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Neighborhood deprivation and childhood autism: a nationwide study from Sweden

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Abstract

Objective: To examine whether there is an association between neighborhood deprivation and childhood autism, after accounting for family- and individual-level sociodemographic characteristics.

Methods: An open cohort of all children aged 2 to 11 years was followed between January 1, 2000 and December 31, 2010. Childhood residential locations were geocoded and classified according to neighborhood deprivation (an index of low education, low income, unemployment, and receipt of welfare assistance). 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 643,456 children, 1,699 (0.3%) were diagnosed with childhood autism. Age-standardized cumulative incidence, defined as first registration for childhood autism during the study period, increased with increasing level of neighborhood deprivation. In the study population, 2.2 per 1,000 and 3.6 per 1,000 children in the least and most deprived neighborhoods, respectively, were diagnosed with childhood autism. Incidence of childhood autism increased with increasing neighborhood-level deprivation across all family and individual-level sociodemographic categories. The odds ratio (OR) for childhood autism for those living in high-deprivation neighborhoods versus those living in low-deprivation neighborhoods was 1.59 (95% confidence interval=1.35–1.88). High neighborhood deprivation remained significantly associated with odds of childhood autism after adjustment for family- and individual-level sociodemographic characteristics (OR=1.28, 95% confidence interval=1.07-1.53, P=0.007).

Conclusions: This study is the largest so far on potential neighborhood influences on childhood autism. Our results show that neighborhood deprivation is associated with childhood autism, independently of family- and individual-level sociodemographic characteristics.

Keywords: childhood autism, incidence, multilevel modeling, neighborhood-level deprivation, sociodemographic factors.

Introduction

Although the specific mechanisms behind childhood autism are largely unknown, risk factors include male sex [1], familial history of autism [1, 2], advanced age in either parent at childbirth [3-5], neuropsychiatric disorders [6], perinatal complications [7], ethnic background and migration [8, 9], and low socioeconomic status [7, 10, 11]. In addition to these individual-level factors, it is possible that certain social features of the neighborhood environment are associated with autism. Neighborhood deprivation is a socioeconomic feature of the neighborhood environment that has often been defined based on the proportion of residents with low socioeconomic status, unemployed people and/or people receiving welfare assistance [12-16]. High levels of neighborhood deprivation have robustly been shown to be associated with increased risks of a number of health outcomes, including mental disorders [17, 18]. Only few studies have, however, examined the association between neighborhood deprivation and autism. For example, one previous study conducted in England found that living in a community with rented social (government-financed) housing is associated with higher prevalence of adult autism [19]. In addition, the results of previous studies are inconsistent [11, 19-22]. To the best of our knowledge, no previous large-scale study have attempted to ascertain whether neighborhood deprivation is associated with childhood autism, after accounting for family and individual factors.

The present study had the following two aims: 1) to examine the association between neighborhood deprivation and childhood autism, after taking family and individual-level sociodemographic factors into account; 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 potential effect on the risk of childhood autism across subcategories of family- and individual-level factors (effect modification).

Methods

Data used in this study were retrieved from a national database, which contains longitudinal information on the entire population of Sweden. 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 information in the present dataset 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. Individuals (children and their parents) were tracked using their personal identification numbers (assigned to each resident of Sweden), which were replaced with serial numbers to provide anonymity. The follow-up period started on January 1, 2000 and proceeded until hospitalization/outpatient treatment for autism, death, emigration or the end of the study period on December 31, 2010. All residents in Sweden aged 2-11 years, a total of 643,456 children, were followed. During the follow-up period, 10,329 children moved out of the country and 827 children died.

Outcome variable: childhood autism

The outcome variable in this study was a hospital or outpatient diagnosis of childhood autism (age at diagnosis 2 to 11 years) during the study period. By age 2, a diagnosis of autism by an experienced professional can be considered very reliable [23]. Data on inpatient and outpatient diagnoses of autism were retrieved from the Hospital Discharge Register (2000–2010) and Outpatient Register (2001-2010). These registers contain information on all hospitalizations and outpatient visits, including clinical diagnoses. We searched the Hospital Discharge Register and Outpatient Register for the International Classification of Diseases (ICD)-10 codes F84.0, denoting autism as the main diagnosis, during the entire 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 autism during the study period. A recent study from Sweden found that 96% of the register-based diagnoses of autism were valid [24].

Neighborhood-level deprivation

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 has been done in previous research [12, 25]. 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) [16].

Individual-level sociodemographic variables

Sex of child: male or female.

Age ranged from 2 to 11 years and was divided into three categories: 2-4, 5-8, and 9-11 years.

Maternal *marital status* was categorized 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 education 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 (≥12 years).

Maternal and paternal country of birth was categorized as Sweden, Western countries (Western Europe, USA, Canada, Oceania), and others.

Maternal *urban/rural status* was 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 those areas with smaller populations than those of small towns. This classification yielded three equally-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.

Maternal age at childbirth and *paternal age at childbirth* was classified as <30, 30-39, and ≥ 40 years.

Because autism is known to cluster in families [1, 2], children were classified according to whether or not they had a *sibling history of autism*.

Comorbidities: Perinatal complications were defined as a hospitalization (within the first year of birth) for a main diagnosis of a perinatal complication (ICD-10: P00-P99); *Psychiatric disorders* were defined as a hospitalization (within 11 years after birth and in the follow-up period) for a main diagnosis of a psychiatric disorder (ICD-9: 290-319, except for 299.0; and ICD-10: F00-F99, except for F84.0).

Statistical analysis

The cumulative incidence for autism was calculated for the total population and for each subgroup after assessment of the neighborhood of residence for the children. Incidence was defined as first registration for childhood autism during the study period. Multilevel (hierarchical) logistic regression models were used to estimate odds ratios (ORs) and 95% confidence intervals (95% CI). 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 risk of childhood autism by level of neighborhood deprivation, a neighborhood model that included only neighborhood-level deprivation was calculated (model 1). Next, a full model that included neighborhood-level deprivation and sex, age (model 2) and the family- and individual-level sociodemographic variables, added simultaneously to the model (model 3), was calculated (Aim 1). Finally, a full model tested the cross-level interactions between the family- and individual-level sociodemographic variables and neighborhood-level deprivation to determine if the effects of neighborhood-level deprivation on childhood incidence 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 [26-28].

For comparison, we also calculated Cox regression models and logistic regression models using the SAS statistical package (version 9.2; SAS Institute, Cary, NC, USA).

Ethical considerations

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

Results

In the total study population (643,456 children), 20%, 62%, and 18% of children aged 2 to 11 years lived in low-, moderate-, and high-deprivation neighborhoods, respectively. During the follow-up period (January 1, 2000 to December 31, 2010), 1699 (0.3%) children were diagnosed with autism (Table 1). The age-standardized cumulative incidence of childhood autism was 2.2 per 1,000 in neighborhoods with low deprivation, 2.5 per 1,000 in neighborhoods with moderate deprivation and 3.6 per 1,000 in neighborhoods with high deprivation. A similar pattern of higher rates with increasing neighborhood deprivation was observed across all the family and individual-level sociodemographic categories.

The OR for childhood autism for children living in a high- versus low-deprivation neighborhoods in the crude neighborhood-level model (model 1) was 1.59 (95% CI=1.35–1.88) (Table 2). Neighborhood-level deprivation remained significantly associated with childhood autism after adjustment for age, sex, and the other family- and individual-level sociodemographic variables (model 3) (OR=1.28, 95% CI=1.07–1.53, P=0.007 for high deprivation neighborhoods versus low-deprivation neighborhoods). The odds of childhood autism was highest in children whose mothers had never married or were widowed or divorced; those whose mothers had the lowest education level; those with advanced paternal age or maternal age; and those with a sibling history of autism.

A test for cross-level interactions between the individual-level sociodemographic variables and neighborhood-level deprivation in the context of odds of childhood autism showed no meaningful cross-level interactions or effect modification.

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 autism incidence between neighborhoods after accounting for neighborhood deprivation and the individual-level variables. Neighborhood deprivation explained 12% of the between-neighborhood variance in the null model (Table 2). After inclusion of the family and individual-level variables, the explained variance increased to 42%.

Results from additional analyses

We performed an additional analysis using logistic regression models and the results were almost identical. In the full model (model 3), the OR for childhood autism was 1.28 (95% CI=1.09–1.52) for children living in the most deprived neighborhoods (Supplementary Table 1).

For comparison, we also performed an analysis using Cox regression models. The hazard ratio (HR) for childhood autism was 1.29 (95% CI=1.09–1.53) among children living in the most deprived neighborhoods in the full model (model 3) (Supplementary Table 2).

Discussion

We found that living in a deprived neighborhood increased the crude odds of childhood autism by 59%. This is an increase in odds with important public health implications. It is noteworthy that this potential effect was found in a country with a comparatively strong system of universal health care and social welfare. Our finding that neighborhood deprivation exerts a potential, independent effect on the odds of childhood autism is an important contribution particularly because previous studies are inconsistent; some studies have shown that neighborhood-level deprivation is associated with childhood autism [20, 22] whereas others have shown the opposite [11, 21].

Neighborhood deprivation has been shown to be associated with unfavorable health-related behaviors, including smoking [12, 14, 15, 29]. In addition, maternal smoking during pregnancy has been shown to be associated with autism [30]. Neighborhood deprivation is often characterized by neighborhood social disintegration (i.e., criminality, high mobility or unemployment) [26, 31, 32] and low social capital [25, 33, 34] that may act as neighborhood stressors. Psychosocial stress can influence immunological and/or hormonal stress reactions [35-37]. In addition, it has been suggested that crime lies in the pathway linking the neighborhood social environment to poor health [31, 32].

If being raised in high deprivation neighborhoods is associated with an increased risk of autism, one might expect that the rates of autism would be higher in developing countries. However, prevalence and incidence data on autism from developing countries are rare. For example, the authors of a recent study from Uganda recommended that autism spectrum disorders should be included in studies of neurodevelopmental disorders in low-resource settings to obtain essential data for planning local public health responses [38].

Neighborhood determinants of health, including childhood autism, are complex. Such determinants may include different access to healthcare services. In Sweden, children with any suspected psychiatric disorder (including autism) are referred for further assessment by a specialized team in a child psychiatry unit. The diagnoses in the present study were made by hospital-based diagnostic teams including a psychiatrist, clinical psychologist and speech pathologist or occupational therapist, depending on clinical manifestations. Like other Nordic countries, autism diagnoses recorded in Swedish registers have been reported to have good validity [24, 39].

Access to healthcare services is uneven in the U.S., where the effects of income inequalities on health are more pronounced [13]. In addition, presence of high-quality health care may increase the detected rates of poor health, including autism. In the U.S. state of New Jersey, autism prevalence was higher in wealthier census tracts, perhaps due to differential access to pediatric and developmental services [9, 11]. A study from the U.K. found similar results; higher neighborhood deprivation was associated with decreased rates of autism [21]. The U.S. and U.K. findings are in contrast with the results of the present study. However, in the present study, no significant associations with individual socioeconomic measures, such as income and education, were observed. Instead, we found that other individual and family factors, such as urban/rural status, were associated with autism (Table 2). Those children living in large cities had higher odds of being diagnosed with autism, which might reflect a higher access to specialized care in urban areas. Other factors associated with autism were familial history of autism [1, 2] and advanced parental age [3-5], findings in agreement with previous research.

The present study has several limitations, including the possibility that some selective factors may operate in the process of hospitalization to favor certain children being hospitalized or seeking health care. The number of diagnoses for autism may thus be underestimated since information only enters the system when the child comes into contact with inpatient or outpatient health care. However, this type of bias is less likely to constitute a problem in studies from Sweden. This is because affordability of healthcare should not be a selective factor, because of equal access to primary and hospital care [40]. Any selective factors should therefore most likely imply a non-differential bias, i.e., the selective factors, if any, are most likely operating in the same way across neighborhoods. However, we have no information on whether those clinical teams serving deprived neighborhoods had better training in diagnostic procedures. Finally, it is possible that residual confounding exists because socioeconomic status cannot be measured completely by family income and education level.

The limitations of the study are countered by its strengths, which include: 1) the ability to analyze data on a large national cohort of children 2-11 years; 2) the prospective design. It is possible to follow all Swedish individuals in the registers due to the existence of a personal registration number, provided to each person in Sweden with a residence permit and replaced by a serial number. This means that there is a minimum of loss to follow-up, which allowed calculation of exact risk periods; 3) 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 autism); 4) the uniqueness of the Swedish Population Registers that are almost entirely complete with very little missing data (for example, only 1% of the data on maternal education and family income were missing). This enabled us to adjust our models for socioeconomic status; 5) the use of small, well-defined neighborhoods with an average of 1,000 residents. Neighborhood-level deprivation was determined using a well-specified principal component analysis based on established socioeconomic indicators; and 6) The overall diagnostic validity of the Swedish Inpatient Register is high, 87% [41, 42], and 96% of register-based diagnoses of autism are valid [24].

Conclusions

This prospective nationwide study showed that, after accounting for family- and individual-level sociodemographic factors, neighborhood deprivation was associated with increased odds of childhood autism. Future studies could examine the possible mechanisms behind our findings.

Conflict of Interest:

The authors have no conflicts of interest to disclose.

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References

1. Newschaffer CJ, Croen LA, Daniels J *et al*: The epidemiology of autism spectrum disorders. *Annu Rev Public Health* 2007, 28:235-258.
2. Hallmayer J, Cleveland S, Torres A *et al*: Genetic heritability and shared environmental factors among twin pairs with autism. *Arch Gen Psychiatry* 2011, 68:1095-1102.
3. Shelton JF, Tancredi DJ, Hertz-Picciotto I: Independent and dependent contributions of advanced maternal and paternal ages to autism risk. *Autism Res* 2010, 3:30-39.
4. Parner ET, Baron-Cohen S, Lauritsen MB *et al*: Parental age and autism spectrum disorders. *Annals of epidemiology* 2012, 22:143-150.
5. Reichenberg A, Gross R, Weiser M *et al*: Advancing paternal age and autism. *Arch Gen Psychiatry* 2006, 63:1026-1032.
6. Lichtenstein P, Carlstrom E, Rastam M *et al*: The genetics of autism spectrum disorders and related neuropsychiatric disorders in childhood. *Am J Psychiatry* 2010, 167:1357-1363.
7. Larsson HJ, Eaton WW, Madsen KM *et al*: Risk factors for autism: perinatal factors, parental psychiatric history, and socioeconomic status. *American journal of epidemiology* 2005, 161:916-925; discussion 926-918.
8. Magnusson C, Rai D, Goodman A *et al*: Migration and autism spectrum disorder: population-based study. *Br J Psychiatry* 2012, 201:109-115.
9. Bhasin TK, Schendel D: Sociodemographic risk factors for autism in a US metropolitan area. *J Autism Dev Disord* 2007, 37:667-677.
10. Rai D, Lewis G, Lundberg M *et al*: Parental socioeconomic status and risk of offspring autism spectrum disorders in a Swedish population-based study. *J Am Acad Child Adolesc Psychiatry* 2012, 51:467-476 e466.

11. Thomas P, Zahorodny W, Peng B *et al*: The association of autism diagnosis with socioeconomic status. *Autism* 2012, 16:201-213.

12. Cubbin C, Sundquist K, Ahlen H *et al*: Neighborhood deprivation and cardiovascular disease risk factors: protective and harmful effects. *Scandinavian Journal of Public Health* 2006, 34:228-237.

13. Lochner K, Pamuk E, Makuc D *et al*: State-level income inequality and individual mortality risk: a prospective, multilevel study. *Am J Public Health* 2001, 91:385-391.

14. Schempf A, Strobino D, O'Campo P: Neighborhood effects on birthweight: an exploration of psychosocial and behavioral pathways in Baltimore, 1995-1996. *Soc Sci Med* 2009, 68:100-110.

15. Sundquist J, Malmstrom M, Johansson SE: Cardiovascular risk factors and the neighbourhood environment: a multilevel analysis. *Int J Epidemiol* 1999, 28:841-845.

16. Winkleby M, Sundquist K, Cubbin C: Inequities in CHD incidence and case fatality by neighborhood deprivation. *American Journal of Preventive Medicine* 2007, 32:97-106.

17. Ivert AK, Torstensson Levander M, Merlo J: Adolescents' utilisation of psychiatric care, neighbourhoods and neighbourhood socioeconomic deprivation: a multilevel analysis. *PLoS One* 2013, 8:e81127.

18. Doornbos MM, Zandee GL, Degroot J *et al*: Using Community-Based Participatory Research to Explore Social Determinants of Women's Mental Health and Barriers to Help-Seeking in Three Urban, Ethnically Diverse, Impoverished, and Underserved Communities. *Archives of psychiatric nursing* 2013, 27:278-284.

19. Brugha TS, McManus S, Bankart J *et al*: Epidemiology of autism spectrum disorders in adults in the community in England. *Arch Gen Psychiatry* 2011, 68:459-465.

20. Pettygrove S, Pinborough-Zimmerman J, Meaney FJ *et al*: Predictors of ascertainment of autism spectrum disorders across nine US communities. *J Autism Dev Disord* 2013, 43:1867-1879.

21. Emerson E: Deprivation, ethnicity and the prevalence of intellectual and developmental disabilities. *J Epidemiol Community Health* 2012, 66:218-224.

22. Hock R, Ahmedani BK: Parent perceptions of autism severity: Exploring the social ecological context. *Disabil Health J* 2012, 5:298-304.

23. Lord C, Risi S, DiLavore PS *et al*: Autism from 2 to 9 years of age. *Arch Gen Psychiatry* 2006, 63:694-701.

24. Idring S, Rai D, Dal H *et al*: Autism spectrum disorders in the Stockholm Youth Cohort: design, prevalence and validity. *PLoS One* 2012, 7:e41280.

25. Sundquist J, Johansson SE, Yang M *et al*: Low linking social capital as a predictor of coronary heart disease in Sweden: A cohort study of 2.8 million people. *Soc Sci Med* 2006, 62:954-963.

26. Sundquist K, Theobald H, Yang M *et al*: Neighborhood violent crime and unemployment increase the risk of coronary heart disease: A multilevel study in an urban setting. *Social Science and Medicine* 2006, 62:2061-2071.

27. Johnell K, Lindstrom M, Melander A *et al*: Anxiolytic-hypnotic drug use associated with trust, social participation, and the miniaturization of community: a multilevel analysis. *Social Science and Medicine* 2006, 62:1205-1214.

28. Johnell K, Lindstrom M, Sundquist J *et al*: Individual characteristics, area social participation, and primary non-concordance with medication: a multilevel analysis. *BMC Public Health* 2006, 6:52.

29. Odgers CL, Caspi A, Russell MA *et al*: Supportive parenting mediates neighborhood socioeconomic disparities in children's antisocial behavior from ages 5 to 12. *Dev Psychopathol* 2012, 24:705-721.

30. Kalkbrenner AE, Braun JM, Durkin MS *et al*: Maternal smoking during pregnancy and the prevalence of autism spectrum disorders, using data from the autism and developmental disabilities monitoring network. *Environmental health perspectives* 2012, 120:1042-1048.

31. Kawachi I, Kennedy BP, Wilkinson RG: Crime: social disorganization and relative deprivation. *Soc Sci Med* 1999, 48:719-731.

32. Sampson RJ, Raudenbush SW, Earls F: Neighborhoods and violent crime: a multilevel study of collective efficacy. *Science* 1997, 277:918-924.

33. Lofors J, Sundquist K: Low-linking social capital as a predictor of mental disorders: a cohort study of 4.5 million Swedes. *Social Science and Medicine* 2007, 64:21-34.

34. Sundquist K, Yang M: Linking social capital and self-rated health: a multilevel analysis of 11,175 men and women in Sweden. *Health Place* 2007, 13:324-334.

35. Daniel M, Moore S, Kestens Y: Framing the biosocial pathways underlying associations between place and cardiometabolic disease. *Health Place* 2008, 14:117-132.

36. Brosschot JF, Benschop RJ, Godaert GL *et al*: Influence of life stress on immunological reactivity to mild psychological stress. *Psychosom Med* 1994, 56:216-224.

37. McEwen BS, Biron CA, Brunson KW *et al*: The role of adrenocorticoids as modulators of immune function in health and disease: neural, endocrine and immune interactions. *Brain Res Brain Res Rev* 1997, 23:79-133.

38. Kakooza-Mwesige A, Ssebyala K, Karamagi C *et al*: Adaptation of the 'ten questions' to screen for autism and other neuro-developmental disorders in Uganda. *Autism* 2013.

39. Lauritsen MB, Jorgensen M, Madsen KM *et al*: Validity of childhood autism in the Danish Psychiatric Central Register: findings from a cohort sample born 1990-1999. *J Autism Dev Disord* 2010, 40:139-148.

40. van Doorslaer E, Wagstaff A, Bleichrodt H *et al*: Income-related inequalities in health: some international comparisons. *Journal of Health Economy* 1997, 16:93-112.

41. Ludvigsson JF, Andersson E, Ekbom A *et al*: External review and validation of the Swedish national inpatient register. *BMC Public Health* 2011, 11:450.

42. Centre for Epidemiology: **Validity of the diagnoses from the Swedish In-Care Register 1987 and 1995 Swedish**. In. Stockholm: the National Board of Health and Welfare; 2000.

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

	Population	Distribution (%)	Autism event	Neighborhood deprivation Low	Moderate	High
Total population (%)	643456			129566 (20%)	400124 (62%)	113766 (18%)
Total autism events			1699	2.2	2.5	3.6
Gender						
Men	330133	51.3	1272	3.2	3.6	5.5
Women	313323	48.7	427	1.2	1.3	1.7
Age (years)						
2-4	158517	24.6	522	2.5	3.0	5.0
5-8	264663	41.1	714	2.4	2.5	3.6
9-11	220276	34.2	463	2.0	2.1	2.4
Family income						
Low income	161071	25.0	473	2.9	2.8	3.2
Middle–low income	161023	25.0	374	2.0	2.1	3.5
Middle–high income	160625	25.0	450	2.5	2.7	4.0
High income	160737	25.0	402	2.1	2.5	4.8
Marital status						
Married/cohabiting	371312	57.7	889	2.2	2.3	3.2
Never married, widowed, or divorced	272144	42.3	810	2.3	2.8	4.1
Maternal immigrant status						
Sweden	556391	86.5	1401	2.2	2.4	3.6
Western countries	39769	6.2	112	2.3	2.8	3.2
Other countries	47296	7.4	186	3.8	3.5	4.1
Paternal immigrant status						
Sweden	555708	86.4	1404	2.3	2.4	3.5
Western countries	42691	6.6	131	2.0	2.9	3.7
Other countries	45057	7.0	164	2.2	3.4	3.8
Maternal educational attainment						
≤ 9 years	90613	14.1	331	2.4	3.8	3.7
10–11 years	240103	37.3	632	2.6	2.4	3.7
≥ 12 years	312740	48.6	736	2.1	2.2	3.5
Paternal educational attainment						
≤ 9 years	118199	18.4	365	3.3	3.0	3.6
10–11 years	272404	42.3	731	2.5	2.5	3.6
≥ 12 years	252853	39.3	603	2.0	2.3	3.7
Urban/rural status						
Large cities	318756	49.5	1005	2.8	2.9	4.1
Middle-sized towns	149147	23.2	318	1.8	2.0	3.0
Small towns/rural areas	175553	27.3	376	1.5	2.2	2.9
Move						
Not moved	482486	75.0	1147	2.1	2.3	3.3
Moved	160970	25.0	552	2.8	3.2	4.4
Maternal age at child birth						

<30	370577	57.6	964	2.1	2.4	3.7
30-39	257666	40.0	671	2.3	2.4	3.5
>=40	15213	2.4	64	4.4	4.3	3.3
Paternal age at child birth						
<30	250349	38.9	607	2.1	2.3	3.2
30-39	326352	50.7	856	2.2	2.5	3.7
>=40	66755	10.4	236	2.9	3.4	4.5
Family history of autism (siblings)						
No	634436	98.6	1507	2.0	2.2	3.3
Yes	9020	1.4	192	20.4	21.4	21.3
Hospitaliation for perinatal complications						
No	601846	93.5	1517	2.1	2.4	3.5
Yes	41610	6.5	182	3.9	4.1	5.1
Hospitaliation for psychiatric disorders						
No	626361	97.3	1396	1.9	2.1	3.1
Yes	17095	2.7	303	24.2	21.6	29.1

Table 2. Odds ratios (OR) and 95% confidence intervals (CI) for childhood autism. 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	1.10	0.95	1.27	1.11	0.96	1.27	1.05	0.91	1.21	0.549
High	1.59	1.35	1.88	1.58	1.34	1.87	1.28	1.07	1.53	0.007
Age				0.94	0.92	0.96	0.91	0.89	0.93	<0.001
Gender to boys (ref. Girls)				2.83	2.54	3.16	2.96	2.65	3.30	<0.001
Family income (ref. High income)										
Middle-high income							1.06	0.92	1.22	0.424
Middle-low income							0.83	0.71	0.96	0.011
Low income							0.90	0.78	1.05	0.180
Marital status (ref. Married/co-habiting)										
Never married, widowed, or divorced							1.16	1.04	1.28	0.005
Maternal immigrant status (ref. Born in Sweden)										
Western countries							0.99	0.80	1.24	0.920
Others							1.34	1.06	1.68	0.012
Paternal immigrant status (ref. Born in Sweden)										
Western countries							1.09	0.89	1.33	0.424
Others							0.92	0.72	1.17	0.484
Maternal educational attainment (ref. ≥ 12 years)										
≤ 9 years							1.17	1.01	1.36	0.036
10–11 years							1.08	0.96	1.21	0.194
Paternal educational attainment (ref. ≥ 12 years)										
≤ 9 years							1.12	0.97	1.29	0.134
10–11 years							1.11	0.99	1.25	0.072
Urban/rural status (ref. Large cities)										
Middle-sized towns							0.70	0.61	0.80	<0.001
Small towns/rural areas							0.69	0.61	0.78	<0.001
Mobility (ref. Not moved)							1.21	1.09	1.35	<0.001
Maternal age at child birth (ref. <30 years)										
30-39							0.96	0.85	1.07	0.424
≥ 40							1.27	0.96	1.68	0.089
Paternal age at child birth (ref. <30 years)										
30-39							1.14	1.01	1.28	0.036
≥ 40							1.36	1.14	1.63	0.001
Family history of autism (sibling) (ref. Without sibling history of autism)							7.54	6.43	8.84	<0.001
Hospitalization for perinatal complications (ref. No)							1.56	1.33	1.83	<0.001
Hospitalization for psychiatric disorders (ref. No)							8.83	7.73	10.09	<0.001
Variance (S.E.)	*0.375 (0.058)*			*0.370 (0.058)*			*0.245 (0.053)*			
Explained variance (%)	*12*			*13*			*42*			

Model 1: neighborhood deprivation; Model 2: model 1+ age and gender; Model 3: full model.