Neighbourhood deprivation, individual-level familial and socio-demographic factors and diagnosed childhood obesity: a nationwide multilevel study from Sweden.

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Published in:
Obesity Facts

DOI:
10.1159/000365955

2014

Citation for published version (APA):
Neighbourhood Deprivation, Individual-Level Familial and Socio-Demographic Factors and Diagnosed Childhood Obesity: A Nationwide Multilevel Study from Sweden

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\textbf{What Is Already Known about This Subject?}

- Childhood obesity is a major health risk in childhood.
- Childhood obesity is thought to be caused by environmental and inherited factors.
- Neighbourhood environments have been shown to be an important independent risk factor for many childhood health problems.
- Management of incidentally discovered adrenal masses in FAP patients should be the same as the one for the normal population.

\textbf{What This Study Adds?}

- Neighbourhood deprivation exerts an independent effect on childhood obesity.
- Maternal marital status, parental low level education, advanced paternal age, family history of obesity, diabetes, chronic obstructive pulmonary disease, alcoholism, individual age, female gender and comorbidity of diabetes were associated with higher odds of childhood obesity.
- Clinicians and decision-makers should take into account the potentially negative effect of neighbourhood deprivation on childhood obesity.
Key Words
Childhood obesity · Neighbourhood-level deprivation · Incidence · Socio-demographic factors · Multilevel modelling

Abstract
Objectives: To examine whether there is an association between neighbourhood deprivation and diagnosed childhood obesity, after accounting for family- and individual-level socio-demographic characteristics. Methods: An open cohort of all children aged 0–14 years was followed between January 1, 2000 and December 31, 2010. Childhood residential locations were geocoded and classified according to neighbourhood deprivation. Data were analysed by multilevel logistic regression, with family- and individual-level characteristics at the first level and level of neighbourhood deprivation at the second level. Results: During the study period, among a total of 948,062 children, 10,799 were diagnosed with childhood obesity. Age-adjusted cumulative incidence for diagnosed childhood obesity increased with increasing level of neighbourhood deprivation. Incidence of diagnosed childhood obesity increased with increasing neighbourhood-level deprivation across all family and individual-level socio-demographic categories. The odds ratio (OR) for diagnosed childhood obesity for those living in high-deprivation neighbourhoods versus those living in low-deprivation neighbourhoods was 2.44 (95% confidence interval (CI) = 2.22–2.68). High neighbourhood deprivation remained significantly associated with higher odds of diagnosed childhood obesity after adjustment for family- and individual-level socio-demographic characteristics (OR = 1.70, 95% CI = 1.55–1.89). Age, middle level family income, maternal marital status, low level education, living in large cities, advanced paternal and maternal age, family history of obesity, parental history of diabetes, chronic obstructive pulmonary disease, alcoholism and personal history of diabetes were all associated with higher odds of diagnosed childhood obesity. Conclusions: Our results suggest that neighbourhood characteristics affect the odds of diagnosed childhood obesity independently of family- and individual-level socio-demographic characteristics.

Introduction
Childhood obesity is a major health risk in children [1]. Childhood obesity is thought to be caused by environmental and inherited factors in about equal proportions [2, 3]. Many environmental risk factors are known, including lack of physical activity, large birth weight, nutritional factors and maternal tobacco smoking during pregnancy [4, 5]. Family history is an important risk factor, which has been shown in twins and adoptees [3]. There is also a growing body of evidence that suggests that individual-level socio-economic status (SES) is a risk factor for obesity [4–7]. Low SES may influence the risk of obesity in multiple ways. For example, exposure to harmful agents may result from residential, lifestyle or occupational factors, all of which may be related to SES [6]. These individual-level socio-demographic characteristics do not, however, fully explain the disparities by SES in childhood obesity risk that exist between different population groups [4–6]. Efforts have therefore been made to study whether the socio-economic environment is associated with the risk of childhood obesity. Neighbourhood environments have been shown to be an important independent risk factor for many childhood health problems [4, 6, 8–15]. However, no previous studies have investigated whether neighbourhood deprivation is associated with diagnosed childhood obesity after accounting for family and individual factors.

The present study had the following two aims: i) to determine whether the relationship between neighbourhood deprivation and odds of diagnosed childhood obesity remains signif-
significant after adjusting for family- and individual-level socio-demographic factors; and ii) to examine possible cross-level interactions between individual-level socio-demographic factors and neighbourhood-level deprivation to determine whether neighbourhood-level deprivation has a differential effect on the odds of diagnosed childhood obesity across subgroups of families and individuals (effect modification).

**Material and Methods**

Data used in this study were retrieved from MigMed, a national database that contains information on the entire population of Sweden for a period of 40 years. The dataset we used contains nationwide information on parents and their offspring at the individual and neighbourhood level, including comprehensive demographic and socio-economic data. The information in MigMed comes from several Swedish national registers. The registers used in the present study were the Total Population Register, the Multi-Generation Register, the Hospital Discharge Register and the Outpatient Register. The Swedish nationwide population and health care registers have exceptionally high completeness and validity [16]. Individuals (children and their parents) were tracked using the personal identification numbers, which are assigned to each resident of Sweden. These identification numbers were replaced with serial numbers to provide anonymity. The follow-up period ran from January 1, 2000 until hospitalisation/out-patient treatment for obesity, death, emigration or the end of the study period on December 31, 2010.

**Outcome Variable: Diagnosed Childhood Obesity**

The outcome variable in this study was a hospital or out-patient diagnosis of childhood obesity (age at diagnosis 0–14 years) during the study period. Data on in-patient and out-patient diagnoses of obesity for 2000–2010 were retrieved from the Hospital Discharge Register and Out-Patient Register, which contain information on all hospital visits, including diagnoses. We searched these two registers for the International Classification of Diseases 10 (ICD-10) codes E65 and E66, denoting obesity as the main diagnosis during the study period. The serial numbers were used to ensure that each individual appeared only once in the dataset, for his or her first diagnosis of obesity during the study period.

**Neighbourhood-Level Deprivation**

The home addresses of all Swedish individuals have been geocoded to small geographic units with boundaries defined by homogeneous types of buildings. These neighbourhood areas, called small area market statistics or SAMS, each contain an average of 1,000 residents and were created by the Swedish Government-owned statistics bureau Statistics Sweden. SAMS were used as proxies for neighbourhoods, as they were in previous research [17, 18]. Neighbourhood of residence is determined annually using the Swedish mapping, cadastral and land registration authority.

A summary index was calculated to characterise neighbourhood-level deprivation. The neighbourhood index was based on information about female and male residents aged 20–64 years because this age group represents those who are among the most socio-economically active in the population (i.e. a population group that has a stronger impact on the socio-economic structure in the neighbourhood than children, younger women and men, and retirees do). The neighbourhood index was based on four items: low education level (<10 years of formal education), low income (income from all sources, including interest and dividends, that is <50% of the median individual income), unemployment (excluding full-time students, those completing military service and early retirees), and receipt of social welfare. The index of the year 2000 was used to categorise neighbourhood deprivation as low (more than 1 SD below the mean), moderate (within 1 SD of the mean), and high (more than 1 SD above the mean) [19].

**Individual-Level Socio-Demographic Variables**

**Sex of child:** male or female.

**Age** ranged from 0 to 14 years and was divided into three categories: 0–4, 5–9 and 10–14 years.

**Marital status** was defined according to maternal marital status, categorized as i) married/cohabitating or ii) never married, widowed or divorced.

**Family income** was calculated as annual family income divided by the number of people in the family. The family income measure took into consideration the ages of the family members and used a weighted
system whereby small children were given lower weights than adolescents and adults. The sum of all family members’ incomes was multiplied by the individual’s consumption weight divided by the family members’ total consumption weight. The final variable was calculated as empirical quartiles from the distribution.

Maternal and paternal education levels were categorised as completion of compulsory school or less (≤9 years), practical high school or some theoretical high school (10–11 years) and completion of theoretical high school and/or college (≥12 years).

Maternal and paternal country of birth was categorised as Sweden, Western country (Western Europe, USA, Canada, Oceania) and other.

Maternal urban/rural status: this variable was included because access to preventive antenatal care may vary according to urban/rural status. Mothers were classified as living in a large city, a middle-sized town or a small town/rural area. Large cities were those with a population of ≥200,000 (Stockholm, Gothenburg and Malmö); middle-sized towns were towns with a population of ≥90,000 but <200,000; small towns were towns with a population of ≥27,000 and <90,000; and rural areas were areas with populations smaller than those of small towns. This classification yielded three equally sized groups.

Mobility: children were classified as having ‘not moved’ or having ‘moved’ to another neighbourhood with the same or a different level of deprivation within 5 years.

Maternal age at childbirth was classified as <20, 20–24, 25–29, 30–34, 35–39, 40–44 and ≥45 years) and paternal age at childbirth was classified as <20, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49 and ≥50 years.

Maternal, paternal and individual hospitalisations were defined as the first diagnosis from the Swedish Hospital Register during the follow-up period of i) diabetes (ICD-10 E10-E14), ii) chronic obstructive pulmonary disease (COPD) (ICD-10 J40-J47) and iii) alcohol-related liver disease (ICD-10 F10 and K70).

Because obesity is known to cluster in families, children were classified according to whether or not they had a family history (parents or siblings) of hospitalization of obesity.

Statistical Analysis

The cumulative rate of obesity was calculated for the total study population and for each subgroup after assessment of neighbourhood of residence for children. Multilevel (hierarchical) logistic regression models were used to estimate odds ratios (ORs) and 95% confidence intervals (95% CIs). The analyses were performed using MLwiN version 2.27 (University of Bristol, Bristol, UK). First, a null model was calculated to determine the variance among neighbourhoods. Then, to determine the crude odds of diagnosed childhood obesity by level of neighbourhood deprivation, a neighbourhood model that included only neighbourhood-level deprivation was calculated (model 1). Next, a full model that included neighbourhood-level deprivation, sex, age and the family- and individual-level socio-demographic variables, added simultaneously to the model, was calculated (aim 1). Finally, a full model tested for cross-level interactions between the family- and individual-level socio-demographic variables and neighbourhood-level deprivation to determine whether the effects of neighbourhood-level deprivation on diagnosed childhood obesity differed across the socio-demographic variables (aim 2).

Random effects: the between-neighbourhood variance was estimated both with and without a random intercept. It was regarded to be significant if it was more than 1.96 times the size of the standard error, which is in accordance with the precedent set in previous studies [20–22].

Ethical Considerations

This study was approved by the Ethics Committee at Lund University.

Results

In the total study population (948,062 children), 20%, 62%, and 18% of children aged 0–14 years lived in low-, moderate- and high-deprivation neighbourhoods, respectively. During the follow-up period (January 1, 2000 to December 31, 2010), 10,799 children were diagnosed with obesity (table 1). Cumulatively diagnosed childhood obesity rates increased from 0.6 per 100 in neighbourhoods with low deprivation to 1.2 per 100 in neighbourhoods
## Table 1. Distribution of population, number of diagnosed childhood obesity events, and age-standardized cumulative rates (per 100) by neighbourhood-level deprivation

<table>
<thead>
<tr>
<th></th>
<th>Population</th>
<th>Obesity events</th>
<th>Neighbourhood deprivation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>no.</td>
<td>no.</td>
<td>low</td>
</tr>
<tr>
<td>Total population (%)</td>
<td>948,062</td>
<td>10,799</td>
<td>187,942 (20%)</td>
</tr>
<tr>
<td>Total obesity events</td>
<td>10,799</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>486,690</td>
<td>5,565</td>
<td>0.6</td>
</tr>
<tr>
<td>Girls</td>
<td>461,372</td>
<td>5,234</td>
<td>0.7</td>
</tr>
<tr>
<td>Age, years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–4</td>
<td>261,589</td>
<td>3,102</td>
<td>0.6</td>
</tr>
<tr>
<td>5–9</td>
<td>340,657</td>
<td>4,437</td>
<td>0.7</td>
</tr>
<tr>
<td>10–14</td>
<td>345,816</td>
<td>3,260</td>
<td>0.6</td>
</tr>
<tr>
<td>Family income</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low income</td>
<td>237,681</td>
<td>3,128</td>
<td>0.8</td>
</tr>
<tr>
<td>Middle–low income</td>
<td>237,772</td>
<td>3,065</td>
<td>0.7</td>
</tr>
<tr>
<td>Middle–high income</td>
<td>236,484</td>
<td>2,605</td>
<td>0.7</td>
</tr>
<tr>
<td>High income</td>
<td>236,125</td>
<td>2,001</td>
<td>0.5</td>
</tr>
<tr>
<td>Marital status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married/cohabiting</td>
<td>553,494</td>
<td>5,566</td>
<td>0.6</td>
</tr>
<tr>
<td>Never married, widowed, or divorced</td>
<td>394,568</td>
<td>5,233</td>
<td>0.7</td>
</tr>
<tr>
<td>Maternal educational attainment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 9 years</td>
<td>298,224</td>
<td>4,476</td>
<td>1.0</td>
</tr>
<tr>
<td>10–11 years</td>
<td>360,568</td>
<td>4,434</td>
<td>0.7</td>
</tr>
<tr>
<td>≥ 12 years</td>
<td>289,270</td>
<td>1,889</td>
<td>0.4</td>
</tr>
<tr>
<td>Paternal educational attainment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 9 years</td>
<td>314,863</td>
<td>4,661</td>
<td>1.0</td>
</tr>
<tr>
<td>10–11 years</td>
<td>357,220</td>
<td>4,354</td>
<td>0.8</td>
</tr>
<tr>
<td>≥ 12 years</td>
<td>275,979</td>
<td>1,784</td>
<td>0.4</td>
</tr>
<tr>
<td>Maternal immigrant status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>818,028</td>
<td>8,955</td>
<td>0.6</td>
</tr>
<tr>
<td>Western countries</td>
<td>59,398</td>
<td>755</td>
<td>0.7</td>
</tr>
<tr>
<td>Other countries</td>
<td>70,636</td>
<td>1,089</td>
<td>1.0</td>
</tr>
<tr>
<td>Paternal immigrant status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>817,772</td>
<td>8,907</td>
<td>0.6</td>
</tr>
<tr>
<td>Western countries</td>
<td>62,948</td>
<td>788</td>
<td>0.7</td>
</tr>
<tr>
<td>Other countries</td>
<td>67,342</td>
<td>1,104</td>
<td>1.2</td>
</tr>
<tr>
<td>Urban/rural status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large cities</td>
<td>280,040</td>
<td>3,541</td>
<td>0.6</td>
</tr>
<tr>
<td>Middle-sized towns</td>
<td>382,270</td>
<td>4,305</td>
<td>0.6</td>
</tr>
<tr>
<td>Small towns/rural areas</td>
<td>285,752</td>
<td>2,953</td>
<td>0.7</td>
</tr>
<tr>
<td>Mobility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not moved</td>
<td>578,542</td>
<td>6,155</td>
<td>0.6</td>
</tr>
<tr>
<td>Moved</td>
<td>369,520</td>
<td>4,644</td>
<td>0.7</td>
</tr>
</tbody>
</table>

*Table 1 continued on next page*
with moderate deprivation and 1.6 per 100 in neighbourhoods with high deprivation. A similar pattern of higher rates with increasing neighbourhood deprivation was observed across all family- and individual-level socio-demographic categories.

The OR for diagnosed childhood obesity for children living in high- versus low-deprivation neighbourhoods in the crude neighbourhood-level model was 2.44 (95% CI = 2.22–2.68) (table 2). High neighbourhood-level deprivation remained significantly associated with the odds of diagnosed childhood obesity after adjustment for age, gender, and the family- and individual-level socio-demographic variables (OR = 1.70, 95% CI = 1.55–1.87; p < 0.001), compared to low-deprivation neighbourhoods. The odds of diagnosed childhood obesity was highest in children in the following subgroups among the included variables: advanced

<table>
<thead>
<tr>
<th>Table 1. Continued</th>
<th>Population no.</th>
<th>Obesity events no.</th>
<th>Neighbourhood deprivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maternal age at child birth, years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;30</td>
<td>545,120</td>
<td>6,217</td>
<td>0.7</td>
</tr>
<tr>
<td>30–39</td>
<td>380,422</td>
<td>4262</td>
<td>0.6</td>
</tr>
<tr>
<td>≥40</td>
<td>22,520</td>
<td>320</td>
<td>0.8</td>
</tr>
<tr>
<td>Paternal age at child birth, years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;30</td>
<td>365,427</td>
<td>4,229</td>
<td>0.6</td>
</tr>
<tr>
<td>30–39</td>
<td>485,142</td>
<td>5,175</td>
<td>0.6</td>
</tr>
<tr>
<td>≥40</td>
<td>97,493</td>
<td>1,395</td>
<td>0.9</td>
</tr>
<tr>
<td>Maternal hospitalization of diabetes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>939,772</td>
<td>10,493</td>
<td>0.6</td>
</tr>
<tr>
<td>Yes</td>
<td>8,290</td>
<td>306</td>
<td>2.3</td>
</tr>
<tr>
<td>Maternal hospitalization of chronic lower respiratory disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>938,197</td>
<td>10,556</td>
<td>0.6</td>
</tr>
<tr>
<td>Yes</td>
<td>9,865</td>
<td>243</td>
<td>1.7</td>
</tr>
<tr>
<td>Maternal hospitalization of alcoholism and related liver disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>938,744</td>
<td>10,631</td>
<td>0.6</td>
</tr>
<tr>
<td>Yes</td>
<td>9,318</td>
<td>168</td>
<td>1.7</td>
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<tr>
<td>Paternal hospitalization of diabetes</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>No</td>
<td>932,296</td>
<td>10,411</td>
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</tr>
<tr>
<td>Yes</td>
<td>15,766</td>
<td>388</td>
<td>1.5</td>
</tr>
<tr>
<td>Paternal hospitalization of chronic lower respiratory disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>941,246</td>
<td>10,642</td>
<td>0.6</td>
</tr>
<tr>
<td>Yes</td>
<td>6,816</td>
<td>157</td>
<td>1.9</td>
</tr>
<tr>
<td>Paternal hospitalization of alcoholism and related liver disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>927,070</td>
<td>10,400</td>
<td>0.6</td>
</tr>
<tr>
<td>Yes</td>
<td>20,992</td>
<td>399</td>
<td>1.3</td>
</tr>
<tr>
<td>Hospitalization of diabetes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>941,835</td>
<td>10,614</td>
<td>0.6</td>
</tr>
<tr>
<td>Yes</td>
<td>6,227</td>
<td>185</td>
<td>2.1</td>
</tr>
<tr>
<td>Family history of obesity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>911,546</td>
<td>8,749</td>
<td>0.5</td>
</tr>
<tr>
<td>Yes</td>
<td>36,516</td>
<td>2,050</td>
<td>4.2</td>
</tr>
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</table>
### Table 2. OR and 95% CI for diagnosed childhood obesity; Results of multi-level logistic regression models

<table>
<thead>
<tr>
<th></th>
<th>Model 1 OR (95% CI)</th>
<th>Model 2 OR (95% CI)</th>
<th>Model 3 OR (95% CI)</th>
<th>Model 4 OR (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neighbourhood-level variable (ref. low)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>1.84 (1.70–2.00)</td>
<td>1.85 (1.70–2.00)</td>
<td>1.56 (1.44–1.69)</td>
<td>1.51 (1.39–1.63)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>High</td>
<td>2.44 (2.22–2.68)</td>
<td>2.43 (2.21–2.67)</td>
<td>1.80 (1.64–1.99)</td>
<td>1.70 (1.55–1.87)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age</td>
<td>0.98 (0.98–0.99)</td>
<td>0.99 (0.99–0.99)</td>
<td>0.99 (0.98–0.99)</td>
<td>0.99 (0.98–0.99)</td>
<td>0.764</td>
</tr>
<tr>
<td>Gender to boys (ref. girls)</td>
<td>1.01 (0.97–1.05)</td>
<td>1.01 (0.97–1.05)</td>
<td>1.01 (0.97–1.05)</td>
<td>1.01 (0.97–1.05)</td>
<td></td>
</tr>
<tr>
<td>Family income (ref. high income)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle-high income</td>
<td>1.07 (1.01–1.14)</td>
<td>1.05 (0.99–1.12)</td>
<td>1.10 (1.03–1.17)</td>
<td></td>
<td>0.110</td>
</tr>
<tr>
<td>Middle-low income</td>
<td>1.15 (1.09–1.22)</td>
<td></td>
<td></td>
<td></td>
<td>0.002</td>
</tr>
<tr>
<td>Low income</td>
<td>1.04 (0.97–1.10)</td>
<td>0.97 (0.91–1.03)</td>
<td>0.96 (0.91–1.03)</td>
<td></td>
<td>0.368</td>
</tr>
<tr>
<td>Marital status (ref. married/co-habiting)</td>
<td>1.16 (1.11–1.21)</td>
<td>1.15 (1.11–1.20)</td>
<td>1.15 (1.11–1.20)</td>
<td>1.15 (1.11–1.20)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Maternal immigrant status (ref. born in Sweden)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>European countries</td>
<td>1.00 (0.92–1.09)</td>
<td>1.02 (0.94–1.12)</td>
<td>0.97 (0.89–1.06)</td>
<td>0.95 (0.86–1.05)</td>
<td>0.617</td>
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<td>Others</td>
<td>0.95 (0.86–1.05)</td>
<td>0.98 (0.89–1.08)</td>
<td>0.96 (0.88–1.04)</td>
<td></td>
<td>0.689</td>
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<td>Paternal immigrant status (ref. born in Sweden)</td>
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<tr>
<td>European countries</td>
<td>0.96 (0.88–1.04)</td>
<td>0.97 (0.89–1.06)</td>
<td>1.23 (1.12–1.35)</td>
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<td>0.549</td>
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<tr>
<td>Others</td>
<td>1.05 (1.02–1.10)</td>
<td>1.04 (1.01–1.11)</td>
<td>1.16 (1.11–1.21)</td>
<td></td>
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<tr>
<td>Maternal education attainment (ref. ≥12 years)</td>
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<tr>
<td>≤9 years</td>
<td>1.67 (1.57–1.78)</td>
<td>1.55 (1.45–1.65)</td>
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<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>10–11 years</td>
<td>1.58 (1.49–1.67)</td>
<td>1.49 (1.41–1.58)</td>
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<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Paternal education attainment (ref. ≥12 years)</td>
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</tr>
<tr>
<td>≤9 years</td>
<td>1.66 (1.56–1.77)</td>
<td>1.58 (1.48–1.68)</td>
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<td>&lt;0.001</td>
</tr>
<tr>
<td>10–11 years</td>
<td>1.57 (1.48–1.67)</td>
<td>1.50 (1.42–1.60)</td>
<td></td>
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<td>&lt;0.001</td>
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<td>Urban/rural status (ref. large cities)</td>
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<td>Middle-sized towns</td>
<td>0.84 (0.80–0.89)</td>
<td>0.85 (0.81–0.90)</td>
<td>0.71 (0.67–0.75)</td>
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<td>&lt;0.001</td>
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<tr>
<td>Small towns/rural areas</td>
<td>0.71 (0.67–0.75)</td>
<td>0.74 (0.69–0.78)</td>
<td>1.07 (1.02–1.11)</td>
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<td>&lt;0.001</td>
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<td>Mobility (ref. not moved)</td>
<td>1.16 (1.09–1.20)</td>
<td>1.15 (1.09–1.20)</td>
<td>1.14 (1.09–1.20)</td>
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<td>&lt;0.001</td>
</tr>
<tr>
<td>Maternal age at child birth, years (ref. &lt;30 years)</td>
<td>1.29 (1.14–1.45)</td>
<td>1.30 (1.15–1.47)</td>
<td>1.30 (1.15–1.47)</td>
<td>1.30 (1.15–1.47)</td>
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<td>30–39</td>
<td>1.14 (1.09–1.20)</td>
<td>1.15 (1.09–1.20)</td>
<td>1.14 (1.09–1.20)</td>
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<td>&lt;0.001</td>
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<tr>
<td>≥40</td>
<td>1.29 (1.14–1.45)</td>
<td>1.30 (1.15–1.47)</td>
<td>1.30 (1.15–1.47)</td>
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<td>&lt;0.001</td>
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<tr>
<td>Paternal age at child birth, years (ref. &lt;30 years)</td>
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<td>1.04 (1.00–1.10)</td>
<td>1.04 (1.00–1.10)</td>
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<td>30–39</td>
<td>1.32 (1.23–1.42)</td>
<td>1.26 (1.17–1.36)</td>
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<td></td>
<td>&lt;0.001</td>
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<tr>
<td>≥40</td>
<td>1.32 (1.23–1.42)</td>
<td>1.26 (1.17–1.36)</td>
<td>1.26 (1.17–1.36)</td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Maternal hospitalization of type 2 diabetes (ref. no)</td>
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<tr>
<td>Maternal hospitalization of chronic lower respiratory disease (ref. no)</td>
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<tr>
<td>Maternal hospitalization of alcoholism and related liver disease (ref. no)</td>
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<td>Maternal hospitalization of diabetes (ref. no)</td>
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<tr>
<td>Paternal hospitalization of chronic lower respiratory disease (ref. no)</td>
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<tr>
<td>Paternal hospitalization of alcoholism and related liver disease (ref. no)</td>
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<tr>
<td>Hospitalization of diabetes (ref. no)</td>
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<tr>
<td>Family history of obesity (ref. without family history)</td>
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</table>

| Variance (S.E.)              | 0.355 (0.018)       | 0.355 (0.018)       | 0.319 (0.017)       | 0.253 (0.015)       |         |
| Explained variance (%)       | 22                  | 22                  | 30                  | 44                  | <0.001  |
parental age at birth, living in large cities, hospitalisation for diabetes, parents who were never married, widowed or divorced, parental low educational level, family moved within 5 years, advanced paternal age at childbirth, a family history of obesity, mothers hospitalised for type 2 diabetes or chronic lower respiratory disease, fathers with non-European country immigration background, fathers hospitalised for diabetes, chronic lower respiratory disease or alcohol-related liver disease.

A test for cross-level interactions between the individual-level socio-demographic variables and neighbourhood-level deprivation in the context of odds of diagnosed childhood obesity showed no meaningful cross-level interactions or effect modification.

The between-neighbourhood variance (i.e. the random intercept) was more than 1.96 times the size of the standard error in all models, indicating that there were significant differences in diagnosed childhood obesity between neighbourhoods after accounting for neighbourhood deprivation and the individual-level variables. Neighbourhood deprivation explained 22% of the between-neighbourhood variance in the null model (table 2). After inclusion of the family- and individual-level variables, the explained variance was 44%.

**Discussion**

We found that living in a deprived neighbourhood increased the odds of diagnosed childhood obesity by 70%. It is noteworthy that we found this effect in a country with a comparatively strong system of universal health care and social welfare. Our finding that neighbourhood deprivation exerts an independent effect on odds of diagnosed childhood obesity is consistent with the findings of a small but growing number of studies that have provided evidence of an association between neighbourhood-level socio-economic factors and diagnosed childhood obesity [9, 10, 12, 14, 15]. Maternal marital status, parental education, paternal age, family history of obesity, co-morbidities, age and living in large cities were associated with higher odds of diagnosed childhood obesity.

Family and individual environments such as parental educational level have been reported to be associated with diagnosed childhood obesity, due to a potential influence on children’s food intake and physical activity [7, 23]. Furthermore, parental smoking and alcohol consumption are associated with higher levels of BMI [24]. However, the causal pathways linking neighbourhood socio-economic deprivation and poor health in childhood are not completely understood [4, 6, 8–12, 14]. One possible mediator could be psychological stress due to isolation/alienation, littered and unsafe environments, vandalism, and violent crime in deprived neighbourhoods [20, 25]. It is possible that the lack of safe environments reduces residents’ ability to exercise, thereby aggravating an unhealthy lifestyle. Additionally, socio-cultural norms regarding diet, smoking and physical activity could vary between neighbourhoods and affect the health of the residents and the risk of disease [15]. For instance, a Swedish study showed that cardiovascular disease risk factors including physical inactivity, obesity and smoking were more common among individuals living in deprived neighbourhoods than among those living in affluent neighbourhoods [26].

Living in deprived neighbourhoods can cause isolation from health-promoting milieus (e.g. safe places to exercise, safe side walks, bike paths, safe parks and decent housing) and services. In comparisons of wealthy nations, associations between neighbourhood characteristics and different health outcomes were inconsistent [27]. This implies that neighbourhood determinants of health are complex. Such determinants may include access to health care, education, and social services. Access to these services is uneven in the USA, where the effects of income inequalities on health are more pronounced [28]. For example, low community income is associated with higher risk of childhood obesity [12]. However, in the present
study, no large associations with family income were observed. Children with parents who were never married, widowed or divorced, with parents with lower level of education, living in large cities, with family history of obesity, with advanced paternal age, with parental co-morbidities and with a history of diabetes had higher odds of obesity. It has been reported previously that neighbourhood socio-economic change (families who moved into different level of neighbourhoods) is associated with the risk of childhood obesity [13].

Level of neighbourhood deprivation may influence risk of childhood obesity through other general mechanisms, including unfavourable health-related behaviours of women during pregnancy [5], neighbourhood social disintegration (i.e. criminality, high mobility or unemployment) [20], low social capital [18, 19, 29], and neighbourhood stress mediated by factors that can influence immunological and/or hormonal stress reactions [30–32]. Consistent with this hypothesis are the results of a US study, which found that neighbourhood socio-economic disparities were associated with childhood and adolescent obesity [9].

The present study has several limitations. These include the possibility that some selective factors operate in the process of hospitalisation to favour certain children being hospitalised. Affordability of health care is not a selective factor in Sweden, nor is the likelihood of seeking medical advice important because of equal access to primary and hospital care [33]. It is, however, possible that residual confounding exists because socio-economic status cannot be fully measured by family income and education level. The Swedish Hospital Discharge Register contains no information about diagnostic procedures, which is a limitation, but any bias this may have caused would most likely be non-differential. However, with respect to childhood obesity, the overall diagnostic validity of the Hospital Discharge Register is close to 90% [34, 35].

The limitations of the study are countered by its strengths, which include: i) the ability to analyse data on a large national cohort of children aged 0–14 years; ii) the prospective design; iii) the completeness of the data (for example, only 1% of the data on maternal education level and family income were missing); iv) the use of small, well-defined neighbourhoods with an average of 1,000 residents; and v) the ability to adjust for a set of family- and individual-level socio-demographic factors (age, sex, family income, maternal marital status, parental country of birth, parental education level, urban/rural status, mobility, parental age, maternal and paternal hospitalisation, and family history of obesity). Accounting for family SES is particularly important, as it is a major confounder that can affect an individual’s choice of neighbourhood. Another strength is the possibility to generalise our results to other populations (external validity), particularly to populations in industrialised societies.

Conclusions

This prospective nationwide study showed that, after accounting for family- and individual-level socio-demographic factors, neighbourhood deprivation was independently associated with increased odds of diagnosed childhood obesity. This finding represents valuable knowledge for health care professionals who work in socially deprived neighbourhoods.

Acknowledgement

The authors wish to thank Science Editor Stephen Gilliver for his useful comments on the text. This work was supported by ALF funding from Region Skåne awarded to Jan Sundquist and Kristina Sundquist, the EU FP7/2007–2013 grant 260715, FAS awarded to Jan Sundquist, and grants from the Swedish Research Council (awarded to Kristina Sundquist and Jan Sundquist). The registers used in the present study are maintained by Statistics Sweden and the National Board of Health and Welfare.
Disclosure Statement

There are no competing interests.

References


