

**SUPPLEMENT ARTICLE**

# Association between neighborhood aesthetics and childhood obesity

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**Summary**

The lack of neighbourhood aesthetics (e.g. public art and well-maintained properties) may reduce walkability in the neighbourhood and increase the risk of childhood obesity. In this study, a literature search was conducted in the Cochrane Library, PubMed and Web of Science for articles published before January 1, 2019 to analyse the associations between neighbourhood aesthetics and weight-related behaviours and outcomes among children and adolescents aged <18. One cohort study and 24 cross-sectional studies, conducted in 10 countries with a median sample size of 1124 were identified. Neighbourhood aesthetics was more commonly assessed by self-reported or parent-reported perceptions than objective measurements. Eighteen of the 25 included studies analysed physical activity (PA) as the outcome of interests, eight studies analysed active transport to school (ATS), and eight studies analysed weight status, including body mass index and overweight/obesity status. About two-thirds

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of studies reported non-significant associations when using PA and weight status as outcomes, and half of studies showed that neighbourhood aesthetics is associated with increased use of ATS. The rest of the studies reported mixed findings with slightly more studies showing neighbourhood aesthetics may promote PA or reduce weight. Better designed studies are necessary to achieve a robust understanding of this epidemiological relationship in the future.

**KEYWORDS**

aesthetics, built environment, obesity, physical activity

## 1 | INTRODUCTION

Obesity is a leading cause of chronic disorders and premature mortality worldwide, and the growth rate of childhood obesity continues to increase in many countries.<sup>1-3</sup> A systematic review of morbidity in adulthood showed that obesity in children and adolescents had adverse effects on premature mortality in adulthood, late disability and cardiac metabolic diseases.<sup>4</sup> It is important to study modifiable determinants of obesity to maintain and improve children's health.<sup>5</sup> Among the known determinants, the neighbourhood environment in which one lives and works shows both positive and negative impacts on an individual's weight status. Such environments are referred as either obesogenic or leptogenic, corresponding to being a risk factor or protective factor for obesity respectively.<sup>6</sup> The majority of existing studies on obesogenic environments analysed environmental factors that are measurable at high-level urban scales, such as street connectivity, green space availability and density of food venues. However, neighbourhood aesthetics, although mentioned as an important feature influencing people's willingness to exercise, walk or stay, is generally ignored in these studies.<sup>7-13</sup>

Neighbourhood aesthetics presents itself through various aspects. Visual cues such as public art and well-maintained properties in the neighbourhood may promote physical activity (PA) and reduce the risk for childhood overweight and obesity.<sup>14-16</sup> Neighbourhood aesthetics can be measured by perceptions of 'whether there are many interesting things to look at while walking in my neighborhood',<sup>17</sup> 'presence of aesthetic features (e.g. attractive buildings, streets free from litter and graffiti)',<sup>18</sup> or 'presence of graffiti, garbage, litter, rundown or dilapidated housing, broken windows, poorly kept or other signs of vandalism'.<sup>19</sup> However, to the best knowledge of the authors, there has not been any literature review on the association between the neighbourhood aesthetics and the childhood obesity. Given that neighbourhood aesthetics may influence children's playability and daily activity, it is important to understand the association between neighbourhood aesthetics and children's weight-related behaviours and outcomes.<sup>20-22</sup>

Against this background, this study aimed to review the existing evidence on the association between neighbourhood aesthetics and weight-related behaviours and outcomes among children and

adolescents. This study attempts to direct the focus of obesogenic environmental research to an understudied but ascending area.

## 2 | METHODS

We conducted a systematic review in compliant with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A keyword search was performed in three electronic bibliographic databases: Cochrane Library, PubMed and Web of Science to include peer-reviewed articles published from the inception of an electronic bibliographic database to January 1, 2019. The search strategy included all possible combinations of keywords related to neighbourhood aesthetics, children, and weight-related behaviours or outcomes. The specific search strategy is provided in Appendix A.

### 2.1 | Study selection

We proceed the study selection process of this review based on the following criteria: (1) study design: cross-sectional or longitudinal including prospective and retrospective cohort studies; (2) study subject: children and adolescents aged <18; (3) exposure of interest: neighbourhood aesthetics; (4) outcome of interest: weight-related behaviours (e.g. PA and sedentary behaviour) or outcomes (e.g. overweight and obesity measured by body mass index [BMI], and waist-to-hip ratio); (5) article type: peer-reviewed original epidemiologic research rather than reviews, commentaries, letters, editorials or study/review protocols and (6) language: English.

Titles and abstracts of the identified articles were screened against the study selection criteria by two reviewers, and potentially relevant articles were retrieved for an evaluation of the full text. Two reviewers independently conducted the title and abstract screening and identified potentially relevant articles for the full-text review. Inter-rater agreement was assessed by using Cohen's kappa ( $\kappa = 0.8$ ). Discrepancies were compiled by the third reviewer and screened by the fourth reviewer. Four reviewers jointly discussed and determined the list of articles for the full-text review. Then, two reviewers independently reviewed the full texts of all articles in the list and

determined the final pool of articles included in the review. Inter-rater agreement was again assessed by Cohen's kappa ( $\kappa = 0.9$ ).

## 2.2 | Data extraction and preparation

Two reviewers independently extracted data from each included study, and two different reviewers resolved the discrepancies. A standardized data extraction form was used to collect methodological and outcome variables from each selected study, including author names, year of publication, study design, study area, sample size, sample characteristics, statistical models, and sample age at baseline, follow-up years, number of repeated measures for cohort studies, as well as measures of the neighbourhood aesthetics, weight-related behaviours and outcomes, and key findings on the associations.

## 2.3 | Study quality assessment

The quality of each included study was assessed using the Agency for Healthcare Research and Quality (AHRQ) checklist for cross-sectional studies and the Newcastle-Ottawa Scale (NOS) quality assessment scale for longitudinal studies (Appendix B). The AHRQ checklist rates each cross-sectional study based on 11 criteria, where a score of 0 or 1 was similarly assigned to each criterion, and a study-specific global score ranging from 0 to 11 was calculated by summing up scores across all criteria. The NOS rates each cohort study based on eight

criteria, where a study can be awarded a maximum of one point for each numbered item in Selection and Outcome categories, and a maximum of two points for the item in Comparability category; a study-specific global score ranging from 0 to 9 was calculated by summing up scores across all criteria. The study quality assessment helped measure the strength of scientific evidence but was not used to determine the inclusion of studies.

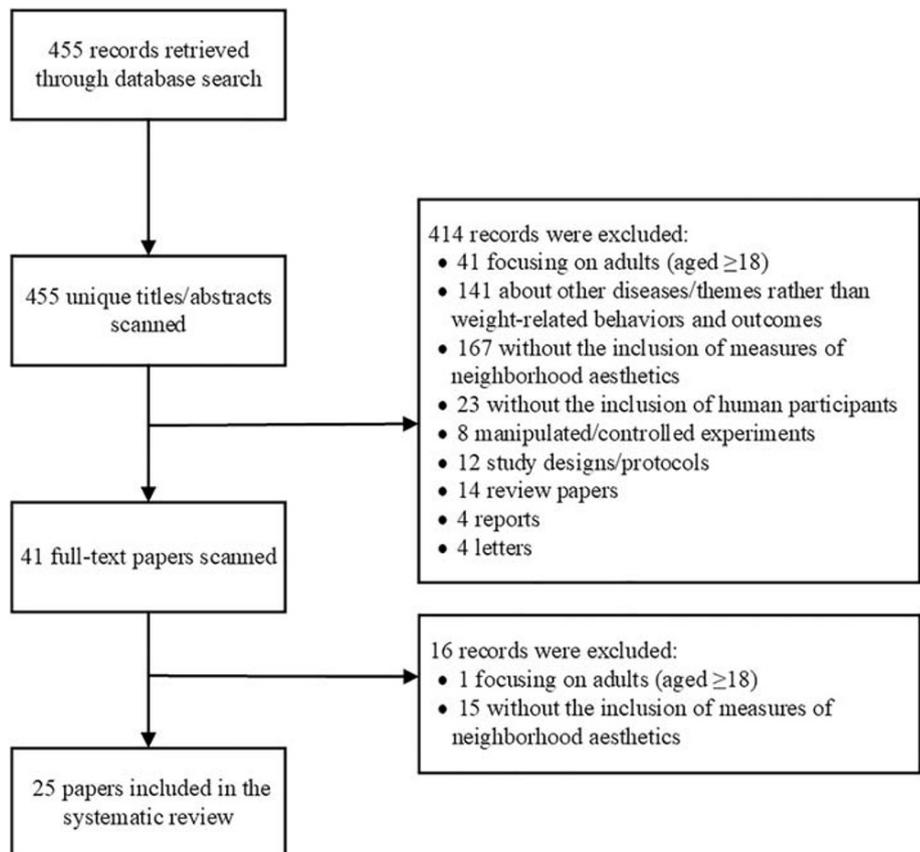
## 3 | RESULTS

### 3.1 | Study selection

Figure 1 shows the study selection flowchart. A total of 455 articles were identified through the keyword search. After the title and abstract screening, 41 articles were included. After the full-text screening, 16 articles against the study selection criteria were removed. The remaining 25 studies that examined the relationship between neighbourhood aesthetics and children's weight-related behaviours and/or outcomes were included in this review.

### 3.2 | Study characteristics

The key characteristics of the 25 studies are summarized (Table 1). Although the earliest study was published in 2006, the majority of included studies ( $n = 19$ ) were published during 2010–2018. Studies



**FIGURE 1** Study inclusion and exclusion flowchart

**TABLE 1** Basic characteristics of 25 studies included

First author (year)	Study design <sup>a</sup>	Study area [scale] <sup>b</sup>	Sample size	Sample age (years, range and/or mean $\pm$ SD) <sup>c</sup>	Sample characteristics (follow-up status for longitudinal studies)	Statistical model
Carson (2014) <sup>23</sup>	C	Kingston, Canada [C]	511	0–5 in 2011	Pre-school students	Multilevel linear regression
Datar (2015) <sup>24</sup>	C	USA [N]	903	12–13 (13.2) in 2013	Children from families of army enlisted personnel located at 12 army installations	Multivariate linear regression
Durand (2012) <sup>25</sup>	C	San Bernardino County, California, USA [CT]	365	11.7	Students in grades 4–8	Multivariate linear regression and multivariate logistic regression
Evenson (2006) <sup>14</sup>	C	Baltimore, Columbia, New Orleans, Minneapolis, San Diego, Tucson, USA [CT6]	610	10–15 in 2002	Girl students in grade 6–8	Multilevel logistic regression
Grafova (2008) <sup>26</sup>	C	USA [N]	2483	5–18 (11.8 $\pm$ 3.72) in 2002–2003	A nationally representative sample of children	Multivariate logistic regression
Haese (2015) <sup>27</sup>	C	Belgium [N]	606	9–12 (10.1 $\pm$ 0.9) in 2011–2013	Students from 18 primary school students	Multilevel logistic regression
Hulst (2013) <sup>28</sup>	C	Quebec, Canada [S]	417	8–10 (9.57 $\pm$ 0.9) in 2015	Children in grade 2–5 from primary school and with a parental history of obesity	Multilevel logistic regression
Hume (2007) <sup>29</sup>	C	Melbourne, Australia [C]	280	10 (10.07 $\pm$ 0.36)	Students in grade 5 from 3 elementary schools located in the low-socio-economic status areas	Multivariate linear regression
Kasehagen (2012) <sup>19</sup>	C	USA [N]	45 392	10–17 in 2007	Children whose parent or guardian participated in a national telephone survey	Multilevel logistic regression
Laxer (2013) <sup>30</sup>	C	Canada [N]	6626	11–15 in 2009–2010	Students in grades 6–10 from 436 schools	Multilevel logistic regression
Lopes (2014) <sup>31</sup>	C	Curitiba, Brazil [C]	1611	14–18 in 2006	High school students	Multivariate logistic regression
Loureiro (2010) <sup>32</sup>	C	Portugal [N]	4877	14 in 2006	Students from 136 schools	Multivariate logistic regression
Machado-Rodrigues (2014) <sup>33</sup>	C	Portugal [N]	1886	7–9 (8.48 $\pm$ 0.87) in 2009–2010	Girl students	Multivariate linear regression
Meester (2014) <sup>18</sup>	C	Flanders, Belgium [N]	736	10–12 (11.2 $\pm$ 0.5) in 2010	Students from 44 elementary schools	Multivariate linear regression
Mota (2007) <sup>17</sup>	C	Aveiro District, Portugal [S]	1561	14.7 $\pm$ 1.6 in 2004	Students in grades 7–12 from 11 urban public secondary schools	Logistic regression
Nelson (2009) <sup>34</sup>	C	Ireland [N]	4587	15–17 in 2003–2005	Students from 61 schools	Multivariate logistic regression
Nelson (2010) <sup>35</sup>	C	Ireland [N]	4720	15–17 (16.04 $\pm$ 0.66) in 2003–2005	Students from 61 schools	Multivariate logistic regression

**TABLE 1** (Continued)

First author (year)	Study design <sup>a</sup>	Study area [scale] <sup>b</sup>	Sample size	Sample age (years, range and/or mean $\pm$ SD) <sup>c</sup>	Sample characteristics (follow-up status for longitudinal studies)	Statistical model
Noonan (2016) <sup>16</sup>	C	Liverpool, UK [C]	194	9–10 in 2014	Students from 10 primary schools	Multivariate linear regression
Noonan (2017) <sup>36</sup>	C	Liverpool, UK[C]	194	9–10 (9.96 $\pm$ 0.30) in 2014	Students from 10 primary schools	Multivariate logistic regression
Oliveira (2014) <sup>37</sup>	C	S. Miguel, Terceira, Faial, Pico, S. Jorge, and Graciosa, Portugal [CT6]	948	15–18 (16.5 $\pm$ 0.9)	Students	Multilevel logistic regression
Page (2010) <sup>38</sup>	C	UK [C]	1300	10–11 in 2006–2008	Students from 23 primary schools students	Multilevel logistic regression
Santos (2009) <sup>39</sup>	C	Aveiro District, Portugal [S]	1124	12–18 in 2005	Students from three middle schools and two high schools	Multivariate logistic regression
Schmidt (2015) <sup>40</sup>	L	Netherlands [N]	1887	4–5 (5.0 $\pm$ 0.5) in 2000–2002	Participants of the KOALA Birth Cohort Study	Generalized Estimating Equations
Voorhees (2010) <sup>41</sup>	C	Baltimore, Minneapolis/St. Paul, Columbia, Tucson, San Diego, and New Orleans, USA [C6]	890	11–12 in 2003	Healthy girl students in grade 6 from 36 schools	Nested mixed effects logistic regression
Wong (2016) <sup>15</sup>	C	Hong Kong, China[C]	1265	8–12 in 2011–2012	Students in grade 3–5 from 24 primary schools	Multilevel linear regression

<sup>a</sup>Study design: C – Cross-sectional study; L – Longitudinal study.

<sup>b</sup>Study scale: [N] – National; [S] – State (e.g. in the United States) or equivalent unit (e.g. province in China and Canada); [CT] – County or equivalent unit; [CTn] – n counties or equivalent units; [C] – City; [Cn] – n cities.

<sup>c</sup>Sample age: Age in baseline year for longitudinal studies or mean age/range in survey year for cross-sectional studies.

were conducted in various countries, among which six studies were conducted in the United States, five in Portugal, three in each of Canada and the United Kingdom, two in each of Belgium and Ireland, and one in each of Australia, Brazil, China, and the Netherlands. Most of the studies were conducted at national levels ( $n = 11$ ), and the rest of studies were conducted at state/province (or equivalent) levels ( $n = 3$ ), city levels ( $n = 8$ ) or county levels ( $n = 3$ ). They were largely cross-sectional ( $n = 24$ ), and only one longitudinal study was included. Most of the studies recruited student samples from schools ( $n = 21$ ), with one of them focused on pre-school students, 10 focused on elementary school students, seven focused on middle school or high school students, and three studies focused on students from both elementary and middle school. Sample sizes ranged widely from 194 to more than 45 000 participants, with a median of 1124.

### 3.3 | Measures of neighbourhood aesthetics and weight-related behaviours and outcomes

Neighbourhood aesthetics was defined from two aspects: the presence of features that improved neighbourhood aesthetics (e.g. trees,

green spaces, attractive nature sights, attractive buildings and interesting things to look at) and the presence of detracting elements (e.g. garbage, litter, graffiti, depilated buildings and vandalism). In this review, 12 studies evaluated the neighbourhood aesthetics based on presence of features that improved neighbourhood aesthetics, six studies based on presence of detracting elements, and seven studies analysed both aspects (Table 2). Measures of neighbourhood aesthetics were based on surveys on parental perceptions in 10 studies and children's perceptions in 11 studies. In addition, four studies conducted on-site or Geographic Information Systems (GIS) assessment of neighbourhood aesthetics by trained observers. Among studies that measured neighbourhood aesthetics based on subjective perceptions, 14 studies adopted items from the Neighbourhood Environment Walkability Scale (NEWS) questionnaire, and seven studies used other questionnaires.

In terms of outcome measures, four studies used BMI or BMI z-score, four studies used overweight/obesity, and one study also measured waist circumference, and all these studies conducted anthropometric measurements for data collection. Twenty-one studies measured weight-related behaviours as the outcomes of interest, and PA was studied in 18 studies in which PA was analysed as PA score

**TABLE 2** Measures of neighbourhood aesthetics and weight-related behaviours and outcomes in 25 included studies

First author (year)	Measures of neighbourhood aesthetics	Other environmental factors adjusted for in the model	Measures of weight-related behaviours	Measures of weight-related outcomes
Carson (2014) <sup>23</sup>	<ul style="list-style-type: none"> <li>• GIS assessed neighbourhood aesthetics, including condition of buildings and grounds, presence of graffiti and presence of litter in home postal zone</li> </ul>	<ul style="list-style-type: none"> <li>• Neighbourhood SES</li> <li>• Built environment: walkability z-score, outdoor play/activity space z-score, recreation facilities, distance to the closest park and yard space at home</li> <li>• Traffic safety (road speed)</li> </ul>	<ul style="list-style-type: none"> <li>• Parent-reported PA score of children and PA score of parents assessed using questionnaire based on duration and frequency of activities</li> <li>• Parent-reported screen time of children and parents assessed using questionnaire</li> </ul>	NA
Datar (2015) <sup>24</sup>	<ul style="list-style-type: none"> <li>• Parental perception of neighbourhood aesthetics, based on presence of trees and interesting things to look at in NEWS-Y questionnaire</li> </ul>	<ul style="list-style-type: none"> <li>• Built environment: land-use mix (diversity and accessibility), recreation facilities, residential density, street connectivity and walking/cycling facilities</li> <li>• Pedestrian/automobile traffic safety</li> <li>• Crime safety</li> </ul>	<ul style="list-style-type: none"> <li>• Self-reported PA frequency (minutes of moderate PA and vigorous PA per week)</li> </ul>	<ul style="list-style-type: none"> <li>• Self-reported BMI z-score (based on 2000 CDC growth charts)</li> </ul>
Durand (2012) <sup>25</sup>	<ul style="list-style-type: none"> <li>• Parental perception of neighbourhood aesthetics, based on presence of attractive natural sights and attractive buildings/homes in NEWS questionnaire</li> </ul>	<ul style="list-style-type: none"> <li>• Community of residence</li> </ul>	<ul style="list-style-type: none"> <li>• PA (minutes of MVPA per day) measured using accelerometers</li> <li>• Self-reported ATS mode, including active commuting (walking or cycling) and passive commuting (car or bus)</li> </ul>	NA
Evenson (2006) <sup>14</sup>	<ul style="list-style-type: none"> <li>• Children's perception of neighbourhood aesthetics, based on presence of trees along the streets, many interesting things to look at while walking, a lot of exhaust fumes or other bad smells and garbage or litter in modified NEWS questionnaire</li> </ul>	NA	<ul style="list-style-type: none"> <li>• Self-reported PA score assessed by the PAQ-C</li> <li>• Self-reported ATS mode (walking, cycling or skating)</li> </ul>	NA
Grafova (2008) <sup>26</sup>	<ul style="list-style-type: none"> <li>• Interviewer recorded observation on the condition and upkeep of the buildings and street surface on the block, and the amount of garbage, broken glass, drug-related paraphernalia, condoms, beer containers and cigarette butts in neighbourhood (summarized as neighbourhood physical disorder)</li> </ul>	<ul style="list-style-type: none"> <li>• Built environment: population density, alpha index of connectivity, urban design and pedestrian danger</li> <li>• Food environment: restaurant density, grocery store density, convenience store density and specialty food store density</li> </ul>	NA	<ul style="list-style-type: none"> <li>• Overweight based on measured BMI <math>\geq</math> 95th percentile in CDC growth charts</li> </ul>
Haese (2015) <sup>27</sup>	<ul style="list-style-type: none"> <li>• Parental perception of neighbourhood aesthetics, based on presence of trees and interesting</li> </ul>	<ul style="list-style-type: none"> <li>• Built environment: land use mix (accessibility and diversity), residential density, street connectivity, walk/cycle</li> </ul>	<ul style="list-style-type: none"> <li>• Parent-reported PA frequency in public recreation places, garden, and nearby streets/sidewalks;</li> </ul>	NA

TABLE 2 (Continued)

First author (year)	Measures of neighbourhood aesthetics	Other environmental factors adjusted for in the model	Measures of weight-related behaviours	Measures of weight-related outcomes
	things to look at in NEWS-Y questionnaire	facilities, recreation facilities • Traffic safety • Crime safety	• Percentage of daily MVPA assessed using accelerometer	
Hulst (2013) <sup>28</sup>	• Neighbourhood aesthetics were assessed by trained observers from presence of graffiti and presence of enough litter to fill up an average size disposable grocery condition for up to 10 street segments in home neighbourhood (summarized as neighbourhood physical disorder and deterioration)	• Neighbourhood poverty • Neighbourhood prestige • Level of urbanicity • Traffic • Pedestrian friendliness	NA	• Obesity (based on measured BMI ≥ 85th percentile in CDC growth charts)
Hume (2007) <sup>29</sup>	• Children's perception of neighbourhood aesthetics, based on presence of lots of nice houses, lots of graffiti and lots of litter and rubbish in a validated questionnaire	• Built environment: number of accessible destinations, whether it is easy to walk/cycle around in model for boys • Whether having friends living in walking/cycling distance in model for girls	• PA (counts per day) assessed using accelerometers. • Self-reported frequencies of walking the dog, walking for exercise, and walking to and from school in a typical week during the previous month	NA
Kasehagen (2012) <sup>19</sup>	• Parental perception of neighbourhood aesthetics, based on presence of detracting elements, including litter, dilapidated housing and vandalism	• Built environment: presence of sidewalks, parks and recreation centres	• Parent-reported PA frequency (number of days participated in PA for at least 20 min in categories of <5 days and ≥5 days)	NA
Laxer (2013) <sup>30</sup>	• GIS assessed neighbourhood aesthetics, including condition of buildings and grounds, graffiti and presence of litter in a 1-km straight-line school buffer zone	• Built environment: walkability score, outdoor play areas, yards at home, density of cul-de-sacs, park space and wooded areas recreation facility density • Average temperature • Average precipitation	• Self-reported PA frequency (in categories of physically active and physically inactive)	NA
Lopes (2014) <sup>31</sup>	• Children's perception of neighbourhood aesthetics, based on whether there are a lot of interesting things to be seen when I take a walk in NEWS-Y questionnaire	• Built environment: presence of places I like, sidewalks, biking tracks or walking trails, and street light • Perception of traffic safety and crime • Perception of seeing people walking and seeing people of my age playing or exercising	• Self-reported PA frequency (whether fulfil five or more days a week for at least 60 min or at least 20 min once a week)	NA
Loureiro (2010) <sup>32</sup>	• Children's perception of whether it is a beautiful area	• Built environment: recreation facilities, street connectivity, public services (health centre, youth centre, etc.)	• Self-reported frequency of PA, exercise, indoor sports and outdoor sports	NA

(Continues)

TABLE 2 (Continued)

First author (year)	Measures of neighbourhood aesthetics	Other environmental factors adjusted for in the model	Measures of weight-related behaviours	Measures of weight-related outcomes
		<ul style="list-style-type: none"> <li>• Traffic safety</li> <li>• Crime safety</li> </ul>		
Machado-Rodrigues (2014) <sup>33</sup>	<ul style="list-style-type: none"> <li>• Parental perception of neighbourhood aesthetics, based on whether there are many interesting things to look at while walking in NEWS questionnaire</li> </ul>	<ul style="list-style-type: none"> <li>• Built environment: accessibility to destination, connectivity of street network, infrastructure for walking and cycling and recreation facilities</li> <li>• Neighbourhood safety</li> <li>• Social environment</li> </ul>	<ul style="list-style-type: none"> <li>• Self-reported PA, including time outside school and minutes per week spent in organized sports outside of school</li> <li>• Self-reported mode and duration of travel to/from school (walking or cycling)</li> </ul>	<ul style="list-style-type: none"> <li>• Measured BMI</li> </ul>
Meester (2014) <sup>18</sup>	<ul style="list-style-type: none"> <li>• Parental perception of neighbourhood aesthetics, based on presence of green spaces, attractive buildings, streets free from litter and streets free from graffiti in modified NEWS-Y questionnaire</li> </ul>	<ul style="list-style-type: none"> <li>• Built environment: land-use mix (diversity and access), proximity to recreation facilities, street connectivity and walking/cycling facilities</li> <li>• Pedestrian/automobile traffic</li> <li>• Safety and crime safety</li> </ul>	<ul style="list-style-type: none"> <li>• Self-reported PA assessed by the FPAQ, including active transport to and from school, walking/cycling for transport during leisure time and overall level of PA</li> <li>• Measured daily number of step counts</li> </ul>	NA
Mota (2007) <sup>17</sup>	<ul style="list-style-type: none"> <li>• Children's perception of neighbourhood aesthetics, based on whether there are many interesting things to look at while walking in NEWS questionnaire</li> </ul>	NA	<ul style="list-style-type: none"> <li>• Self-reported leisure activities (in categories of active and non-active)</li> </ul>	NA
Nelson (2009) <sup>34</sup>	<ul style="list-style-type: none"> <li>• Children's perception of neighbourhood aesthetics, based on presence of litter and whether there are trees along the streets in my neighbourhood in modified NEWS questionnaire</li> </ul>	<ul style="list-style-type: none"> <li>• Built environment: facilities for walking and cycling, street connectivity and convenient facilities</li> <li>• Food environment: proximity to shops and facilities and proximal food locations</li> <li>• Population density</li> <li>• Pedestrian/traffic safety</li> <li>• Personal safety</li> </ul>	NA	<ul style="list-style-type: none"> <li>• Overweight/obesity (based on measured BMI using international age- and gender-specific criteria)</li> </ul>
Nelson (2010) <sup>35</sup>	<ul style="list-style-type: none"> <li>• Children's perception of neighbourhood aesthetics, based on presence of litter and whether there are trees along the streets in my neighbourhood in modified NEWS questionnaire</li> </ul>	<ul style="list-style-type: none"> <li>• Built environment: land-use mix (diversity and accessibility), proximity to recreation facilities, street connectivity and walking/cycling facilities;</li> <li>• Pedestrian/automobile traffic safety</li> <li>• Crime safety</li> </ul>	<ul style="list-style-type: none"> <li>• Self-reported usual ATS mode (walking or cycling)</li> </ul>	NA
Noonan (2016) <sup>16</sup>	<ul style="list-style-type: none"> <li>• Parental perception of neighbourhood aesthetics, based on whether there are trees and interesting things to look at in NEWS-Y questionnaire</li> </ul>	<ul style="list-style-type: none"> <li>• Crime safety</li> </ul>	<ul style="list-style-type: none"> <li>• Self-reported PA score assessed using the PAQ-C</li> <li>• Cardiorespiratory fitness assessed using the Sports Coach UK 20 m multistage shuttle run test</li> </ul>	<ul style="list-style-type: none"> <li>• Measured BMI z-score</li> <li>• Measured waist circumference</li> </ul>
Noonan		NA		NA

TABLE 2 (Continued)

First author (year)	Measures of neighbourhood aesthetics	Other environmental factors adjusted for in the model	Measures of weight-related behaviours	Measures of weight-related outcomes
(2017) <sup>36</sup>	<ul style="list-style-type: none"> <li>Parental perception of neighbourhood aesthetics, based on whether there are trees and interesting things to look at in NEWS-Y questionnaire</li> </ul>		<ul style="list-style-type: none"> <li>Self-reported ATS mode (active or passive)</li> </ul>	
Oliveira (2014) <sup>37</sup>	<ul style="list-style-type: none"> <li>Children's perception of neighbourhood aesthetics, based on whether there are trees along the streets, whether there are many interesting things to look at while walking, whether there are not a lot of exhaust fumes or other bad smells and whether there usually is not garbage or litter in neighbourhood in modified NEWS questionnaire</li> </ul>	<ul style="list-style-type: none"> <li>Facilities</li> <li>Transportation</li> <li>Safety</li> </ul>	<ul style="list-style-type: none"> <li>PA (active or inactive) measured using a sealed pedometer worn over seven consecutive days</li> </ul>	NA
Page (2010) <sup>38</sup>	<ul style="list-style-type: none"> <li>Children's perception of neighbourhood aesthetics, based on presence of litter, graffiti, vandalism and dog fouling</li> </ul>	NA	<ul style="list-style-type: none"> <li>Self-reported PA frequency</li> <li>Self-reported ATS mode (active or passive)</li> </ul>	NA
Santos (2009) <sup>39</sup>	<ul style="list-style-type: none"> <li>Children's perception of neighbourhood aesthetics, based on whether there are trees and interesting things to look at in NEWS-Y questionnaire</li> </ul>	<ul style="list-style-type: none"> <li>Built environment: presence of free or low-cost recreation facilities, perception of places to go within easy walking distance of my home</li> <li>Perception of seeing many people being physically active</li> </ul>	<ul style="list-style-type: none"> <li>Self-reported PA index based on frequency of PA outside school</li> </ul>	NA
Schmidt (2015) <sup>40</sup>	<ul style="list-style-type: none"> <li>Parental perception of neighbourhood aesthetics, based on availability of green, amount of litter, presence of residential blocks, presence of detached houses, presence of abandoned houses, amount of noise, and amount of dog faeces in a validated questionnaire.</li> </ul>	<ul style="list-style-type: none"> <li>Physical environment</li> <li>Social environment</li> <li>Perception of safety</li> </ul>	NA	<ul style="list-style-type: none"> <li>Parents measured BMI z-score based on the Dutch reference population surveyed in 1996–1997</li> </ul>
Voorhees (2010) <sup>41</sup>	<ul style="list-style-type: none"> <li>Children's perception of neighbourhood aesthetics, based on whether there are many interesting things to look at in the neighbourhood in a validated questionnaire</li> </ul>	<ul style="list-style-type: none"> <li>Built environment: distance to school, total active destinations, townsend index, street connectivity index, block size index, land use mix (diversity) index</li> <li>Perception on presence of places like to walk, sidewalks, and</li> </ul>	<ul style="list-style-type: none"> <li>Self-reported ATS frequency (number of days walk to/from school)</li> </ul>	NA

(Continues)

TABLE 2 (Continued)

First author (year)	Measures of neighbourhood aesthetics	Other environmental factors adjusted for in the model	Measures of weight-related behaviours	Measures of weight-related outcomes
Wong (2016) <sup>15</sup>	<ul style="list-style-type: none"> <li>• Parental perception of neighbourhood aesthetics, based on presence of attractive natural sights and attractive buildings</li> </ul>	biking/walking trails, safety to walk, walkers/bikers from my home, whether there is too much, whether there is a lot of crime whether the streets are well lit and total perceived active places to go in my neighbourhood. <ul style="list-style-type: none"> <li>• Built environment: availability of sports facilities, nearest network distance to park and local destinations</li> <li>• Preference for outdoor play</li> </ul>	<ul style="list-style-type: none"> <li>• Percentage time during MVPA measured using a validated questionnaire and an accelerometer</li> </ul>	<ul style="list-style-type: none"> <li>• Obesity based on measured BMI using international criteria</li> </ul>

Abbreviations: ATS, active transport to school; BMI, body mass index; CDC, Center for Disease Control and Prevention; FPAQ, Flemish Physical Activity Questionnaire; GIS, Geographic Information Systems; MVPA, moderate-to-vigorous-intensity physical activity; NEWS, Neighbourhood Environment Walkability Scales; NEWS-Y, Neighbourhood Environment Walkability Scales–Youth version; PA, physical activity; PAQ-C, Physical Activity Questionnaire for Older Children; SES, socioeconomic status.

( $n = 5$ ), PA frequency ( $n = 7$ ), frequency or the percentage of time doing moderate-to-vigorous physical activity (MVPA,  $n = 4$ ), or PA categories (i.e. active or inactive,  $n = 3$ ). PA was measured by accelerometers in four studies and pedometers in one study, and the other studies used self-reported PA ( $n = 11$ ) or parent-reported PA ( $n = 2$ ). Eight studies analysed active transport to school (ATS) that was measured by self-reported mode of transport ( $n = 6$ ), including active transport (i.e. walking and cycling) and passive transport (i.e. bus or car), and frequency of using active transportation ( $n = 3$ ). Other outcomes of interests included step counts, screen time and cardiorespiratory fitness, with each of them being used in one study.

### 3.4 | Association between neighbourhood aesthetics and weight-related behaviours and outcomes

All four studies that used overweight or obesity as the outcome variable revealed no associations in the adjusted model (Table 3). Four studies analysed BMI or BMI z-score and parental perceptions of neighbourhood aesthetics and reported mixed findings: one study found a negative association, one study found a positive association, one study found a non-significant association, and the last study found a negative association among children lived in areas of high deprivation, whereas the association was insignificant among children lived in areas of median deprivation.

Among the 18 studies analysing PA, 12 studies reported non-significant associations between neighbourhood aesthetics and PA, whereas five studies reported positive associations and one study reported a negative association. We observed different results when

stratifying the results by measures of neighbourhood aesthetics. When aesthetics was measured using parental perceptions, six out of nine studies reported non-significant associations, one study reported a negative association and one study reported a positive association. When aesthetics was measured using children's perceptions, four out of seven studies reported no associations, and the rest three studies reported positive associations. Six studies conducted a stratified analysis by gender, two studies of which reported a positive association among girls only, one study reported a negative association in boys only, and three studies reported consistent results by gender, including one positive, one negative and one non-significant association in both genders. Of eight studies analysed ATS, four studies reported negative associations, two studies reported positive associations and two studies reported no associations. Three studies conducted a stratified analysis by gender, where one study found a positive association in girls only, one study found a negative association in boys only and one study reported negative associations in both genders. One study also conducted stratified analysis by the type of community, where a positive association between perception of aesthetics was associated with ATS only in the smart growth community, not in the conventional community.

### 3.5 | Study quality assessment

The criterion-specific and global ratings were reported from the quality assessment of all included studies, where the only cohort study scored 8 out of 9 and all other cross-sectional studies scored from 5 to 7 out of 11, with an average of 5.92 (Table 4).

**TABLE 3** Estimated associations between neighbourhood aesthetics and weighted-related behaviours and outcomes in 25 included studies

First author (year)	Estimated associations of neighbourhood aesthetics with	
	Weight-related behaviours	Weight-related outcomes
Carson (2014) <sup>23</sup>	<ul style="list-style-type: none"> <li>• Neighbourhood aesthetics was not associated with PA in children (<math>\beta = 0.05</math>, 95% CI [-0.10, 0.21]).</li> <li>• Neighbourhood aesthetic was not associated with screen time in children (<math>\beta = -0.00</math>, 95% CI [-0.32, 0.32]).</li> </ul>	NA
Datar (2015) <sup>24</sup>	<ul style="list-style-type: none"> <li>• Among families living on-post, environmental aesthetics was not associated with PA (Min/week of vigorous PA <math>\beta = 18.60</math>, 95% CI [-2.68 to 39.88]; Min/week of moderate PA <math>\beta = 7.45</math>, 95% CI [-12.33, 27.23]).</li> <li>• Among families living off-post, environmental aesthetics was not associated with PA (Min/week of vigorous PA (<math>\beta = -8.79</math>, 95% CI [-25.43, 7.84]); Min/week of moderate PA (<math>\beta = -2.84</math>, 95% CI [-18.24 to 12.56])).</li> </ul>	<ul style="list-style-type: none"> <li>• Among families living on-post, environmental aesthetics was not associated with BMI z-score (<math>\beta = 0.00</math>, 95% CI [-0.19, 0.19]).</li> <li>• Among families living off-post, environmental aesthetics was not associated with BMI z-score (<math>\beta = -0.06</math>, 95% CI [-0.21, 0.09]).</li> </ul>
Durand (2012) <sup>25</sup>	<ul style="list-style-type: none"> <li>• Neighbourhood aesthetics was not associated with minutes per day of MVPA (<math>\beta = 1.24</math>, 95% CI [-2.18, 4.65]).</li> <li>• Neighbourhood aesthetics was not associated with ATS for those in the conventional communities (OR = 1.46, 95% CI [0.93, 2.29]).</li> <li>• Neighbourhood aesthetics was associated with increased ATS for those in the smart growth community (OR = 2.91, 95% CI [1.31, 6.46]).</li> </ul>	NA
Evenson (2006) <sup>14</sup>	<ul style="list-style-type: none"> <li>• Compared to those with PA score below median, girls with PA score above median were more likely to report more trees (OR = 1.78, 95% CI [1.17, 2.72]), interesting things to look at (OR = 2.36, 95% CI [1.56, 3.59]), and lack of garbage or litter (OR = 1.78, 95% CI [1.20, 2.65]) in the neighbourhood, where reporting interesting things to look at remained associated with PA in the overall model (OR = 1.91, 95% CI [1.17, 3.11]).</li> <li>• Not having bad smells in the neighbourhood was associated with a decreased odds of reporting ATS (OR = 0.43, 95% CI [0.26, 0.71]) and remained in the overall model (OR = 0.43, 95% CI [0.24, 0.75]).</li> </ul>	NA
Grafova (2008) <sup>26</sup>	NA	<ul style="list-style-type: none"> <li>• Not observing signs of physical disorder in neighbourhood was associated with reduced overweight (OR = 0.5, 95% CI [0.4, 0.8]).</li> </ul>
Haese (2015) <sup>27</sup>	<ul style="list-style-type: none"> <li>• Neighbourhood aesthetics was not associated with children's PA in public recreation spaces inside or outside the neighbourhood (OR = 1.07, 95% CI [0.79, 1.45]), in the garden (OR = 1.26, 95% CI [0.89, 1.78]), or in their neighbourhood (OR = 1.33, 95% CI [1.00, 1.77]).</li> </ul>	NA

(Continues)

TABLE 3 (Continued)

First author (year)	Estimated associations of neighbourhood aesthetics with	
	Weight-related behaviours	Weight-related outcomes
Hulst (2013) <sup>28</sup>	<ul style="list-style-type: none"> <li>Neighbourhood aesthetics was not associated with objectively measured % of time doing MVPA (OR = 0.87, 95% CI [0.61, 1.25]).</li> </ul>	<ul style="list-style-type: none"> <li>No relationship between neighbourhood physical disorder and deterioration and obesity in family (low vs. high: OR = 0.84, 95% CI [0.58, 1.23]; average vs. high: OR = 1.01, 95% CI [0.72, 1.42]) was found.</li> </ul>
Hume (2007) <sup>29</sup>	<ul style="list-style-type: none"> <li>Perceiving lots of graffiti was positively associated with walking frequency (times/week) among girls (<math>\beta</math> = 2.72, 95% CI [0.10, 5.34]).</li> <li>Perceiving lots of litter and rubbish was positively associated with overall PA (accelerometer counts/day) (<math>\beta</math> = 101.4, 95% CI [41.78, 161.0]) among boys.</li> </ul>	NA.
Kasehagen (2012) <sup>19</sup>	<ul style="list-style-type: none"> <li>Parental perception of detracting elements, including litter, dilapidated housing, and vandalism, was not associated with PA (OR = 0.99, 95% CI [0.88–1.12]), and the association was not significant when stratified by different rural–urban commuting areas (i.e. urban core area, other urban, large rural core area, other large rural area, small rural core area, other small rural core area, and isolated rural area).</li> </ul>	NA
Laxer (2013) <sup>30</sup>	<ul style="list-style-type: none"> <li>Neighbourhood aesthetics was associated with physical inactivity in unadjusted model, (2 vs. 1(best): RR = 0.96, 95% CI [0.78, 1.18]; 3 vs. 1 (best): RR = 0.94, 95% CI [0.76, 1.15]; 4 (worst) vs. 1 (best): RR = 1.28, 95% CI [1.08, 1.49].</li> <li>Neighbourhood aesthetics was not associated with physical inactivity after adjustment (2 vs. 1 (best): RR = 0.96, 95% CI [0.78, 1.18]; 3 vs. 1(best): RR = 0.88, 95% CI [0.70, 1.07]; 4 (worst) vs. 1(best): RR = 1.16, 95% CI [0.97, 1.36]).</li> </ul>	NA
Lopes (2014) <sup>31</sup>	<ul style="list-style-type: none"> <li>PA of at least 20 minutes/day once a week was associated with perception of 'presence of interesting things' among girls (aOR = 1.77, 95% CI [1.05, 2.96]) and "there are places I like (aOR = 2.18, 95% CI [1.33, 3.58]) and "I see people my age" among boys.</li> </ul>	NA.
Loureiro (2010) <sup>32</sup>	<ul style="list-style-type: none"> <li>Place evaluated as being ugly was associated with reduced outdoor sports (OR = 0.8, 95% CI [0.7, 0.9]), while it is not associated with PA (OR = 1.0, 95% CI [0.8, 1.3]), exercise (OR = 0.9, 95% CI [0.7, 1.1]), and indoor sports (OR = 1.0, 95% CI [0.8, 1.2]).</li> </ul>	NA
Machado-Rodrigues (2014) <sup>33</sup>		

TABLE 3 (Continued)

First author (year)	Estimated associations of neighbourhood aesthetics with	
	Weight-related behaviours	Weight-related outcomes
	<ul style="list-style-type: none"> <li>• Neighbourhood aesthetics was not associated with children's habitual PA (<math>\beta = 11.13</math>, 95% CI [-1.772, 24.030]).</li> </ul>	<ul style="list-style-type: none"> <li>• Neighbourhood aesthetics was positively associated with children's BMI (<math>\beta = 0.32</math>, 95% CI [0.052, 0.587]).</li> </ul>
Meester (2014) <sup>18</sup>	<ul style="list-style-type: none"> <li>• In boys, perception of aesthetics was significantly associated with walking for transport during leisure time leisure (<math>\beta = -0.116</math>, 95% CI [-0.210, -0.022]), and the associations were non-significant for ATS (<math>\beta = -0.064</math>, 95% CI [-0.156, 0.028]), cycling for transport during leisure time leisure (<math>\beta = -0.049</math>, 95% CI [-0.147, 0.049]), overall level of PA (<math>\beta = -0.012</math>, 95% CI [-0.049, 0.025]), and daily number of step counts (<math>\beta = -214.570</math>, 95% CI [-787.431, 358.291]).</li> <li>• In girls, perception of aesthetics was not associated with ATS (<math>\beta = -0.089</math>, 95% CI [-0.187, 0.009]), walking for transport during leisure time leisure (<math>\beta = -0.077</math>, 95% CI [-0.181, 0.027]), cycling for transport during leisure time leisure (<math>\beta = -0.043</math>, 95% CI [-0.141, 0.055]), overall level of PA (<math>\beta = 0.012</math>, 95% CI [-0.029, 0.053]), and daily number of step counts (<math>\beta = -67.354</math>, 95% CI [-557.628, 422.920]).</li> </ul>	NA
Mota (2007) <sup>17</sup>	<ul style="list-style-type: none"> <li>• Perception of aesthetics was positively associated with leisure time PA (OR = 1.59, 95% CI [1.07, 2.34]) in girls.</li> <li>• Perception of aesthetics was not associated with leisure time PA in boys.</li> </ul>	NA
Nelson (2009) <sup>34</sup>	NA	<ul style="list-style-type: none"> <li>• Perception of aesthetics was not related to overweight/obese (aOR = 0.98, 95% CI [0.96, 1.0]);</li> <li>• Perception of aesthetics was not related to obese (uOR = 0.97, 95% CI [0.93, 1.01]).</li> </ul>
Nelson (2010) <sup>35</sup>	<ul style="list-style-type: none"> <li>• Perception of aesthetics was related to ATS among males (aOR = 0.93, 95% CI [0.90, 0.97]); perception of aesthetics was not related to ATS among females (aOR = 0.97, 95% CI [0.94, 1.01]).</li> <li>• Boys who perceived interesting features (OR = 0.65, 95% CI [0.45, 0.96]) or attractive natural sights (OR = 0.42, 95% CI [0.29, 0.62]) in their neighbourhood were less likely to walk or cycle to school.</li> <li>• Perceptions of litter free streets were linked with reduced odds of ATS among females (OR = 0.54, 95% CI [0.38, 0.78]).</li> </ul>	NA
Noonan (2016) <sup>16</sup>	<ul style="list-style-type: none"> <li>• No association was found between PA score and neighbourhood aesthetics.</li> </ul>	<ul style="list-style-type: none"> <li>• Neighbourhood aesthetics was negatively associated with BMI z-scores (<math>\beta = -0.50</math>, 95% CI [-0.85, -0.15]), and waist circumferences (<math>\beta = -0.31</math>, 95% CI [-5.38, -0.83]) in children living in areas of high deprivation.</li> </ul>

(Continues)

TABLE 3 (Continued)

First author (year)	Estimated associations of neighbourhood aesthetics with	
	Weight-related behaviours	Weight-related outcomes
Noonan (2017) <sup>36</sup>	<ul style="list-style-type: none"> <li>• ATS was inversely associated with neighbourhood aesthetics (<math>\beta = -0.44</math>, OR = 0.65, 95% CI [0.44, 0.95]).</li> </ul>	<ul style="list-style-type: none"> <li>• Neighbourhood aesthetics was not associated with BMI z-scores (<math>\beta = -0.21</math>, 95% CI [-0.60, 0.17]), and waist circumferences (<math>\beta = -0.01</math>, 95% CI [-2.23, 2.21]) in children living in areas of medium deprivation.</li> </ul>
Oliveira (2014) <sup>37</sup>	<ul style="list-style-type: none"> <li>• Neighbourhood aesthetics was not associated with PA (crude OR = 0.982, 95% CI [0.721, 1.339]; aOR = 0.979, 95% CI [0.716, 1.339]).</li> </ul>	NA
Page (2010) <sup>38</sup>	<ul style="list-style-type: none"> <li>• Neighbourhood aesthetics was not associated with the likelihood of playing every day (Boy: OR = 0.90, 95% CI [0.69, 1.17]; Girl: OR = 1.16, 95% CI [0.86, 1.57]), taking part in structured exercise/sport everyday (Boy: OR = 0.78, 95% CI [0.59, 1.03]; Girl: OR = 1.16, 95% CI [0.89, 1.53]) and walking/cycling home from school (Boy: OR = 0.93, 95% CI [0.65, 1.31]; Girl: OR = 1.04, 95% CI [0.77, 1.41]).</li> </ul>	NA
Santos (2009) <sup>39</sup>	<ul style="list-style-type: none"> <li>• Neighbourhood aesthetics was not associated with being active among boys (OR = 1.19, 95% CI [0.81, 1.76]).</li> <li>• Neighbourhood aesthetics was associated with being active among girls (OR = 1.46, 95% CI [1.03, 2.07]) in univariate logistic regressions, and the association is insignificant after adjustment for confounders (aOR = 1.19, 95% CI [0.81, 1.74]).</li> </ul>	NA.
Schmidt (2015) <sup>40</sup>	NA	<ul style="list-style-type: none"> <li>• Neighbourhood aesthetics was inversely associated with BMI z-score at 4–5 years of age (<math>\beta = -0.078</math>, 95% CI [-0.127, -0.028]).</li> <li>• Neighbourhood attractiveness was related to a lower BMI z-score over 4–5 years (<math>\beta = -0.076</math>, 95% CI [-0.116, -0.035]).</li> </ul>
Voorhees (2010) <sup>41</sup>	<ul style="list-style-type: none"> <li>• Neighbourhood aesthetics was not associated with walking to or from School (OR = 1.01, 95% CI [0.66, 1.55]).</li> </ul>	NA
Wong (2016) <sup>15</sup>	<ul style="list-style-type: none"> <li>• Perceiving attractive natural sights in the neighbourhood was associated with objectively assessed %MVPA (<math>\beta = 0.101</math>, 95% CI [0.018, 0.185]).</li> <li>• Perceiving attractive buildings was not associated with questionnaire-determined MVPA (<math>\beta = 0.082</math>, 95% CI [-0.008, 0.173]).</li> </ul>	<ul style="list-style-type: none"> <li>• Presence of trees was negatively associated with obesity (<math>\beta = -0.345</math>, 95% CI [-0.655, -0.035]).</li> </ul>

Abbreviations: ATS, active transport to school; aOR, adjusted OR; CI, confidence interval; BMI, body mass index; PA, physical activity; MVPA, moderate-to-vigorous physical activity; OR, odds ratio; uOR, unadjusted OR.

**TABLE 4** Study quality assessment for cross-sectional studies (see 11 questions in Appendix B) and cohort studies (see 8 questions in Appendix B)

ID Criterion	1	2	3	4	5	6	7	8	9	10	11	Total score
Carson (2014) <sup>23</sup>	Y	Y	D	Y	N	Y	D	Y	D	Y	D	6
Datar (2015) <sup>24</sup>	Y	Y	D	Y	N	Y	D	Y	D	Y	D	6
Durand (2012) <sup>25</sup>	Y	Y	D	Y	N	Y	D	Y	D	N	D	5
Evenson (2006) <sup>14</sup>	Y	Y	D	Y	N	Y	Y	Y	D	N	D	6
Grafova (2008) <sup>26</sup>	Y	Y	D	Y	N	Y	Y	Y	Y	N	D	7
Haese (2015) <sup>27</sup>	Y	Y	D	Y	N	Y	D	Y	Y	Y	D	7
Hulst (2013) <sup>28</sup>	Y	Y	D	Y	N	Y	Y	Y	D	Y	D	7
Hume (2007) <sup>29</sup>	Y	Y	D	Y	N	Y	D	Y	Y	Y	D	7
Kasehagen (2012) <sup>19</sup>	Y	Y	D	Y	N	Y	D	Y	Y	N	D	6
Laxer (2013) <sup>30</sup>	Y	Y	D	Y	N	Y	Y	Y	D	Y	D	7
Lopes (2014) <sup>31</sup>	Y	Y	D	Y	N	Y	D	Y	D	Y	D	6
Loureiro (2010) <sup>32</sup>	Y	Y	D	Y	N	Y	D	Y	D	N	D	5
Machado-Rodrigues (2014) <sup>33</sup>	Y	Y	D	Y	N	Y	D	Y	D	N	D	5
Meester (2014) <sup>18</sup>	Y	Y	D	Y	N	Y	D	Y	D	Y	D	6
Mota (2007) <sup>17</sup>	Y	Y	D	Y	N	Y	D	Y	D	Y	D	6
Nelson (2009) <sup>34</sup>	Y	Y	D	Y	N	Y	D	Y	D	N	D	5
Nelson (2010) <sup>35</sup>	Y	Y	D	Y	N	Y	D	Y	D	N	D	5
Noonan (2016) <sup>16</sup>	Y	Y	D	Y	N	Y	D	Y	Y	Y	D	7
Noonan (2017) <sup>36</sup>	Y	Y	D	Y	N	Y	D	Y	D	Y	D	6
Oliveira (2014) <sup>37</sup>	Y	Y	D	Y	N	Y	D	Y	Y	N	D	6
Page (2010) <sup>38</sup>	Y	Y	D	Y	N	Y	D	Y	D	Y	D	6
Santos (2009) <sup>39</sup>	Y	Y	D	Y	N	Y	D	Y	D	N	D	5
Schmidt (2015) <sup>40</sup>	Y	Y	Y	N	Y	Y	Y	Y	NA	NA	NA	8
Voorhees (2010) <sup>41</sup>	Y	Y	D	Y	N	Y	D	Y	D	N	D	5
Wong (2016) <sup>15</sup>	Y	Y	D	Y	N	Y	D	Y	D	N	D	5

Abbreviations: D, Do not know; N, No; NA, not applicable to cohort studies.

## 4 | DISCUSSION

This systematic review included 25 studies analysing the association between neighbourhood aesthetics and childhood obesity. The majority of studies were cross-sectional studies conducted in the last 10 years, and most of these studies recruited students from schools as the study participants. Most studies measured neighbourhood aesthetics based on perceptions of parents or children, and four studies conducted an on-site or GISs assessment by trained observers. We identified 21 studies that focused on weight-related behaviours, whereas only eight studies reported body-weight status among children and adolescents. When analysing PA, 12 out of 18 studies found insignificant associations, whereas five studies found the presence of neighbourhood aesthetic elements was associated with increased PA, and one study found that it is negatively associated with PA. In eight studies that analysed ATS, four studies reported negative associations, two studies reported positive associations and two studies reported non-significant associations. In eight studies measured weight-status,

five studies reported non-significant associations, two studies reported negative associations and one study reported a positive association.

This review is motivated by the hypothesis that environmental aesthetics can promote PA in children and adolescents and thus prevent obesity. Unlike environmental attributes that are more commonly reported to influence PA, such as land-use mix and residential density, which are directly linked to the convenience of outdoor activity,<sup>42</sup> aesthetics is thought to impact more subtly through influencing the impression of the neighbourhood. Researchers hypothesized that environmental preference could be influenced by a rapid, unconscious type of cognition that may precede certain affective judgments and therefore influence human behaviors.<sup>43</sup> The 'broken window effect', proposed by Wilson and Kelling,<sup>44</sup> indicates that if a laissez-faire attitude to a harmful phenomenon in the human environment is taken, people especially children and adolescents will follow it and/or intensify it.<sup>45,46</sup> As human behaviours and environments are strongly suggestive and inducible, the poor neighbourhood environment may

induce further destructive behaviours in children, which could decrease neighbourhood habitability and affect normal activities such as physical exercise in children.

Gender difference is another important factor. In this review, seven of the included studies conducted stratified analyses by gender, and three studies reported gender-different results. Studies have shown that boys in general had greater morbidity and were independent earlier than girls, which might influence children's PA to some extent.<sup>47</sup> These factors should be considered as potential confounders when analysing the association between neighbourhood aesthetics and childhood obesity. Neighbourhood socioeconomic status and safety could also be potential confounders, where better-off neighbourhoods are always accompanied by safety and aesthetics in them.

In this review, neighbourhood aesthetics was commonly measured using items from validated questionnaires, such as the NEWS, and the assessment included presence of features promoting aesthetics, such as trees, nice houses and attractive nature sights, and presence of detracting features, such as litter, graffiti, rubbish and vandalism in the neighbourhood. Measures of aesthetics may influence the associations observed. We found that studies measured children's perceptions were more likely to report a positive association between neighbourhood aesthetics and PA than studies measured parental perceptions. It is possible that using children's perceptions, which would influence children's behaviours more directly, has higher validity than using parental perceptions, although children's age may be an effect modifier (e.g. younger children may be more likely to be influenced by their parental perceptions). Besides, children and adolescents may have a different preference for aesthetic styles compared with their parents, especially in terms of graffiti and interesting things to look at. It is also important to note that reverse causation may influence the association when used subjective measurements. Subjects with higher levels of PA in the neighbourhood may be more familiar with the environment and thus are more likely to perceive the presence of aesthetic features.<sup>48</sup> Therefore, objective measures, such as using street view imagery and computer vision, should be promoted in future studies.<sup>49-52</sup> For instance, the use of location-based technologies, such as ecologic momentary assessment, may facilitate better measurement of such environmental factors<sup>53,54</sup> and potentially measure how children perceive their surrounding environment directly.<sup>55</sup> Moreover, the use of high-resolution satellite imagery,<sup>6</sup> which could match multi-temporal measurements of several aesthetics-related aspects of the neighbourhoods to individuals in cohort studies, may allow more longitudinal even life course studies in the future.<sup>56</sup>

This review has some limitations. First, due to the limited number of existing studies included and the variation of measures between studies, we were not able to conduct a meta-analysis for the pooled effective size, or a stratified analysis with potential confounding factors, such as socioeconomic status, ethnicity or other sociodemographic characteristics. Second, the measures of neighbourhood aesthetics were mostly based on subjective perceptions collected from questionnaire surveys, and the items being used

varied across studies. It is necessary to promote a standardized questionnaire in future studies to improve the consistency, as well as objective measures to increase the accuracy of measurements.<sup>53,57</sup> Lastly, most existing studies are cross-sectional rather than longitudinal. Future studies should incorporate more longitudinal designs to capture the dynamic interaction between neighbourhood aesthetics and children's behaviours and weight status over time.

## 5 | CONCLUSIONS

This systematic review of cross-sectional studies and longitudinal studies revealed a rather weak relationship between neighbourhood aesthetics and weight-related behaviours/outcomes. About two-thirds of studies reported non-significant associations when using PA and weight status as outcomes, and half of studies showed that neighbourhood aesthetics is associated with increased ATS. The rest of studies reported mixed findings, and a slightly higher proportion of them showed that neighbourhood aesthetics may promote PA or reduce weight. This review implied that neighbourhood aesthetics should be better measured and considered in obesogenic environmental research. Some emerging approaches, such as ecologic momentary assessment, will facilitate the measurement of environmental factors that would otherwise not have been well measured by traditional approaches.

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## CONFLICTS OF INTEREST

We declare no conflicts of interest.

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## APPENDIX A

### Search Strategy

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

(1) 'neighborhood aesthetic\*', 'neighbourhood aesthetic\*', 'community aesthetic\*', 'environment aesthetic\*', 'environmental aesthetic\*', 'ecologic aesthetic\*', 'ecological aesthetic\*', 'streetscape\*', 'neighborhood landscape\*', 'neighbourhood landscape\*', 'community landscape\*', 'neighborhood scene\*', 'neighbourhood scene\*', 'community scene\*', 'well-maintained neighborhood\*', 'well-maintained neighbourhood\*', 'well maintained neighborhood\*', 'well maintained neighbourhood\*', 'well-maintained communit\*', 'well maintained communit\*', 'neighborhood garbage', 'neighbourhood garbage', 'community garbage', 'neighborhood qualit\*', 'neighbourhood qualit\*', 'community qualit\*', 'neighborhood graffiti', 'neighbourhood graffiti',

'community graffiti', 'neighborhood litter', 'neighbourhood litter', 'community litter', 'neighborhood trash', 'neighbourhood trash', 'community trash', 'neighborhood broken window\*', 'neighbourhood broken window\*', 'community broken window\*', 'neighborhood unclean\*', 'neighbourhood unclean\*', 'community unclean\*', 'neighborhood clean\*', 'neighbourhood clean\*', 'community clean\*', 'neighborhood pollution\*', 'neighbourhood pollution\*', 'community pollution\*', 'neighborhood pollutant\*', 'neighbourhood pollutant\*', 'community pollutant\*', 'neighborhood vandalism', 'neighbourhood vandalism', 'community vandalism', 'neighborhood environment\*', 'neighbourhood environment\*', 'community design\*', 'neighborhood design\*', 'neighbourhood design\*', 'urban design\*';

(2) 'child\*', 'juvenile\*', 'pubescent\*', 'puberty\*', 'adolescent\*', '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 behavior\*', 'dietary behavior\*', 'eating\*', 'eating behavior\*', 'food\*', 'food intake\*', 'food consume\*', 'energy intake\*', 'energy consume\*', 'energy balance', 'calorie\*', 'caloric intake\*', 'physical activity\*', 'physical exercise\*', 'exercise\*', 'body activity\*', 'body mass index', 'BMI', 'weight', 'weight status', 'weight-related behavior\*', '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', 'physical disorder'.

## APPENDIX B

Study quality assessment tools for cross-sectional and longitudinal studies

Agency for Healthcare Research and Quality

1. Define the source of information (survey and record review)
2. List inclusion and exclusion criteria for exposed and unexposed subjects (cases and controls) or refer to previous publications
3. Indicate time period used for identifying patients
4. Indicate whether or not subjects were consecutive if not population-based
5. Indicate if evaluators of subjective components of study were masked to other aspects of the status of the participants
6. Describe any assessments undertaken for quality assurance purposes (e.g., test/retest of primary outcome measurements)
7. Explain any patient exclusions from analysis
8. Describe how confounding was assessed and/or controlled.
9. If applicable, explain how missing data were handled in the analysis
10. Summarize patient response rates and completeness of data collection

11. Clarify what follow-up, if any, was expected and the percentage of patients for which incomplete data or follow-up was obtained

NOS Quality Assessment Scale

**Selection**

- 1) Representativeness of the exposed cohort

- a) truly representative of the average \_\_\_\_\_ (describe) in the community
- b) somewhat representative of the average \_\_\_\_\_ in the community
- c) selected group of users eg nurses, volunteers
- d) no description of the derivation of the cohort

- 2) Selection of the non exposed cohort

- a) drawn from the same community as the exposed cohort
- b) drawn from a different source
- c) no description of the derivation of the non exposed cohort

- 3) Ascertainment of exposure

- a) secure record (eg surgical records)
- b) structured interview
- c) written self report
- d) no description

- 4) Demonstration that outcome of interest was not present at start of study

- a) yes
- b) no

**Comparability**

- 1) Comparability of cohorts on the basis of the design or analysis

- a) study controls for \_\_\_\_\_ (select the most important factor)
- b) study controls for any additional factor (This criteria could be modified to indicate specific control for a second important factor.)

**Outcome**

- 1) Assessment of outcome

- a) independent blind assessment
- b) record linkage
- c) self report
- d) no description

- 2) Was follow-up long enough for outcomes to occur

- a) yes (select an adequate follow up period for outcome of interest)
- b) no

- 3) Adequacy of follow up of cohorts

- a) complete follow up - all subjects accounted for
- b) subjects lost to follow up unlikely to introduce bias - small number lost - > \_\_\_\_ % (select an adequate %) follow up, or description provided of those lost)
- c) follow up rate < \_\_\_\_% (select an adequate %) and no description of those lost
- d) no statement