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Mothers, places and risk of hospitalisation for childhood asthma: a nationwide study from Sweden

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Abstract

Objective: This study examines whether neighbourhood deprivation increases the risk of hospitalisation for childhood asthma, after accounting for individual-level maternal sociodemographic characteristics.

Design: An open cohort of all singleton children aged 2 to 11 years was followed between January 1, 1995 and December 31, 2006. Childhood residential addresses were geocoded and classified according to the level of neighbourhood deprivation. Data were analyzed by multilevel logistic regression, with individual-level characteristics (sex, age, maternal marital status, family income, maternal educational attainment, maternal immigration status, maternal urban/rural status, mobility, maternal asthma history, and maternal smoking) at the first level and level of neighbourhood deprivation at the second level.

Results: During the study period, among a total of 866,860 children, 17,682 (2.0%) were hospitalized with childhood asthma. Age-adjusted hospital rates for childhood asthma increased with increasing level of neighbourhood deprivation. In the study population, 1.9% and 2.3% of children in the least and most deprived neighbourhoods, respectively, were affected by childhood asthma. Hospital rates of childhood asthma increased with increasing neighbourhood-level deprivation across all individual-level maternal sociodemographic categories, including marital status, educational attainment, urban/rural status, maternal history of asthma and smoking. The odds ratio (OR) for those living in high-deprivation neighbourhoods versus those living in low-deprivation neighbourhoods was 1.23 (95% confidence interval, 1.16–1.30). High neighbourhood deprivation remained significantly associated with childhood asthma risk after adjustment for maternal sociodemographic characteristics (OR=1.08, $p=0.016$).

Conclusions: This study is the largest so far on neighbourhood influences on childhood asthma. Our results suggest that neighbourhood characteristics affect the risk of hospitalization for childhood asthma

independently of maternal sociodemographic characteristics.

Keywords: childhood asthma, neighbourhood-level deprivation, incidence, sociodemographic factors, multilevel modelling

Introduction

Asthma is a major health risk in childhood [1-3]. Although the specific mechanisms behind childhood asthma are largely unknown, risk factors include smoking during pregnancy [4], familial history of asthma [5], young maternal age at pregnancy [6] and low socioeconomic status [7-9]. These individual-level sociodemographic characteristics do not, however, fully explain the disparities in childhood asthma risk that exist between different population groups. Efforts have therefore been made to study whether the socioeconomic environment is associated with the risk of childhood asthma.

Previous studies have examined the effects of the neighbourhood environment on childhood asthma. A U.S. study found that children who lived in census tracts facing intersections with highways or railroads had a higher risk of asthma than those who lived in census tracts not facing intersections[10]. The results of other studies showed that the overall risk of childhood asthma was increased among families living in neighbourhoods with high crime rates. [11, 12]

The present study had the following two aims: 1) to determine whether the relationship between neighbourhood deprivation and risk of hospitalization for childhood asthma remained significant after adjusting for individual-level maternal sociodemographic factors; and 2) to examine possible cross-level interactions between individual-level maternal sociodemographic factors and neighbourhood-level deprivation to determine whether neighbourhood-level deprivation had a differential effect on risk of

hospitalization for childhood asthma across subgroups of women (effect modification).

Methods

The study population consisted of an open cohort of all singleton children born in Sweden, who were followed between January 1, 1995 and December 31, 2006. The dataset we used contains nationwide information on maternal and childhood factors at both the individual and neighbourhood levels, including comprehensive demographic and socioeconomic data. The information in the database comes from several Swedish national registers. The registers used in the present study were the Medical Birth Register, the Hospital Discharge Register and the Total Population Register. The Swedish nationwide population and health care registers have an exceptionally high completeness and validity [13].

Individuals (mothers and children) were tracked using their personal identification numbers, which were replaced with serial numbers to provide anonymity.

Outcome variable: childhood asthma

The outcome variable in this study was a first hospital diagnosis of childhood asthma (age at diagnosis 2 to 11 years) during the study period. Data on first hospital diagnoses of asthma were retrieved from the Hospital Discharge Register (1995–2006). This register includes information on all hospital visits, including diagnoses. We searched the Hospital Discharge Register for the following International Classification of Diseases (ICD) codes for asthma as the main diagnosis during the study period: 493 (ICD-9; used in Swedish hospitals between 1995 and 1996), J45 and J46 (ICD-10; 1997–2006). The serial numbers were used to ensure that each individual appeared only once in the dataset, for his or her first hospital diagnosis of asthma 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 has been done in previous research [14, 15]. Neighbourhood of residence is determined annually using the National Land Survey of Sweden register. The child's neighbourhood of residence was assessed at start of the follow-up, i.e., in 1995.

A summary index was calculated to characterise neighbourhood-level deprivation. The neighbourhood index was based on information about female and male residents aged 20 to 64 because this age group represents those who are among the most socioeconomically active in the population (i.e. a population group that has a stronger impact on the socioeconomic structure in the neighbourhood than children, younger women and men, and retirees do). The neighbourhood index was based on four items: low educational status (<10 years of formal education), low income (income from all sources, including that from interest and dividends, <50% of median individual income), unemployment (excluding full-time students, those completing military service, and early retirees), and receipt of social welfare. The index was categorised as low neighbourhood deprivation (more than one SD below the mean), moderate neighbourhood deprivation (within one SD of the mean), and high neighbourhood deprivation (more than one SD above the mean) [16].

Individual-level sociodemographic variables

Sex of child: male or female.

Age ranged from 2 to 11 years and was divided into 2-5, 6-8, and 9-11-year categories.

Maternal marital status (data for which were obtained from the Medical Birth Register) was grouped as (1) married/cohabitating or (2) 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 parameter 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 educational attainment was 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/university (≥ 12 years).

Maternal immigration status: country of birth was categorised as Sweden, Western countries (Western Europe, USA, Canada, Oceania), and others.

Maternal urban/rural status: mothers were classified as living in a large city, a middle-sized town, or a small town/rural area. This variable was included because urban/rural status may be associated with access to preventive antenatal care and air pollution. Large cities were those with a population of $\geq 200,000$ (Stockholm, Gothenburg and Malmö). Middle-sized towns were towns with a population of $\geq 90,000$ and $< 200,000$. Small towns were towns with a population of $\geq 27,000$ and $< 90,000$; 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 “moved” to another neighbourhood with the same or a different level of deprivation within five years.

Because asthma is known to cluster in families [5], children were classified according to whether or not they had a *maternal history of asthma* (hospital-diagnosed).

Maternal smoking: non-smokers and smokers.

Statistical analysis

Hospital rates of asthma were calculated for the total population and for each subgroup after assessment of each neighbourhood of residence for the children. Multilevel (hierarchical) logistic regression models were used to estimate odds ratios (ORs). The analyses were performed using MLwiN version 2.02. First, a null model was calculated to determine the variance among neighbourhoods. Then, to determine the crude risk of childhood asthma by level of neighbourhood deprivation, a neighbourhood model that included only neighbourhood-level deprivation was calculated. Next, a full model that included neighbourhood-level deprivation and sex, age and the eight individual-level maternal sociodemographic variables, added simultaneously to the model, was calculated (Aim 1). Finally, a full model tested the cross-level interactions between the individual-level sociodemographic variables and neighbourhood-level deprivation to determine if the effects of neighbourhood-level deprivation on hospitalization for childhood asthma differed across the sociodemographic variables (Aim 2).

Random effects: the between-neighborhood variance was estimated both with and without a random intercept. It was regarded to be significant if it was larger than 1.96 times the standard error, in accordance with the precedent set in previous studies [17-19].

Ethical considerations

This study was approved by the Ethics Committee at Lund University (approval number: 71/2008).

Results

Of the total study population, 26.7%, 58.5%, and 14.8% of children lived in low-, moderate- and high-deprivation neighbourhoods, respectively. During the follow-up period (January 1, 1995 to December 31, 2006), there were 864,468 singleton births aged 2 to 11 years; 17,672 (2.0%) of these children were diagnosed with childhood asthma (Table 1). Hospital rates of childhood asthma rates increased from 1.9% in neighbourhoods with low deprivation to 2.0% in neighbourhoods with moderate deprivation and 2.3%

in neighbourhoods with high deprivation. A similar pattern of higher hospital rates with each increasing level of neighbourhood deprivation was observed across all ten individual-level sociodemographic categories.

The odds ratio (OR) for hospitalization for childhood asthma for children living in a high- versus low-deprivation neighbourhoods in the crude neighbourhood-level model was 1.23 (95% confidence interval (CI), 1.16–1.30) (Table 2). Neighbourhood-level deprivation remained significantly associated with childhood asthma risk after adjusting for sex, age, and the eight individual-level maternal sociodemographic variables. The OR=1.08 (95% CI, 1.01–1.15, p-value=0.016) for high deprivation neighbourhoods.

Risk of childhood asthma was highest in those whose mothers: were never married, widowed or divorced; had the lowest educational attainment; had a history of asthma; and/or were smokers. All categories showed a gradient effect across level of neighbourhood deprivation.

The test for cross-level interactions between the individual-level sociodemographic variables and neighbourhood-level deprivation in the context of risk of childhood asthma showed no meaningful cross-level interactions or effect modification.

The between-neighbourhood variance (i.e., the random intercept) was over 1.96 times the standard error in all models, indicating that there were significant differences in childhood asthma between neighbourhoods after accounting for neighbourhood deprivation and the individual-level variables.

Neighbourhood deprivation explained 5% of the between-neighbourhood variance in the null model (see Table 2). After inclusion of the individual-level variables, the explained variance was 12%.

Discussion

We found that living in a deprived neighbourhood increased the odds of hospitalisation for childhood asthma by 23%. This is a modest increase in risk, but one with important public health consequences in deprived neighbourhoods. It is noteworthy that this effect was found 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 risk of childhood asthma is consistent with the findings of a small but growing number of studies that have provided evidence of an association between neighbourhood-level socioeconomic factors and childhood asthma [10, 20-22]. Few previous researchers studying neighbourhood-level deprivation have had access to data enabling them to use childhood asthma as a specific outcome variable. One study on neighbourhood deprivation and risk of childhood asthma from Chicago found a risk of childhood asthma of 1.32 among children who lived in the most deprived neighbourhoods [22]. Our study confirms this finding in a larger, nationwide sample of singleton children.

Level of neighbourhood deprivation may influence risk of childhood asthma through a number of general mechanisms, including unfavourable health-related behaviours [14, 23, 24], neighbourhood social disintegration (i.e. criminality, high mobility or unemployment) [25], low social capital [15, 26, 27] and neighbourhood stress mediated by factors that can influence immunological and/or hormonal stress reactions [28-30]. For example, it has been suggested that crime lies in the pathway linking the neighbourhood social environment and health [31, 32]; indeed, and a consistent association between neighbourhood social deprivation and crime has been found in previous studies [31]. Socially deprived neighbourhoods in the U.S. are often affected by both criminal violence and residential instability [32]. It is possible that women are particularly vulnerable to stressors such as crime during pregnancy [33].

Consistent with this hypothesis are the results of a 2009 U.S. study, which found that parents' perceptions

of neighbourhood safety were associated with childhood asthma [12]. Living in a deprived neighbourhood can cause isolation from health-promoting milieus (e.g. safe places to exercise, decent housing) and services.

The present study has several limitations. Firstly, it is possible that residual confounding exists because socioeconomic status cannot be measured entirely by family income and educational attainment.

Secondly, the sample sizes were too small to allow us to analyse whether the children of women from specific countries are at higher risk of childhood asthma. This would be a limitation if ethnicity is one of the mechanisms underlying the neighbourhood effect on childhood asthma [34]. Thirdly, the variable for marital status underestimated the proportion of mothers who were cohabiting with a partner. However, we retained this variable in the analysis because marital status was associated with risk of childhood asthma, and because underestimation of the proportion of mothers who were cohabiting will result in an underestimation of the risk estimates rather than an overestimation.

Other limitations include the reduction in the number of cases and the possibility that some selective factors operated in the process of hospitalization that favoured some children being hospitalized.

Affordability of healthcare is, however, most likely not a selective factor in Sweden, nor is the likelihood of seeking medical advice because of the equal access to primary and hospital care [35].

The Swedish Hospitalization Discharge Register contains no information about diagnostic procedures, which might be a limitation, but it would be a nondifferential bias. However, with respect to asthma, the overall diagnostic validity of the Swedish Inpatient Register is close to 90% [36, 37]. Moreover, the diagnosis of asthma in the Swedish Inpatient Register has been validated and found to be correct in 93% of asthma diagnoses [36, 38].

The limitations of the study are countered by its strengths, which include: 1) the ability to analyse data on a large national cohort of children over a period of 12 years; 2) the prospective design; 3) the completeness of the data (for example, only 1% of the data on maternal education and family income were missing); 4) the use of small, well-defined neighbourhoods with an average of 1,000 residents; and 5) the ability to adjust for a set of individual-level maternal sociodemographic factors, including family income, as well as maternal history of asthma and maternal smoking. This is particularly important, as family income is a major confounder that can affect an individual's choice of neighbourhood. Another strength is the possibility of generalising our results to other populations (external validity), particularly to populations in other industrialised societies.

Conclusions

This prospective nationwide study showed that, after accounting for individual-level sociodemographic factors as well as maternal history of asthma and smoking, neighbourhood deprivation increased the risk of childhood asthma. This finding represents valuable knowledge for health care professionals who work in neighbourhoods with varying levels of neighbourhood deprivation.

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Competing interests

There are no competing interests.

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Table 1. Distribution of population, number of hospitalized asthma events, and age-standardized hospitalized rates (%) by neighborhood-level deprivation

	Population	Distribution (%)	Number of asthma events	Neighborhood deprivation		
				Low	Moderate	High
Total population (%)	864468			231369 (26.7)	505503 (58.5)	127596 (14.8)
All asthma events			17672	1.9	2.0	2.3
Sex						
Male	446035	51.6	11699	2.4	2.6	3.0
Female	418433	48.4	5973	1.3	1.4	1.6
Age, years						

2-5	323214	37.4	7639	2.2	2.4	2.6
6-8	287382	33.2	6104	1.9	2.2	2.5
9-11	253872	29.4	3929	1.4	1.5	1.7
Maternal marital status						
Married/cohabiting	815379	94.3	16168	1.8	2.0	2.2
Never married, widowed, or divorced	49089	5.7	1504	2.4	2.9	3.5
Family income						
Low income	58985	6.8	1330	2.1	2.2	2.3
Middle-low income	211511	24.5	4814	2.1	2.2	2.5
Middle-high income	344985	39.9	6864	1.9	2.0	2.2
High income	248987	28.8	4664	1.8	2.0	2.5
Maternal educational attainment						
Compulsory school or less (≤ 9 years)	151852	17.6	3821	2.4	2.5	2.7
Practical high school or some theoretical high school (10–11 years)	373524	43.2	8087	2.1	2.1	2.4
Theoretical high school and/or college (≥ 12 years)	339092	39.2	5764	1.7	1.7	1.8
Maternal immigrant status						
Sweden	768188	88.9	15916	1.9	2.1	2.5
Western countries*	50489	5.8	964	1.5	2.0	2.1
Others	45791	5.3	792	1.6	1.7	1.7
Maternal urban/rural status						
Large cities	281480	32.6	5660	1.8	2.1	2.3
Middle-sized towns	314371	36.4	6934	1.9	2.2	2.7
Small towns/rural areas	268617	31.1	5078	1.9	1.9	2.0
Mobility						
Not moved	504418	58.4	9708	1.9	2.0	2.3
Moved	360050	41.6	7964	1.9	2.2	2.4

Maternal history of asthma

No	861973	99.7	17535	1.9	2.0	2.3
Yes	2495	0.3	137	4.9	6.1	4.6
Maternal smoking						
No	632823	73.2	11083	1.7	1.8	1.9
Yes	231645	26.8	6589	2.7	2.8	3.3

*: Western countries include Western Europe, USA, Canada, and Oceania.

Table 2. Odds ratios (OR) and 95% confidence intervals (CI) for hospitalized childhood asthma; Results of multi-level logistic regression models

				Model 1			Model 2			Model 3			
													P-
				OR	95% CI		OR	95% CI		OR	95% CI		value
Neighborhood deprivation (ref. Low)													
Moderate				1.09	1.04	1.13	1.08	1.04	1.13	1.02	0.97	1.06	0.484
High				1.23	1.16	1.30	1.22	1.15	1.29	1.08	1.01	1.15	0.016
Age, years (ref. 2-5 years)													
6-8							0.90	0.87	0.93	0.91	0.87	0.94	<0.001
9-11							0.65	0.63	0.68	0.65	0.62	0.68	<0.001
Sex, Female (ref. Male)							0.53	0.52	0.55	0.53	0.51	0.55	

					<0.001
Maternal marital status (ref. Married/co-habiting)					
Never married, widowed, or divorced	1.28	1.21	1.36		<0.001
Family income (ref. High income)					
Middle-high income	0.96	0.92	0.99		0.021
Middle-low income	1.00	0.95	1.05		0.968
Low income	0.91	0.85	0.97		0.007
Maternal education attainment (ref. Theoretical high school and/or college (≥ 12 years))					
Compulsory school or less (≤ 9 years)	1.28	1.23	1.34		<0.001
Practical high school or some theoretical high school (10–11 years)	1.17	1.13	1.22		<0.001
Maternal immigration status (ref. Born in Sweden)					
Western countries*	0.88	0.83	0.94		<0.001
Others	0.80	0.74	0.86		<0.001
Maternal urban/rural status (ref. Large cities)					
Middle-sized towns	1.08	1.03	1.13		<0.001
Small towns/rural areas	0.93	0.88	0.97		0.001
Mobility (ref. Not moved)	1.09	1.06	1.13		<0.001

Maternal history of asthma (ref. No)			2.49	2.08	2.97	<0.001
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Maternal smoking (ref. No)			1.53	1.48	1.58	<0.001
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<i>Variance (S.E.)</i>	<i>0.139(0.009)</i>	<i>0.140 (0.009)</i>	<i>0.128 (0.009)</i>
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<i>Explained variance (%)</i>	<i>5</i>	<i>5</i>	<i>13</i>
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*: Western Europe, USA, Canada, and Oceania.