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Neighborhood, family, and childhood and adolescent epilepsy: a nationwide epidemiological study from Sweden

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Abstract

Purpose: To examine whether neighborhood deprivation increases the odds of hospital registration for childhood and adolescent epilepsy, after accounting for family- and individual-level sociodemographic characteristics.

Methods: An open cohort of all children aged 2 to 17 years was followed between January 1, 2000 and December 31, 2010. Children's residential addresses were geocoded and classified according to neighborhood deprivation. Data were analyzed by multilevel logistic regression, with family- and individual-level characteristics at the first level and level of neighborhood deprivation at the second level.

Results: During the study period, among a total of 1,020,766 children, 9309 (0.9%) were registered with childhood and adolescent epilepsy. Age-adjusted cumulative hospital rates of childhood and adolescent epilepsy increased with increasing neighborhood-level deprivation across all family- and individual-level sociodemographic categories. The odds ratio (OR) for hospital registration for childhood and adolescent epilepsy for those living in high-deprivation neighborhoods versus those living in low-deprivation neighborhoods was 1.15. High level deprivation remained significantly associated with higher odds of childhood and adolescent epilepsy after adjustment for family- and individual-level sociodemographic characteristics (OR=1.12, 95% CI=1.04–1.21, p=0.003).

Conclusions: Our results suggest that neighborhood characteristics modestly affect the odds of hospital registration for childhood and adolescent epilepsy independently of family- and individual-level sociodemographic characteristics.

Keywords: childhood and adolescent epilepsy, cumulative incidence, multilevel modeling, neighborhood-level deprivation, sociodemographic factors

Introduction

Epilepsy is a common disabling condition, which affects approximately 3% of the world population during their lifetime. Epilepsy is a major health risk in childhood and adolescence [1], although the specific mechanisms behind childhood and adolescent epilepsy are largely unknown, except for cerebrovascular disorders, head trauma, brain tumors, developmental disorders, generative disorders, and infections, which explain approximately 50% of the cases [2]. There is a growing body of evidence implicating individual risk factors such as family history of epilepsy [3] and low socioeconomic status as risk factors for epilepsy in children and adolescents [4, 5]. These individual-level sociodemographic characteristics do not, however, fully explain the disparities in childhood and adolescent epilepsy 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 and adolescent epilepsy [6-8].

The present study had the following two aims: (1) to determine whether the relationship between neighborhood deprivation and odds of hospital registration for childhood and adolescent epilepsy remained significant after adjusting for individual-level sociodemographic factors; and (2) to examine possible cross-level interactions between individual-level sociodemographic factors and neighborhood-level deprivation in order to determine whether neighborhood-level deprivation has a differential effect on odds of childhood and adolescent epilepsy across subcategories of family- and individual-level variables (effect modification).

Methods

Data used in this study were retrieved from a nationwide 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 neighborhood levels, including comprehensive demographic and socioeconomic data. The data sources come 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 [9]. Individuals (children and their parents) were tracked using their personal identification numbers, which are assigned to each resident of Sweden. Their identification numbers were replaced with serial numbers to provide anonymity. The follow-up period ranged from January 1, 2000 until first hospitalization/out-patient registration for epilepsy during the study period, death, emigration or the end of the study period on December 31, 2010.

Outcome variable: childhood and adolescent epilepsy

The outcome variable in this study was a first hospital or out-patient diagnosis of childhood and adolescent epilepsy (age at diagnosis 2 to 17 years) during the study period. Data on in-hospital or out-patient diagnoses of epilepsy were retrieved from the Hospital Discharge Register (2000–2010) and Outpatient Register (2001–2010). These registers include information on all hospital visits, including diagnoses. We searched the Hospital Discharge Register and Out-Patient Register for the International Classification of Diseases (ICD)-10 code G40, denoting for epilepsy 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 hospital diagnosis of epilepsy during the study period.

Neighborhood-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 neighborhood 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 neighborhoods, as they were in previous research [10, 11]. Neighborhood of residence is determined annually using the National Land Survey of Sweden Register.

A summary index was calculated to characterize neighborhood-level deprivation. The neighborhood 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 neighborhood than children, younger women and men, and retirees do). The neighborhood index was based on four items: low education level (<10 years of formal education), low income (income from all sources, including that from interest and dividends, <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 was used to categorize neighborhood deprivation as low (more than one SD below the mean), moderate (within one SD of the mean), and high (more than one SD above the mean) [12].

Individual-level sociodemographic variables

Sex of the child or adolescent: male or female.

Age ranged from 2 to 17 years and was divided into three categories: 2–4, 5–11, and 12–17 years.

Because a poor antenatal and intrapartum environment is known to be a risk factor for epilepsy in term newborns [13, 14], children's age was limited to ages over 1 year.

Marital status was grouped according to the maternal marital status, 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 and paternal educational level was categorized 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 and paternal country of birth was categorized as Sweden, Western countries (Western Europe, USA, Canada, Oceania), and Others.

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. 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; rural areas were areas with populations smaller than those of small towns. This classification yielded three equal-sized groups.

Mobility: children were classified as having "not moved" or "moved" to another neighborhood with the same or a different level of deprivation within five years before the start of the follow-

up.

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

Maternal and paternal comorbidity was defined as hospitalization (within 10 years before the start of the follow-up) for a main diagnosis of the following diseases: (1) chronic obstructive pulmonary disease (ICD-9 490–496 and ICD-10 J40–J49); (2) alcoholism and alcohol-related diseases (ICD-9 291 and 303 and ICD-10 F10 and K70).

Because epilepsy is known to cluster in families [3], children were classified according to whether or not they had a *parental or sibling history of epilepsy*.

Statistical analysis

The rate of cumulative hospital registration rates for epilepsy was calculated for the total population and for each subgroup after assessment of neighborhood of residence for children. Multilevel logistic regression was performed with individuals at the first level and neighborhoods at the second level [15, 16]. The fixed effects are presented as odds ratios (ORs) with 95% confidence intervals (CIs) (significance would be accepted at $p < 0.05$). The multilevel approach allowed us to calculate random effects; they were calculated as the variance between neighborhoods and the explained variance. Logistic regression was considered to be a good approximation of Cox's proportional hazard models because we had a large sample size, a relatively low incidence rate, risk ratios of moderate size, and a relatively short follow-up period [17]. The analyses were performed using MLwiN version 2.27. First, a null model was calculated to determine the variance among neighborhoods. Then, to determine the crude odds of childhood and adolescent epilepsy by level of neighborhood deprivation, a neighborhood model

that included only neighborhood-level deprivation was calculated. Next, a full model that included neighborhood-level deprivation and sex, age and the family and individual-level sociodemographic variables, added simultaneously to the model, was calculated (Aim 1). Finally, cross-level interactions between the individual-level sociodemographic variables and neighborhood-level deprivation were tested to determine whether the effects of neighborhood-level deprivation on the odds 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 as significant if it was more than 1.96 times the size of the standard error, in accordance with the precedent set in previous studies [18-20]. For comparison, we also calculated Cox regression models and logistic regression models using the SAS statistical package (version 9.3; SAS Institute, Cary, NC, USA).

Ethical considerations

The design of this study was approved by the Ethics Committee at Lund University.

Results

In the total study population (1,020,776 children and adolescents), 20%, 63%, and 17% of children aged 2 to 17 years lived in low-, moderate- and high-deprivation neighborhoods, respectively. During the follow-up period (January 1, 2000 to December 31, 2010), 9309 children and adolescents were diagnosed with epilepsy (Table 1). Childhood and adolescent cumulative hospital registration rates increased from 8.7 per 1000 in neighborhoods with low deprivation to 9.0 per 1000 in neighborhoods with moderate deprivation and 10.0 per 1000 in neighborhoods with high deprivation. A similar pattern of higher hospital registration rates with

increasing neighborhood deprivation was observed across all family and individual-level sociodemographic categories.

The OR for hospital registration for childhood and adolescent epilepsy for those individuals living in a high- versus low-deprivation neighborhoods was 1.15 (95% CI=1.07–1.23) in the crude neighborhood-level model (Table 2). Neighborhood-level deprivation remained significantly associated with childhood and adolescent epilepsy risk after adjustment for age, sex, and the other family- and individual-level sociodemographic variables; the OR=1.12 (95% CI= 1.04–1.21, p=0.003) for high-deprivation neighborhoods versus low-deprivation neighborhoods. The odds of childhood and adolescent epilepsy were highest in children whose parents had lower educational level, those who had moved within 5 years, those with advanced paternal age, those with a parental or sibling history of epilepsy, and those whose mothers had been registered for chronic obstructive pulmonary disease or whose fathers had been hospitalized for alcoholism or liver-related disease. Low ORs for children and adolescent epilepsy were found in those with low family income, those whose mothers were born in other countries, and those living in small towns/rural areas.

A test for cross-level interactions between the individual-level sociodemographic variables and neighborhood-level deprivation in the context of odds of childhood and adolescent epilepsy showed no meaningful cross-level interactions (i.e., effect modification). For example, the interactions between neighborhood deprivation and parental educational attainment are shown in Table 3. For children and adolescents whose parents had a low educational level, the odds of epilepsy were higher than for those whose parents had a high level of education, and the directions of these associations were similar in all types of neighborhoods with the exception of

paternal education in moderately deprived neighborhoods. However, we judge that this potential interaction is minor and unlikely to be clinically meaningful.

The between-neighborhood variance (i.e., the random intercept) was over 1.96 times greater than the standard error in all models, indicating that there were significant differences in childhood and adolescent epilepsy rates between neighborhoods after accounting for neighborhood deprivation and the individual-level variables. Neighborhood deprivation explained 6% of the between-neighborhood variance in the null model (see Table 2). After inclusion of the family- and individual-level variables, the explained variance was 36%.

We performed an additional analysis of the potential effects of moving between different levels of neighborhood deprivation. Supplementary Table 1 shows the ORs for individuals who moved between different levels of neighborhood deprivation within 5 years before the start of the follow-up. However, only those individuals who moved from moderately deprived neighborhoods to highly deprived neighborhoods had a significantly increased odds (OR = 1.14, 95% CI 1.02–1.27).

To strengthen the choice of multi-level analysis, we also performed an additional analysis using logistic regression models and the results were almost identical (Supplementary Table 2). In the full model, the OR for childhood and adolescent epilepsy was 1.12 (95% CI=1.04–1.21) for children living in the most deprived neighborhoods compared with those living in the least deprived neighborhoods.

We also performed an analysis using Cox regression models (Supplementary Table 3). In the full model, the hazard ratio (HR) for childhood and adolescent epilepsy was 1.13 (95% CI=1.05–1.21) among children living in the most deprived neighborhoods compared with those living in the least deprived neighborhoods.

Discussion

We found that living in a deprived neighborhood increased the odds of hospital registration for childhood and adolescent epilepsy by 15%. This is a modest increase in odds, but it may have important public health implications for deprived neighborhoods, as epilepsy is often a disease with serious consequences for the affected families. 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 neighborhood deprivation exerts an independent effect on the risk of childhood and adolescent epilepsy is consistent with the findings of a small but growing number of studies that have provided evidence of an association between neighborhood-level socioeconomic factors and childhood and adolescent epilepsy [6-8]. However, few previous researchers studying neighborhood-level deprivation have had access to data enabling them to use childhood and adolescent epilepsy as a specific outcome variable. One study on neighborhood deprivation and risk of childhood and adolescent epilepsy from the U.K. found a risk of epilepsy of 1.04 among children who lived in the most deprived neighborhoods [6], and another U.K. study showed a risk of epilepsy around 2.5 in 0–14-year-old children living in the highest socioeconomic deprivation [8]. Our study confirms this finding in a larger nationwide sample of children and adolescents.

The level of neighborhood deprivation may influence the risk of childhood and adolescent

epilepsy through a number of general mechanisms, including unfavorable health-related behaviors [10, 21, 22], neighborhood social disintegration (i.e. criminality, high mobility, or unemployment) [18], low social capital [11, 23, 24], and neighborhood stress mediated by factors that can influence immunological and/or hormonal stress reactions [25-27]. For example, it has been suggested that crime lies in the pathway linking the neighborhood social environment and health [28, 29], with a consistent association between neighborhood social deprivation and crime having been found in previous studies [28]. Socially deprived neighborhoods in the U.S. are often affected by both criminal violence and residential instability [29]. It is possible that women are particularly vulnerable to stressors such as crime during pregnancy [30]. Living in a deprived neighborhood can cause isolation from health-promoting milieus (e.g. safe places to exercise, decent housing) and services.

The experience of being discriminated against in deprived neighborhoods with a poor reputation may also contribute to a negative epilepsy risk profile [8]. In comparisons of wealthy nations, associations between neighborhood characteristics and different health outcomes have been inconsistent [6]. This implies that neighborhood determinants of health are complex. Such determinants may include access to healthcare, education, and social services. Access to these services is uneven in the U.S., where the effects of income inequalities on health may be more pronounced [31]. In Iceland, low socioeconomic status, indexed by low education or lack of home ownership, was reported to be associated with a higher risk of epilepsy in adults, but not in children [32]. In contrast, family income was not associated with adult or childhood epilepsy in the multivariate analyses [32]. The present study found that children and adolescents living in families with lower incomes had lower odds of epilepsy. Another Swedish study by Mattson et al. found that more recently licensed antiepileptic drugs were prescribed more extensively to

children whose parents had higher incomes than to those children with low household incomes. In addition, their data indicated that sociodemographic status influences access to neuropediatricians and individual antiepileptic drugs for children and adolescents with epilepsy [33]. Thus, a possible reason behind our contradictory finding is that families with higher family incomes may be more likely to seek treatment for children and adolescents with unexplained seizures [32].

Neighborhood-level inequities include unequal access to and quality of primary and secondary healthcare services [34]. In Sweden, medical care is provided to all permanent residents, and primary healthcare clinics and hospitals are equally distributed and located centrally in all types of neighborhoods [34]. However, the actual number of health professionals working in, for example, primary healthcare clinics can vary considerably by neighborhood type [33]. This is due to difficulties in recruiting and retaining healthcare personnel in high-deprivation neighborhoods. The misdistribution of medical personnel across neighborhoods has also been documented in England, another country with universal health care [35].

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 analyze whether the children of women from specific countries are at higher risk of childhood and adolescent epilepsy. This would be a limitation if ethnicity is one of the mechanisms underlying the neighborhood effect on childhood and adolescent epilepsy [36]. 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 and adolescent epilepsy, and because underestimation of the proportion of mothers who were cohabiting will result in an underestimation of the risk estimates rather than an overestimation.

The limitations include the reduction in the number of cases and the possibility that some selective factors operate in the process of hospitalization to favor certain children being hospitalized. Affordability of healthcare is not a selective factor in Sweden, nor is the possibility of seeking medical advice selective because access to primary and hospital care is equal [34].

The Swedish Hospital Discharge Register contains no information about diagnostic procedures, which is a limitation, but any bias this caused would be non-differential. However, with respect to epilepsy, the overall diagnostic validity of the Swedish Inpatient Register is close to 90% [37, 38].

The limitations of the study are countered by its strengths, which include: (1) the ability to analyze data on a large national cohort over a period of 11 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 neighborhoods with an average of 1,000 residents; and (5) the ability to adjust for a set of family- and individual-level sociodemographic factors (age, sex, family income, maternal marital status, parental country of birth, parental education level, urban/rural status, mobility, advanced parental age, and family history of epilepsy). Accounting for family income is particularly important, as it is a major confounder that can affect an individual's choice of neighborhood. Another strength is the possibility to generalize our results to other populations (external validity), particularly to

populations in industrialized societies. Finally, our results are comparable with previously observed prevalence and incidence rates of epilepsy in children, reported by Hauser [39].

Conclusions

This prospective nationwide study showed that, after accounting for family- and individual-level sociodemographic factors, neighborhood deprivation is associated with a modestly increased odds of childhood and adolescent epilepsy. This finding may represent valuable knowledge for health care professionals who work in neighborhoods with varying levels of neighborhood deprivation as well as for public health policy makers.

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Competing interests

There are no competing interests.

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Table 1. Distribution of population, number of childhood and adolescent epilepsy events, and age-standardized cumulative incidence (per 1000) by neighborhood-level deprivation

	Population		Epilepsy events		Neighborhood deprivation		
	No.	%	No.	%	Low	Moderate	High
Total population (%)	1020776				203311 (20%)	640296 (63%)	177169 (17%)
Total epilepsy events			9309		8.7	9.0	10.0
Gender							
Men	524520	51.4	4811	51.7	8.4	9.0	10.5
Women	496256	48.6	4498	48.3	9.0	9.0	9.4
Age (years)							
2–4	218237	24.7	2141	23.0	9.3	9.5	11.3
5–11	425219	41.7	3938	42.3	9.0	9.2	9.7
12–17	377320	37.0	3230	34.7	7.9	8.5	9.4
Family income							
Low income	256114	25.1	2210	23.7	8.6	8.4	9.2
Middle–low income	255147	25.0	2320	24.9	8.9	8.9	10.1
Middle–high income	254959	25.0	2285	24.5	8.2	8.8	10.5
High income	254556	24.9	2494	26.8	8.9	10.0	11.7
Marital status							
Married/cohabiting	623173	61.0	5501	59.1	8.7	8.7	9.6
Never married, Widowed, or divorced	397603	39.0	3808	40.9	8.7	9.5	10.4
Maternal immigrant status							
Sweden	883646	86.6	8074	86.7	8.7	9.0	10.3
Western countries	67284	6.6	634	6.8	8.1	9.2	10.3
Other countries	69846	6.8	601	6.5	8.0	8.4	8.7
Paternal immigrant status							
Sweden	885629	86.8	8069	86.7	8.6	9.0	10.4
Western countries	68791	6.7	641	6.9	8.8	9.2	9.6
Other countries	66356	6.5	599	6.4	10.2	8.6	9.1
Maternal educational attainment							
Compulsory school or less (≤ 9 years)	157707	15.4	1616	17.4	9.7	10.1	10.8
Practical high school or some theoretical high school (10–11 years)	389196	38.1	3690	39.6	9.2	9.4	10.3
Theoretical high school and/or college (≥ 12 years)	473873	46.4	4003	43.0	8.3	8.3	8.9
Paternal educational attainment							
Compulsory school or less (≤ 9 years)	215613	21.1	2099	22.5	10.5	9.3	10.9
Practical high school or some theoretical high school (10–11 years)	408809	40.0	3837	41.2	8.2	9.4	10.3
Theoretical high school and/or college (≥ 12 years)	396354	38.8	3373	36.2	8.6	8.4	8.6
Urban/rural status							
Large cities	498102	48.8	4673	50.2	8.9	9.3	10.2
Middle-sized towns	235982	23.1	2216	23.8	9.0	9.3	10.0
Small towns/rural areas	286692	28.1	2420	26.0	8.0	8.4	9.4

Move							
Not moved	706924	69.3	6322	67.9	8.5	8.8	9.8
Moved	313852	30.7	2987	32.1	9.4	9.6	10.2
Maternal age at child birth							
<30	605767	59.3	5516	59.3	8.3	9.0	10.2
30–39	392384	38.4	3567	38.3	9.1	8.9	9.6
≥ 40	22625	2.2	226	2.4	8.9	10.8	8.5
Paternal age at child birth							
<30	408723	40.0	3749	40.3	8.8	8.9	10.5
30–39	513888	50.3	4549	48.9	8.5	8.9	9.3
≥ 40	98165	9.6	1011	10.9	9.7	10.3	10.5
Sibling history of epilepsy							
No	987330	96.7	8573	92.1	8.2	8.6	9.5
Yes	33446	3.3	736	7.9	27.3	21.9	22.2
Parental history of epilepsy							
No	1007235	98.7	9027	97.0	8.6	8.9	9.7
Yes	13541	1.3	282	3.0	20.8	20.2	24.3
Maternal hospitalization of alcoholism and liver-related disease							
No	1009712	98.9	9187	98.7	8.7	9.0	9.9
Yes	11064	1.1	122	1.3	10.6	11.0	12.5
Maternal hospitalization of chronic obstructive pulmonary disease							
No	1009518	98.9	9166	98.5	8.6	9.0	9.9
Yes	11258	1.1	143	1.5	15.8	11.3	14.6
Paternal hospitalization of alcoholism and liver-related disease							
No	995578	97.5	9018	96.9	8.6	9.0	9.8
Yes	25198	2.5	291	3.1	11.4	11.1	14.0
Paternal hospitalization of chronic obstructive pulmonary disease							
No	1012571	99.2	9216	99.0	8.7	9.0	9.9
Yes	8205	0.8	93	1.0	9.6	11.2	12.5

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

	Model 1			Model 2			Model 3			
	OR	95% CI		OR	95% CI		OR	95% CI		P-value
Neighborhood-level variable (ref. Low)										
Moderate	1.04	0.98	1.10	1.04	0.98	1.10	1.02	0.97	1.08	0.424
High	1.15	1.07	1.23	1.15	1.07	1.23	1.12	1.04	1.21	0.003
Age				0.99	0.99	0.99	0.99	0.98	0.99	<0.001
Gender (ref. Girls)				1.01	0.97	1.05	1.02	0.97	1.06	0.484
Family income (ref. High income)										
Middle-high income							0.87	0.82	0.92	<0.001
Middle-low income							0.86	0.81	0.91	<0.001
Low income							0.79	0.74	0.84	<0.001
Marital status (ref. Married/cohabiting)										
Never married, widowed, or divorced							1.03	0.99	1.08	0.134
Maternal immigrant status (ref. Born in Sweden)										
European countries							1.01	0.92	1.11	0.764
Others							0.87	0.77	0.98	0.028
Paternal immigrant status (ref. Born in Sweden)										
European countries							0.99	0.90	1.09	0.842
Others							1.04	0.92	1.17	0.484
Maternal education attainment (ref. Theoretical high school and/or college (≥ 12 years))										
Compulsory school or less (≤ 9 years)							1.16	1.09	1.24	<0.001
Practical high school or some theoretical high school (10–11 years)							1.10	1.05	1.16	<0.001
Paternal education attainment (ref. Theoretical high school and/or college (≥ 12 years))										
Compulsory school or less (≤ 9 years)							1.10	1.03	1.16	0.002
Practical high school or some theoretical high school (10–11 years)							1.07	1.02	1.13	0.005
Urban/rural status (ref. Large cities)										
Middle-sized towns							1.00	0.95	1.05	0.920
Small towns/rural areas							0.90	0.85	0.95	<0.001
Mobility (ref. Not moved)							1.06	1.01	1.11	0.012
Maternal age at child birth (ref. <30 years)										
30–39							0.98	0.93	1.03	0.484
≥ 40							0.96	0.83	1.11	0.549
Paternal age at child birth (ref. <30 years)										
30–39							0.98	0.93	1.03	0.424

≥ 40				1.11	1.02	1.21	0.012
Sibling history of epilepsy (ref. Without sibling history of epilepsy)				2.38	2.20	2.57	<0.001
Parental history of epilepsy (ref. Without parental history of epilepsy)				2.20	1.95	2.48	<0.001
Maternal hospitalization of alcoholism and liver-related disease (ref. No)				1.01	0.84	1.21	0.920
Maternal hospitalization of chronic obstructive pulmonary disease (ref. No)				1.30	1.10	1.53	0.002
Paternal hospitalization of alcoholism and liver-related disease (ref. No)				1.11	0.99	1.25	0.072
Paternal hospitalization of chronic obstructive pulmonary disease (ref. No)				1.15	0.94	1.41	0.194
Variance (S.E.)	*0.034 (0.010)*	*0.034 (0.010)*	*0.023 (0.009)*				
Explained variance (%)	*6*	*6*	*36*				

Table 3. Interaction between neighborhood deprivation and parental educational attainment; results of multilevel regression models

	Neighborhood-level variable									P value
	Low			Moderate			Higher			
	OR	95% CI		OR	95% CI		OR	95% CI		
Maternal educational attainment										p=0.804
Compulsory school or less (≤ 9 years)	1.13	0.95	1.36	**1.18**	**1.07**	**1.29**	**1.32**	**1.17**	**1.48**	
Practical high school or some theoretical high school (10–11 years)	1.09	0.98	1.21	**1.13**	**1.04**	**1.22**	**1.21**	**1.09**	**1.35**	
Theoretical high school and/or college (≥ 12 years)	1.00	ref		1.01	0.94	1.09	**1.12**	**1.00**	**1.25**	
Paternal educational attainment										p=0.370
Compulsory school or less (≤ 9 years)	**1.18**	**1.03**	**1.36**	1.05	0.96	1.15	**1.25**	**1.11**	**1.40**	
Practical high school or some theoretical high school (10–11 years)	**1.09**	**1.01**	**1.18**	**1.09**	**1.01**	**1.18**	**1.17**	**1.06**	**1.30**	
Theoretical high school and/or college (≥ 12 years)	1.00	ref		1.00	0.92	1.08	1.04	0.92	1.17	

Adjusted for age, gender, family income, parental marital status, parental immigration status, region of residence, moving within 5 years of follow-up, parental age at child birth, family (parents and siblings) history of epilepsy, and parental comorbidities