables: NA</td>
<td>• Intention to cycle for transport</td>
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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.
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<tr>
<td>Alejandra (2016)\textsuperscript{16}</td>
<td>• At the 0.4-km buffer, AT was associated with the presence of posted speed limits (&lt;6% vs. &gt;12%: OR = 0.36). Similar relationships were observed at the 0.8-km buffer.</td>
<td>• The presence of posted speed limits was associated with increased AT.</td>
</tr>
<tr>
<td>Carson (2014)\textsuperscript{17}</td>
<td>NA</td>
<td>• 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.</td>
</tr>
<tr>
<td>Carver (2008)\textsuperscript{18}</td>
<td>• Total number of speed humps was positively associated with adolescent boys’ MVPA during evenings ($\beta$ = 0.25, $p &lt; 0.01$). • 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]).</td>
<td>• 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.</td>
</tr>
<tr>
<td>Carver (2010)\textsuperscript{19}</td>
<td>• The number of speed humps was positively associated with $\Delta$MVPA among adolescent boys ($\beta$ = 0.23, $p = 0.015$) and girls ($\beta$ = 0.33, $p = 0.02$) after school. • The number of traffic/pedestrian lights was associated with $\Delta$AT ($\beta$ = 0.45, $p = 0.004$) and negatively associated with $\Delta$MVPA ($\beta$ = −0.88, 95% CI [−1.41, −0.35]) during evenings among younger girls.</td>
<td>• 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.</td>
</tr>
<tr>
<td>Christiansen (2014)\textsuperscript{20}</td>
<td>• Perceiving high-speed traffic in the neighbourhood was associated with significantly fewer ATS (OR = 0.50, 95% CI [0.40, 0.61]).</td>
<td>• Perceived high-speed traffic was associated with fewer ATS.</td>
</tr>
<tr>
<td>Coughenour (2014)\textsuperscript{21}</td>
<td>• The number of high-speed streets was associated with decreased odds of doing vigorous activity in the park (OR = 0.76, $p = 0.05$).</td>
<td>• The number of high-speed traffic was associated with decreased odds of doing vigorous activity.</td>
</tr>
<tr>
<td>Dessing (2016)\textsuperscript{22}</td>
<td>• 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]).</td>
<td>• No association was observed between street bumps and choice of ATS route. • The number of traffic lights was associated with choice of ATS route.</td>
</tr>
<tr>
<td>Ghenadenik (2018)\textsuperscript{23}</td>
<td>NA</td>
<td>• 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.</td>
</tr>
<tr>
<td>Huertas-Delgado (2018)\textsuperscript{24}</td>
<td>NA</td>
<td>• No association was observed between perceived traffic speed/speeding and perceived independent mobility/active independent morbidity.</td>
</tr>
<tr>
<td>Larouche (2014)\textsuperscript{25}</td>
<td>• At schools that identified safe routes to school and where traffic-calming measures were observed, children were</td>
<td>• An interaction was observed for a safe route to school and traffic-calming measures, and the coexistence of both</td>
</tr>
</tbody>
</table>
1000-m road network buffers made it more likely to observe significant associations between built environment and PA than using smaller scales. 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. 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. 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-S) 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.

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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', 'adolescent', 'youth', 'teen', 'kid', 'young', 'youngster', 'minor', 'student', 'pupil', 'pediatric', 'preschooler', 'pre-schooler', 'schoolchild', 'school-child', 'school age', 'school-age', 'school age':