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Neighbourhood residential density and childhood obesity

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Summary

Residential density is considered an important attribute of the built environment that may be relevant to childhood obesity. However, findings remain inconclusive, and there are no reviews yet on the association between residential density and childhood obesity. This study aimed to systematically review the associations between residential density and weight-related behaviours and outcomes. A comprehensive literature search was conducted using the Cochrane Library, PubMed and Web of Science for articles published before 1 January 2019. A total of 35 studies conducted in 14 countries were identified, including 33 cross-sectional studies, one longitudinal study and one containing both study designs. Residential density was measured by Geographic Information Systems in 28 studies within a varied radius from 0.25 to 2 km around the individual residence. Our study found a general positive association between residential density and physical activity (PA); no significant associations were observed. This study provided evidence for a supportive role of residential density in promoting PA among children. However, it remained difficult to draw a conclusion between residential density and childhood obesity. Future longitudinal studies are warranted to confirm this association.

KEYWORDS

adolescent, built environment, child, obesity, overweight, physical activity, population density, residential density

Yuxuan Zou and Yanan Ma contributed equally to this work.

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1 | INTRODUCTION

Worldwide, overweight and obesity are now the fifth leading cause of death.[1] Childhood obesity is more likely to develop noncommunicable diseases in later life, such as hypertension, cardiovascular disease and even some social and psychological problems.[2–4] The global prevalence of overweight and obesity has substantially increased from 1980 to 2013, with a 47.1% increase in children.[5] Childhood obesity has become a serious public health concern.[5,6]

Neighbourhood built environments have been identified as factors influencing children's weight status because they can encourage or discourage children's physical activity (PA) and food intake and thereby influence their energy expenditure and intake.[7–10] One of the potentially important attributes of built environments that may be related to childhood overweight and obesity is residential density.[11] Several studies have demonstrated links between a higher residential density and more PA among children, such as walking and cycling.[12–15] Children's active transport could also affect their weight status.[16,17] In addition, some studies revealed a protective effect of residential density on children's weight status,[18–21] whereas other studies showed opposite results[22,23] or no significant relationships between them.[10,24] Findings of the association between residential density and children's weight status remain inconclusive, but no systematic review has examined this association yet.

Therefore, we aimed to reveal and evaluate the association of residential density with children's weight-related behaviours and outcomes. For an integrated understanding of these associations, we considered, on the one hand, a wide range of definitions of residential density (e.g., at multiple sites, such as at home and at school) and expanded the concept of residential density to population density, which is sometimes used as an indicator of residential density or vice versa; on the other hand, we also examined both weight status and weight-related behaviours (e.g., PA, sedentary behaviours and dietary behaviours). Our findings would be helpful for future study designs and walkable and healthy city planning.

2 | METHODS

A systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews.

2.1 | Study selection criteria

Studies were included in the review if they met all of the following criteria: (1) study design: longitudinal or cross-sectional; (2) study subject: children and adolescents aged 18 years or younger; (3) exposure of interest: residential density or population density; (4) study outcome: weight-related behaviours (e.g., PA, sedentary behaviours and dietary behaviours) or outcomes (e.g., measurement of overweight and obesity by body mass index [BMI, kg/m^2], waist circumference, waist-to-hip ratio or body fat); (5) article type: peer-reviewed original research, excluding letters, editorials, study/review protocols and review articles; (6) time of publication: from the inception of electronic bibliographical databases to 1 January 2019; and (7) language: English.

2.2 | Search strategy

A keyword literature search was performed in three electronic bibliographic databases: Cochrane Library, PubMed and Web of Science. Database search strategies used all possible combinations of keywords from the three groups related to residential density, children and weight-related behaviours or outcomes (Appendix S1).

The titles and abstracts of the articles identified through the keyword search were screened against the eligibility criteria of study inclusion. Potentially relevant articles were obtained for a comparative evaluation of the full texts. All steps were independently conducted by reviewers Y.Z. and Y.M.

2.3 | Data extraction and preparation

A standardized data extraction form was used to collect methodological and outcome variables from each selected study whenever applicable. The data considered included year of publication, authors, study area, country, age at baseline, duration of follow-up, sample size, sample characteristics, number of repeated measures, measures of residential density, measures of weight-related behaviours, measures of body weight status, statistical model, attrition rate and key findings of the association of residential density with weight-related behaviours and/or outcomes.

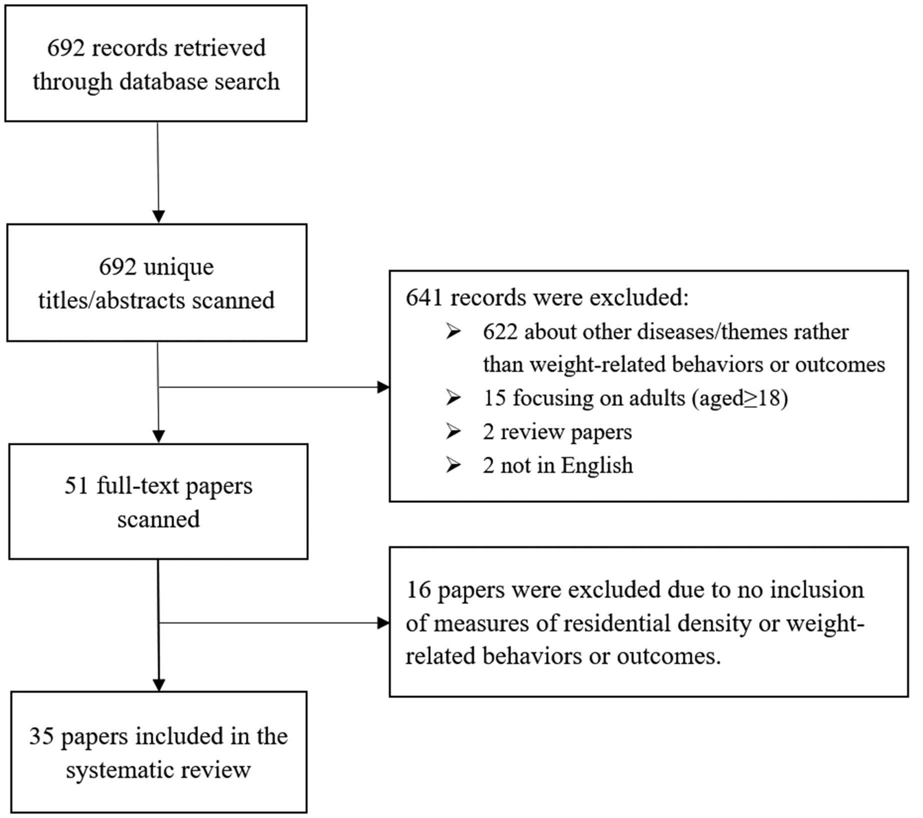

FIGURE 1 Study exclusion and inclusion flowchart

2.4 | Study quality assessment

The quality of each included study was assessed by the National Institutes of Health's Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies.[25] This assessment tool rates each study on the basis of 14 criteria (Table S2). For each criterion, a score of 1 was assigned to a 'yes' response and a score of 0 was assigned otherwise (i.e., an answer of 'no', 'not reported', 'not applicable' or 'cannot determine'). A study-specific global score ranging from 0 to 14 was calculated by summing the scores for each criterion. The study quality assessment helped to evaluate the strength of the scientific evidence but was not used to determine the inclusion of studies.

3 | RESULTS

3.1 | Study selection

The flowchart of the study selection is shown in Figure 1. Overall, 692 unique studies were included for title and abstract screening. Articles were excluded due to irrelevant themes (*n* = 617), focusing on adult populations (*n* = 15), being review articles (*n* = 7), being written in a language other than English (*n* = 2) and having no measures of residential density or weight-related outcomes (*n* = 16). The remaining 35 articles exploring the association of residential density with weight-related behaviours and/or outcomes were assessed and included in this study.

3.2 | Study characteristics

Table 1 summarizes the basic characteristics of the 35 included studies, which comprised 33 cross-sectional studies, one longitudinal study and one involving both study designs. All studies were published since 2006. The sample sizes in these studies ranged from 98 to 980 000. Most of the studies were conducted in the United States (*n* = 16), followed by Belgium (*n* = 4), Canada (*n* = 2), China (n = 2), Germany (n = 2) and one study each in Australia, Brazil, Finland, New Zealand, Nigeria, Malaysia, Mexico, Spain and the Netherlands. Seven studies were conducted at national level, and seven were conducted at subnational level (i.e., in a single state). Additionally, two were conducted at county level and the rest at city level (including six that involved more than one city).

3.3 | Measure of residential density

The measure of residential density was shown in Table S1. Residential density, also referred to as population density (*n* = 14), was either objectively measured by Geographic Information Systems (*n* = 28) or subjectively perceived by children (*n* = 7), parents (*n* = 2) or both children and parents (*n* = 1). About half of the Geographic Information Systems-based studies (*n* = 13) measured the housing units or population within individual house centred- or school centred-straight line (*n* = 4) or street network (*n* = 9) buffer zones with varying radii (from 0.25 to 2 km). Some studies also measured at postal code or block level if individual house and school addresses were not available.

TABLE 1 Basic characteristics of the studies included [Colour table can be viewed at wileyonlinelibrary.com]

First author	Study design[a]	Study area, country [scale][b]	Sample size	Sample age (years, range and/or mean ± SD)[c]	Sample characteristics (follow-up status for longitudinal studies)	Statistical model
Bailey-Davis (2012)[26]	C	Pennsylvania, USA [S]	980 000	5–12 in 2006–2009	Elementary school students	Bivariate association and multivariate association analyses
Buck (2015)[27]	C	Delmenhorst, Germany [C]	400	2–9 in 2007–2008	Children in IDEFICS study	Gamma log-regression
Carlson (2014)[28]	C	Baltimore and Seattle, USA [C2]	294	12–15 in 2009–20211	School students	Mixed effects multinomial regression
Carlson (2015)[29]	C	Baltimore and Seattle, USA [C2]	690	12–16 in 2009–2011	NA	Three-level mixed-effects random intercept linear regression
Cheah (2012)[23]	C	Kuching, Malaysia [C]	316	14–16	School students	Univariate data analysis
de Vries (2007)[30]	C	Netherlands [N]	422	6–11 in 2004–2005	Elementary school students	Univariate and multivariate linear regression analyses
Duncan (2014)[21]	C&L	Massachusetts, USA [S]	49,700	4–19 in 2011–2012	Children and adolescents from 14 paediatric practices of Harvard Vanguard Medical Associates	Multivariable cross-sectional models
Ghekiere (2015)[14]	C	Melbourne, Australia [C]	677	10–12	School children	Multilevel linear regression
Grafova (2008)[10]	C	USA [N]	2482	5–18 in 2002–2003	NA	Logistic regression
Grant (2018)[19]	C	Virginia, USA [N]	27 538	2–17	Children who visited the Virginia Commonwealth University Medical Center	SS forward stepwise regression, SS incremental forward stagewise regression, SS least angle regression (LARS), and SS lasso
Hermosillo-Gallardo (2018)[16]	C	Mexico City and Oaxac, Mexico [C2]	4079	15–18 in 2016	School students	Multivariable regression
Hinckson (2017)[13]	C	Auckland and Wellington, New Zealand [C2]	524	15.78 ± 1.62 in 2013–2014	School children	Additive mixed models
Jago (2006)[31]	C	Houston, USA [C]	210	10–14	Boy Scouts	Bivariate correlations and hierarchical regressions models
Jago (2006)[32]	C	Houston, USA [C]	210	10–14	Boy Scouts	Hierarchical regressions models
Kligerman (2007)[24]	C	San Diego County, USA [CT]	98	14.6–17.6 in mid-1980s	White or Mexican-American adolescents	Bivariate correlations
Kowaleski-Jones (2016)[15]	C	USA [N]	2706	6–17 in 2003–2006	Children in National Health and Nutrition Examination Surveys	Linear regression
Kyttä (2012)[33]	C	Turku, Finland [C]	1837	10–12 and 13–15 in 2008	School students	Mainly logistic regression analysis
Lange (2011)[34]	C	Kiel, Germany [C]	3440	13–15 in 2004–2008	School students	Linear and logistic multilevel regression

TABLE 1 (Continued)

First author	Study design[a]	Study area, country [scale][b]	Sample size	Sample age (years, range and/or mean ± SD)[c]	Sample characteristics (follow-up status for longitudinal studies)	Statistical model
Larsen (2009)[35]	C	London, Canada [C]	614	11–13 in 2006–2007	Children living within 1 mile of school	Logistic regression
McDonald (2008)[36]	C	USA [N]	14 553	5–18 in 2001	School students	Binary models
Meester (2013)[37]	C	Belgium [N]	637	3–15 in 2008–2009	NA	Stepwise linear regression
Meester (2014)[38]	C	Flanders, Belgium [S]	736	10–12 in 2010–2011	Elementary school students	Multiple linear regression
Molina-García (2018)[17]	C	Valencia, Spain [C]	465	12–18 in 2013–2015	High school students	Self-organizing map analysis
Oyeyemi (2014)[39]	C	Maiduguri, Nigeria [C]	1006	12–19 in 2011	School students	Hierarchical multiple moderated linear regression
Rodríguez (2011)[40]	L	Minneapolis and San Diego, USA [C2]	293	15–18	Female adolescents	Random intercept multinomial logistic regression models
Rosenberg (2009)[41]	C	Boston, Cincinnati and San Diego, USA [C3]	458	5–18 in 2004	NA	One-way analysis of covariance
Schwartz (2011)[42]	C	Pennsylvania, USA [S]	47,769	5–18 in 2011–2008	NA	Multilevel regression analysis
Silva (2015)[43]	C	Brazil [N]	109,104	13–15	NA	Stepwise regression
Van Dyck (2013)[44]	C	Ghent, Belgium [S]	477	13–15	NA	Multilevel moderated regression
van Loon (2014)[45]	C	Vancouver, Canada [C]	366	8–11 in 2005–2006	School students	Generalized estimating equations
Verhoeven (2016)[12]	C	Flanders, Belgium [S]	513	17–18 in 2013	School children	Zero-inflated negative binomial regression
Wasserman (2014)[22]	C	Kansas, USA [S]	12 118	4–12 in 2008–2009	School students	Two-level variance components model
Xu (2009)[46]	C	Nanjing, China [C]	2375	13–15 in 2004	School students	Mixed-effects logistic regression models
Xu (2010)[47]	C	Nanjing, China [C]	2375	13–15 in 2004	School students	Mixed-effects logistic regression models
Yang (2018)[20]	C	Shelby, USA [CT]	41 283	Pre-K to 9 grade in 2014–2015	Children enrolled in Shelby County Schools	Multilevel logistic regression models

Abbreviations: IDEFICS, Identification and prevention of Dietary- and lifestyle-induced health EFfects In Children and infantS; NA, not applicable.
[a]Study design: [C], cross-sectional study; [L], longitudinal study.
[b]Study scale: [N], national; [S], state (e.g., in the United States) or equivalent unit (e.g., province in China and Canada); [Sn], *n* states or equivalent units; [CT], county or equivalent unit; [CTn], *n* counties or equivalent units; [C], city; [Cn], *n* cities.
[c]Sample age: Age in baseline year for longitudinal studies or mean age in survey year for cross-sectional studies.

The most commonly used perceived measure was the Neighborhood Environment Walkability Scale–Youth version (NEWS-Y) questionnaire (n = 4), which includes one question on residential density: 'How common are different types of homes in the neighborhood?' (1 = there are no homes, 5 = all residences are homes). The weights applied to each type of housing to estimate the density and responses were averaged (higher scores indicate higher density). In addition, residential density was measured with the PA Neighborhood Environment Scale (PANES) questionnaire (n = 1), the Neighborhood Environment Walkability Scale (NEWS) questionnaire (n = 2) and the Dutch version of the NEWS questionnaire (n = 1).

3.4 | Association between residential density and weight-related behaviours

Twenty-eight studies examined the association between residential density and weight-related behaviours, including PA (n = 27), physical inactivity (n = 1), sedentary behaviour (n = 2), snacking behaviour (n = 1) and mobility licenses (n = 1). PA-related behaviours included total PA, moderate-to-vigorous physical activity (MVPA) and active transport (active commuting; Table S1). A positive association between residential density and PA was found in most studies in Europe, whereas there were as many studies with positive results as studies with no significant associations in the United States. Through different study designs, a Finnish study (odds ratio = 1.53; 95% confidence interval, 1.40–1.68) and a Canadian study (β = 10.74, p < 0.05) showed the most positive associations. Of the 27 studies that measured PA, six reported a positive association of residential density with PA or MVPA, whereas two showed opposite results. One study found that the relationship between population density and MVPA varied by age.[15] Ten studies reported that residential density was positively associated with active transport, whereas one study showed a reverse association. Eight studies reported null associations of residential density with weight-related behaviours. Of the two studies measuring sedentary behaviours as outcome variables, one reported no significant association between residential density and total objective sedentary time[13]; the other showed that students living in an area with a higher residential density spent more time on sedentary behaviors.[47] Children had significantly more limited mobility licenses, which are the parental rules concerning children's mobility possibilities, if their homes were located in areas with a high residential density.[33] There were no significant associations between residential density and snacking behaviours or physical inactivity.[34]

3.5 | Association between residential density and weight-related outcomes

Nineteen studies collected weight-related outcome data, including BMI (n = 14), BMI z-scores (n = 3), BMI percentile (n = 1) and overweight (n = 1). The BMI percentile was calculated from the algorithm produced by the Centers for Disease Control and Prevention (CDC), which accounts for height, weight, sex and age.[22]

Five studies reported a positive relationship between residential density and weight status, whereas three studies showed the opposite result. Two studies reported no significant associations of residential density with weight-related outcomes. Wasserman et al.[22] measured the BMI percentiles and found that, at the community level, a larger population size increased the likelihood of childhood overweight. Cheah et al.[23] and Xu et al.[46] measured BMI, with both studies reporting that residential density was positively associated with overweight. However, Grant et al.[19] and Duncan et al.[21] measured the BMI z-score and determined that a lower residential density was associated with a higher BMI z-score. Bailey-Davis et al.[26] also measured BMI as a weight-related outcome and found that the obesity prevalence was higher in rural schools than in urban. Of the two studies that measured BMI, Yang et al.[20] found that the risk of overweight and obesity was inversely associated with population density; Schwartz et al.[42] reported that a higher population density was associated with a lower BMI in those aged 14–18 years.

3.6 | Study quality assessment

The criterion-specific ratings from the study quality assessment were reported in Table S2. The included studies scored 7.2 out of 14 on average, with a range from 5 to 9.

4 | DISCUSSION

We systematically reviewed 35 studies assessing the association of residential/population density with weight-related behaviours or outcomes in children and adolescents. This is the first systematic review of the association between residential density and children's weight status. We found that, although a supportive role of residential density on PA was found among children and adolescents, there was no conclusive association between residential density and childhood obesity.

Residential density has been widely considered to be positively related to weight-related behaviour among children. Although unlikely to stimulate PA directly, a higher residential density usually allows for mass retail services and facilities and thus tends to increase the number of potential destinations within walking or cycling distance, which could increase the PA levels of residents.[48,49] Among the studies that focused on weight-related behaviours, 16 studies reported that a higher residential density encourages more active behaviours, whereas three showed the opposite. As a whole, the evidence indicated an inconclusive positive relationship between residential density and PA, which is supported by the results of Lee et al.[50] and Saelens et al.[51]

In our review, results on the association between residential density and child weight-related outcomes were generally inconsistent. Half of the studies in the systematic review reported a negative relationship between residential density and weight status, whereas the other half showed a positive relationship. One possible explanation is that child weight status might be related to other demographic variables, such as race, household income and vacant housing rate. Moreover, some studies showed stronger associations between population density and weight status among black children compared with white children; residence in more affluent areas might result in a greater ability to devote money to PA, which would help to lower the BMI. Other studies reported that BMI was related to the percentage of vacant housing, which affected the actual population distribution.[19,52] The inconsistent evidence on residential density and obesity may have several explanations. First, most of the studies had a cross-sectional design and not a longitudinal design. Second, too few studies were focused on the direct links between residential density and child weight status. Third, self-reported data, which may be subject to recall bias, were commonly used for measuring residential density and weight status. Fourth, the study design and conclusions may have been influenced by the scale of space units. Therefore, future longitudinal studies and studies of how residential density affects children's weight status are warranted.

The present study has several limitations. First, only publications written in English were considered, which might cause a language selection bias. The residential structures may vary considerably among countries, even among different parts of large countries, such as China. In addition, the associations of obesogenic environmental factors, including residential density, with weight-related behaviours and outcomes could vary greatly across countries and regions.[53,54] Second, residential density, as an inherently spatial concept, was measured by various spatial methods (e.g., different types of buffer zones and/or different radii) on the basis of different data sources (e.g., the Atlas of Human Development in Brazil and the American Community Survey).[20,43] A reporting guideline for describing spatial data and methods used in spatial, life course or environmental epidemiologic studies would be extremely useful for improving not only the clarity and quality of individual studies but also the interstudy comparability.[55] The varying data quality of different countries may affect their results. Third, we excluded a number of studies using population density not as an indicator of residential density. Given the high correlation between these two factors in some countries, these excluded studies may also hold value for summarizing the association of living density with outdoor PA and childhood obesity. Future efforts should cover all studies using residential density or population density in different contexts and review them through innovative strategies. Lastly, most included studies were cross-sectional, which cannot shed full light on the causal association between residential density and childhood obesity. For example, subjects may change their residential locations over time, which could cause exposure misclassification issues.[56] More longitudinal studies should be designed to examine this association by linking multitemporal residential density (at different locations) with cohort studies with individual addresses recorded.[57] In addition, because residential density is one of the attributes that could potentially be calculated from administrative data, such as censuses, future studies should take full advantage of certain official resources, such as census or registry data.[56]

5 | CONCLUSION

This systematic review revealed a supportive role of residential density on PA among children and adolescents. However, it was difficult to draw a conclusion regarding the relationship between residential density and childhood obesity. Longitudinal studies are warranted to confirm the association between residential density and childhood obesity.

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SUPPORTING INFORMATION

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

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