Parental socioeconomic status and asthma in children: Using a population-based cohort and family design

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Abstract

Background: The observed association between the parental socioeconomic status (SES, measured as education/income) and asthma or wheezing in offspring may be explained by confounding of unmeasured factors (shared genes and family environment). We aimed to study the association between parental SES and asthma/wheeze using cousin comparison.

Method: Data were collected on individuals born in Sweden 2001–2013. Parental SES (education and income) was gathered from Statistics Sweden. Asthma/wheeze was identified using national health registers. The association between parental SES at birth and incident asthma/wheeze was estimated using Cox regression also comparing differently exposed cousins. The association between parental SES at 5 years and current asthma was estimated using logistic regression.

Results: Included were 955,371 individuals. Mothers with compulsory school only (lowest education group) compared with those with further education (highest education group) was associated with incident asthma/wheeze below 1 year of age HRadj = 1.45 (1.38–1.52) and over 1 year of age HRadj = 1.17 (1.13–1.20). The corresponding estimates for the lowest income group were HRadj = 1.61 (1.54–1.69) and HRadj = 0.94 (0.92–0.97), respectively. In maternal cousin comparisons, the associations for asthma/wheeze over 1 year of age was HRadj = 1.21 (1.05–1.40) for compulsory school only and HRadj = 0.94 (0.84–1.07) for the lowest income group. The ORadj for current asthma at 5 years was 1.05 (1.00–1.11) for mother’s compulsory school only and 0.98 (0.94–1.02) for mother’s lowest income group. Results for estimates were similar for father’s SES.

Conclusion: We confirm an association between low parental SES (measured as education) and asthma/wheeze. Cousin comparison suggests that this association is not wholly due to confounding of unknown familial factors, therefore supporting a causal relationship. The relationship between parental income and asthma/wheeze is less clear. This study is important for understanding risk factors for asthma/wheeze and for future prevention strategies. Further research is warranted to investigate the possible mechanisms for association between parental education and asthma/wheeze.
1 | INTRODUCTION

Asthma, a chronic condition often diagnosed in childhood, is characterized by symptoms of wheeze and cough.\(^1\)\(^2\) The prevalence of asthma varies worldwide, and among Swedish children, it is around 10%.\(^2\)\(^3\) Asthma results from complex gene–environment interactions\(^1\)\(^2\)\(^4\) and can be preceded preschool wheeze (respiratory symptoms in early years due to viral infection).\(^2\) To inform future asthma prevention strategies, research has focused on understanding the risk factors for asthma.\(^2\) Risk factors include a family history of asthma, maternal smoking during pregnancy and male sex.\(^1\)\(^2\)\(^5\) Additionally, factors shared within the family environment contribute, including environmental smoke exposure,\(^6\) maternal stress,\(^6\)\(^7\) housing and socioeconomic status (SES).\(^8\)\(^9\)

Socioeconomic status is often defined using education, income or occupation,\(^8\)\(^9\) and the relationship between parental SES in early childhood and later disease is of interest.\(^10\) Low parental SES is associated with asthma and with asthma outcomes such as a decreased amount of dispensed controller medication,\(^8\) increased prevalence of severe asthma\(^11\) and increased frequency of hospitalization.\(^12\) Though a recent Mendelian randomization study suggests that the relationship between education and asthma may be causal,\(^13\) the association observed between parental SES and asthma could be due to unmeasured exposures shared within families (such as genes and family environment) influencing both SES and asthma (familial confounders). For example, parental childhood SES has been shown to be associated with asthma control in offspring independent of current parental SES, and an association has been found between maternal bereavement in childhood and offspring asthma.\(^14\)\(^15\) Establishing if the association is explained by unmeasured confounding or if there is a causal relationship between parental SES and asthma is of importance in implementation of asthma prevention strategies.

Family design has been used to study the role of shared genes and environment in families which influence the associations between early life exposures and later disease, by accounting for

**Key Messages**
- This study confirms an association between parental SES, particularly parental education, and asthma/wheeze in childhood.
- Cousin analysis suggests a possible causal relationship between low parental education and asthma/wheeze in childhood.
- The association between the parental SES variables education and income with asthma/wheeze followed different patterns.
familial confounders. Cousin comparison (family design which compares the outcome in differently exposed first cousins) adjusts for familial confounders (~12.5% shared genes and/or environmental exposures [such as childhood SES and lifestyle]) shared by the parents’ generation (Figure S1). If the association between the exposure and the outcome persists in the cousin comparison analysis, which accounts for familial confounders, the exposure is more likely to be a causal risk factor for the outcome. If the association is weakened, it suggests unmeasured exposures confound the association and the association is not causal.  

In order to study the relationship between parental SES in early life and childhood asthma and explore if unmeasured exposures shared in the family confound the relationship, this cohort study used data on parental SES at two time points (birth and at 5 years) and data on incident asthma/wheeze and current asthma. We studied (a) the association between measures of parental SES at birth and incident asthma/wheeze in the whole cohort and in a cousin comparison and (b) the association between measures of parental SES and current asthma at age 5. Our hypothesis was that low parental SES is associated with an increased risk of asthma/wheeze, which could be explained by confounding of unmeasured familial exposures.

2 MATERIAL AND METHODS

2.1 Study design and study population

This register-based cohort study used data held by the Swedish National Board of Health and Welfare and Statistics Sweden. Data from the study individuals and their families were linked using the personal identification number (PIN), a unique identifier held by every person residing in Sweden, but pseudonymized before analysis (Figure S2).

Study individuals were identified from the Medical Birth Register (MBR; covering 99% of all births) as live singleton children born in Sweden between 1 January 2001 and 30 December 2013 (n = 1,303,517). Study individuals were linked to their parents using the Multi-Generation Register (MGR). In order to define parental SES, the PINs for both parents had to be available (excluded n = 19,281; 1.5%). Parents who were born abroad had to have immigrated to Sweden before 15 years of age, as the education variables have been found to be less accurate for individuals immigrating later (excluded n = 337,194; 25.9%). The final cohort was 955,371 study individuals (total excluded n = 348,146; 26.7%). All cousin pairs within the final cohort were identified through the MGR.

2.2 Exposure

Data on parental SES (education and income) were obtained from the longitudinal integration database for health insurance and labour market studies (LISA by Swedish acronym). The LISA database is updated annually on individuals ≥16 years living in Sweden.

Education was defined as the highest attained education of each parent. Education was categorized as compulsory school only (<9 years), high school (10–12 years) or college/further education (>12 years). Data on mother’s and father’s education were gathered from the year the study individual was born and the year the study individual turned 5 years.

Income of each parent was defined as the individual parent’s total annual disposable income adjusted for the household consumption unit and the consumer price index (CPI 2019 = 100) and then divided into quintiles. Data on the mother’s and father’s income were collected from the year before the study individual was born and the year the study individual turned 5.

2.3 Outcome

Asthma/wheeze was identified using data from the National Patient Register (NPR; covers all inpatient hospital care from 1987 and 75% of outpatient visits from 2001) and the Prescribed Drug Register (PDR; covers all prescribed drugs dispensed at pharmacies in Sweden from 2005). Asthma/wheeze was defined by a method from a previous validation study, using doctor’s diagnosed asthma and/or dispensed asthma medications from a doctor’s prescription. Data were collected on incident asthma/wheeze and current asthma. Incident asthma/wheeze was defined as the date of the first hospital admission/outpatient visit with a primary diagnosis of asthma, which was identified using the corresponding code from the International Classification of Disease (ICD)-10 codes J45-J46 in the NPR or as the date of the first dispensed asthma medication: inhaled corticosteroids, β-agonists, combination products or leukotriene receptor antagonists using the corresponding Anatomic Therapeutic Chemicals classification codes R03BA, R03AC, R03AK, R03DC, retrieved from the PDR. If an individual had dates recorded in both the NPR and the PDR, the earliest date was used. Current asthma was defined as having incident asthma/wheeze and at least one record of asthma in the NPR and/or a dispensed asthma medication from the PDR in the 12 months prior to the fifth birthday. Current asthma at 5 years was studied in order to distinguish it from cases of preschool wheeze.

2.4 Covariates

Study individual characteristics (sex, preterm birth, small for gestational age [SGA] and parity) were retrieved from the MBR. The number of siblings born during the study individual’s first 5 years of life was extrapolated from data in the study population. Covariates relating to family characteristics (maternal smoking during pregnancy, maternal country of birth and mother’s/father’s age at delivery) were retrieved from the MBR and the Total Population Register (contains demographic data on all persons registered in Sweden).
2.5 | Statistical methods

The study individuals were followed from birth, and observations were censored at death, emigration or the 31 December 2013 (whichever occurred first). Attained age was the underlying timescale.

The Cox proportional hazards model was used to estimate hazard ratios (HRs) with 95% confidence intervals (CIs) for incident asthma/wheeze by the exposure variables: the mother’s education/income at the birth of the study individual and the father’s corresponding variables. The sandwich estimator was used for the standard errors to account for clustering within families. Decision to analyse mothers’ and fathers’ SES separately was made a priori to allow for later cousin comparison.

The proportional hazard assumption was tested, based on Schoenfeld residuals, and where violated for the exposure variables, we allowed for a time (age)-varying effect. We fitted an unadjusted model and then a model adjusted for sex, parity, maternal country of birth and the mother’s/father’s age at the study individual’s birth according to the directed acyclic graph (DAG) (Figure S3). According to the DAG, preterm birth, SGA and maternal smoking during pregnancy were defined as mediators, not confounders, and therefore not adjusted for in the model.

In order to account for unmeasured familial confounders, a cousin comparison was made (Figure S1). A Cox proportional hazard model, stratified by cousin pairs, with the sandwich estimator (to account for pairs clustering within families), was fitted for incident asthma/wheeze. HR and 95% CI for the association between parental SES and incident asthma/wheeze were estimated for the maternal and paternal cousins separately. Adjusted models were fitted using the same covariates as above.

Logistic regression models, with a sandwich estimator for the standard errors to account for clustering within families, were used to estimate odds ratio (OR) and 95% CI for the association between mother’s/father’s SES when the study individual was 5 years old and current asthma. The models were adjusted for sex, preterm birth, SGA, parity, number of siblings born during first 5 years of study individual’s life, maternal smoking during pregnancy, maternal country of birth and mother’s/father’s age at study individual’s birth, according to the DAG (Figure S4).

The study was approved by the Ethical Review Board in Stockholm, Sweden, and as it was strictly register based, informed consent was not required.

All statistical analyses were conducted using STATA version 16.

3 | RESULTS

In total, 88,540 children with asthma/wheeze were identified resulting in a cumulative incidence of asthma/wheeze of 9.3%. The mean asthma/wheeze onset age was 2.4 years (95% CI 2.38–2.40). The mean follow-up time was 5.7 years (SD =3.8). A total of 577,638 individuals turned 5 years during the follow-up period, and current asthma was found in 36,372 (6.3%) individuals (Table 1).

Children with incident asthma/wheeze and current asthma were more likely to be male, born premature, SGA or have been exposed to maternal smoking in pregnancy. Data on parental SES at birth were available for >99% of the cohort. In the incident asthma/wheeze group, 9.7% of mothers had compulsory school only (the lowest education group) compared with 8.3% in the no-asthma/wheeze group. In the incident asthma/wheeze group, 20.4% of mothers were in the lowest income quintile group compared with 19.9% in the no-asthma/wheeze group. Similar patterns were seen for the father’s education and income at the birth of the study individual (Table 1 and Table S1).

3.1 | Main results

Due to violation of the proportional hazard assumption, separate HRs were estimated for incident asthma/wheeze below 1 year of age and over 1 year of age. The HR for incident asthma/wheeze below 1 year of age was higher than for incident asthma/wheeze over 1 year of age. Furthermore, a dose response was seen between the levels of the exposure variable for both education and income.

For SES measured as education, the unadjusted HR for incident asthma/wheeze below 1 year of age in the mother’s compulsory education only group versus further education group was 1.47 (95% CI 1.41–1.54), with an adjusted HR (HRadj) of 1.45 (1.38–1.52). For incident asthma/wheeze over 1 year of age, the unadjusted HR in the mother’s compulsory education only group versus further education group was 1.18 (1.15–1.22), and the HRadj was 1.17 (1.13–1.20) (Figure 1A,B and Table 2).

For SES measured as income, the unadjusted HR for incident asthma/wheeze below 1 year of age in the mother’s lowest income group versus highest group was 1.69 (1.62–1.76), and the HRadj was 1.61 (1.54–1.69). For incident asthma/wheeze at over 1 year of age, the unadjusted HR in the mother’s lowest income group versus highest group was 0.99 (0.96–1.02), whereas the HRadj was 0.94 (0.92–0.97) (Figure 1A,B and Table 2).

Similar patterns were seen for the association between father’s education/income and incident asthma/wheeze (Figure 2A,B and Table 2).

3.2 | Cousin comparison

Cousin comparison was performed for maternal and paternal cousins using the final cohort. There were 262,339 maternal cousin pairs of which 16,455 pairs were discordant for both education and incident asthma/wheeze and 31,459 pairs were discordant for both income and asthma/wheeze. There were 249,823 paternal cousin pairs of which 19,210 pairs were discordant for both education and incident asthma/wheeze and 30,477 pairs were discordant for both income and incident asthma/wheeze.
In the maternal cousin comparison, the association between mother’s education and incident asthma/wheeze was attenuated for incident asthma/wheeze below 1 year of age and remained for incident asthma/wheeze over 1 year of age. In the compulsory education group versus the further education group, the HRadj for incident asthma/wheeze below 1 year of age was 1.19 (0.98–1.43), and the HRadj for incident asthma/wheeze over 1 year of age was 1.21 (1.05–1.40). In the lowest income versus the highest income groups, the HRadj for incident asthma/wheeze below 1 year of age was 1.35 (1.17–1.57), and over 1 year of age, the HRadj was 0.94 (0.84–1.07) (Figure 1A,B and Table S2a). Similar patterns were seen in the paternal cousin comparison, where the HRadj for the association father’s education and incident asthma/wheeze below 1 year of age was HRadj 1.14 (0.94–1.38) and over 1 year of age was HRadj 1.16 (1.01–1.33). The association in the paternal cousin comparison between father’s income and incident asthma/wheeze below 1 year of age was HRadj 1.22 (1.05–1.41) and for incident asthma/wheeze over 1 year of age was HRadj 0.86 (0.76–0.96) (Figure 2A,B and Table S2b).

### 3.3 Current asthma at 5 years

The study of parental SES at 5 years and current asthma showed similar results for mother’s and father’s education/income, although with lower effect sizes compared with incident asthma/wheeze. The adjusted OR (ORadj) for current asthma in the mother’s compulsory education only group versus further education group was 1.05 (1.00–1.11). The ORadj for current asthma in the mother’s lowest income group versus highest income group was 0.98 (0.94–1.02) (Figure 3A and Table S3). The corresponding ORadj for fathers were 1.06 (1.02–1.11) and 1.05 (1.01–1.09) (Figure 3B and Table S3). The effect sizes for current asthma were deemed too small to be studied in a cousin analysis.

### TABLE 1 Parental education and income related to incident asthma/wheeze and current asthma in a Swedish cohort

|                     | No asthma/wheeze | Incident asthma/wheeze | No asthma at 5 years of age | Current asthma at 5 years of age |
|---------------------|------------------|------------------------|----------------------------|---------------------------------|
| **Mothers**         |                  |                        |                            |                                 |
| Education           |                  |                        |                            |                                 |
| Compulsory school   | 71,964 (8.3)     | 8677 (9.7)             | 35,376 (6.5)               | 2430 (6.7)                      |
| High school         | 375,500 (43.3)   | 41,620 (46.8)          | 237,630 (43.9)             | 16,515 (45.4)                   |
| Further education   | 416,635 (48.1)   | 37,917 (42.8)          | 266,932 (49.3)             | 17,365 (47.8)                   |
| Missing             | 2732 (0.3)       | 326 (0.4)              | 1328 (0.3)                 | 62 (0.2)                        |
| Income              |                  |                        |                            |                                 |
| Lowest              | 172,864 (19.9)   | 18,098 (20.4)          | 108,470 (20.0)             | 6778 (18.6)                     |
| Lower middle        | 172,302 (19.9)   | 18,665 (21.1)          | 107,784 (19.9)             | 7549 (20.8)                     |
| Middle              | 171,785 (19.8)   | 19,149 (21.6)          | 107,786 (19.9)             | 7553 (20.8)                     |
| Upper middle        | 173,068 (20.0)   | 17,862 (20.2)          | 108,097 (20.0)             | 7271 (20.0)                     |
| Highest             | 176,259 (20.3)   | 17,071 (16.6)          | 108,165 (20.0)             | 7184 (19.8)                     |
| Missing             | 553 (0.1)        | 65 (<0.1)              | 964 (0.2)                  | 37 (0.2)                        |
| **Fathers**         |                  |                        |                            |                                 |
| Education           |                  |                        |                            |                                 |
| Compulsory school   | 87,660 (10.1)    | 9881 (11.2)            | 50,970 (9.4)               | 3490 (9.6)                      |
| High school         | 450,942 (52.0)   | 48,935 (55.3)          | 283,863 (52.4)             | 19,798 (54.4)                   |
| Further education   | 325,939 (37.6)   | 29,459 (33.3)          | 203,831 (37.7)             | 12,928 (35.5)                   |
| Missing             | 2290 (0.3)       | 265 (0.3)              | 2602 (0.5)                 | 156 (0.5)                       |
| Income              |                  |                        |                            |                                 |
| Lowest              | 172,377 (19.9)   | 18,576 (21.0)          | 107,906 (19.9)             | 7088 (19.5)                     |
| Lower middle        | 171,077 (19.7)   | 19,859 (22.4)          | 107,986 (20.0)             | 7051 (19.3)                     |
| Middle              | 171,957 (19.8)   | 18,972 (21.4)          | 107,583 (19.8)             | 7506 (20.6)                     |
| Upper middle        | 174,005 (20.1)   | 16,941 (19.2)          | 107,559 (19.9)             | 7526 (20.7)                     |
| Highest             | 176,814 (20.4)   | 14,137 (16.0)          | 108,004 (20.0)             | 7070 (19.4)                     |
| Missing             | 601 (<0.1)       | 55 (<0.1)              | 2228 (0.4)                 | 131 (0.4)                       |

Abbreviation: SES, socioeconomic status.
DISCUSSION

This population-based cohort study with cousin comparisons demonstrates that low parental SES at birth (measured as education) is associated with childhood asthma. An association was seen between parental education at birth and incident asthma/wheeze below 1 year and over 1 year of age, with estimates persisting in the cousin analysis for incident asthma/wheeze over 1 year. The results of the cousin analysis imply that confounding of exposures (genes and familial environment), to the extent they are shared by cousins, does not fully explain the association between parental education and asthma/wheeze over 1 year of age. This supports the possibility of a causal relationship between parental education and offspring asthma/wheeze, also reported by Li et al. Further, an association between parental education when the child was 5 years and current asthma was also seen, albeit with lower effect estimates, adding support for an association between parental education and childhood asthma. The association between low parental income and asthma/wheeze did not follow the same pattern as parental education. An association was seen between low parental income at birth and incident asthma/wheeze below 1 year, which persisted in the maternal and paternal cousin analysis. However, the association between low parental income at birth and incident asthma/wheeze did not remain for asthma/wheeze over 1 year of age. An association was only seen between low income in fathers at 5 years and current asthma.

This study demonstrates the importance of SES in early childhood by providing further evidence for an association between low parental SES at birth and later disease. This study also sheds light on important aspects in relation to the association between parental SES and childhood asthma/wheeze. First, our study confirms previous observations of an association between low parental income at birth and incident asthma/wheeze which we have previously reported as have others. Additionally, this is the first study to use a cousin comparison to explore the association between parental SES and asthma/wheeze. The design accounts for familial confounders (genes and the environment) shared by the parents’ generation, and results suggest a possible causal relationship. Results for maternal and paternal SES and asthma/wheeze were similar (overlapping CIs) in both the cohort analyses and cousin

![Figure 1](image-url)
analyses, suggesting that the mother’s or father’s SES is not more influential than the other. The mechanisms which could account for the association between parental SES and asthma/wheeze include poor lifestyle choices, family stress, fewer material resources and low social support.28,29 How these factors would explain a causal relationship between parental education and asthma/wheeze remains unclear, but in all likelihood, targeting parental education may help to prevent early asthma/wheeze, and more research is needed to understand how parental education is associated with asthma.

Second, education and income did not follow the same pattern in their relationship with asthma/wheeze over 1 year of age. Whereas low education was associated with asthma/wheeze over 1 year age, low income was not. There is consistent evidence that lower parental education is associated with childhood asthma. 8,24,25 Lewis et al. reported that children of mothers in the lowest education group were 46% more likely to develop asthma compared with children of mothers in the highest education group (95% CI 1.26–1.71).24 Low parental income has been shown to be associated with adverse childhood health outcomes,10 but the evidence for parental income and asthma is less clear. In our study, the relationship between parental income and incident asthma/wheeze demonstrated an association for asthma/wheeze below 1 year but not over 1 year of age, which was also observed in our previous study.8 The relationship between low parental income and asthma has previously shown conflicting results. Kozyrskyj et al.26 demonstrated an association between chronic low parental income and asthma. However, a Danish study did not find an association between parental income and asthma, though they, like us, observed an association between education and asthma.27 Proposed explanations for the discrepancies for the association between low income and asthma/wheeze include monetary wealth having less effect on health outcomes in countries with universal healthcare or different SES measurements being associated with disease in different ways.27,30 However, different health-seeking behaviour among low income families may also account for the association between low parental income and asthma/wheeze.

Third, in the adjusted model, the HRs for incident asthma/wheeze below 1 year of age were higher compared with incident asthma/wheeze over 1 year of age, which also mirrors results in our previous study.8 This suggests that there may be an earlier onset of asthma/wheeze in children to parents with low SES or that factors associated with parental SES play a stronger role in health outcomes.

### TABLE 2 Unadjusted and adjusted hazard ratio (HR) and 95% confidence interval (95% CI) for incident asthma/wheeze by parental socioeconomic status

| Age of asthma/wheeze onset | Below 1 year | Over 1 year |
|---------------------------|--------------|-------------|
|                           | Unadjusted HR (95% CI) | Adjusteda HR (95% CI) | Unadjusted HR (95% CI) | Adjusteda HR (95% CI) |
|                           | Mother       | Father      | Mother       | Father      |
| Education                |              |             |              |             |
| Compulsory school        | 1.47 (1.41–1.54) | 1.45 (1.38–1.52) | 1.18 (1.15–1.22) | 1.17 (1.13–1.20) |
| High school              | 1.15 (1.12–1.18) | 1.13 (1.10–1.16) | 1.12 (1.10–1.14) | 1.10 (1.08–1.12) |
| Further education        | ref          | ref         | ref          | ref         |
| Income                   |              |             |              |             |
| Lowest                   | 1.69 (1.62–1.76) | 1.61 (1.54–1.69) | 0.99 (0.96–1.02) | 0.94 (0.92–0.97) |
| Lower middle             | 1.45 (1.39–1.52) | 1.40 (1.34–1.46) | 1.03 (1.01–1.06) | 0.99 (0.96–1.02) |
| Middle                   | 1.18 (1.13–1.24) | 1.15 (1.09–1.20) | 1.07 (1.04–1.09) | 1.03(1.00–1.06) |
| Upper middle             | 1.10 (1.05–1.15) | 1.07 (1.02–1.12) | 1.06 (1.04–1.09) | 1.04 (1.01–1.06) |
| Highest                  | ref          | ref         | ref          | ref         |

aAdjusted for sex, parity, maternal country of birth and mother’s/father’s age at study individual’s birth.
in early life compared with later childhood. Alternatively, the results could be explained by parental SES being associated differently depending on the asthma or wheezing phenotypes.

Our study provides important evidence of an association between parental SES and asthma/wheeze. Parental SES is, therefore, an important risk factor for childhood asthma/wheeze, alongside other known risk factors such as family history of asthma and maternal smoking during pregnancy.

4.1 | Strengths and limitations

There are several strengths to this study. The large study population, the use of validated registers to identify the exposure (parental SES) and the validated method to identify the outcome (asthma/wheeze) lead to robust results and allow for a cousin comparison analysis, a method which has been previously used in asthma research using register-based studies. As the registers are population based, the results are considered generalizable.

The SES variables were retrieved from data generated in an automated way, overcoming bias associated with self-reported information on SES. The asthma/wheeze variables were based on doctor’s diagnosed asthma and/or on dispensed asthma medications from a doctor’s prescription. The method used for identifying incident asthma/wheeze may capture preschool wheeze. However, preschool wheeze is a known risk factor for childhood asthma, and the method used has been shown to carry a high positive predictive value for asthma.

This study has its limitations. In order to increase the validity and accuracy of the SES variables, we excluded study individuals whose parents immigrated to Sweden after 15 years of age due to the potential misclassification bias of keeping these individuals within the cohort. Some asthma cases recorded in primary care may have been missed; however, the majority will be captured by including the PDR. Finally, we cannot account for bias from non-shared confounding.

5 | Conclusion

We confirm an association between low parental education and incident asthma/wheeze in cohort and cousin comparison as well as low parental education at 5 years and current asthma. Results from the
cousin comparison on incident asthma/wheeze suggest the relationship cannot be fully explained by shared genetic or environmental exposures shared by first cousins and may be causal. The relationship between parental income and asthma/wheeze is less clear. This study is important for understanding risk factors for asthma which is needed for implementation of prevention strategies. Future research ought to explore the possible causal relationship between parental education and asthma and the association between parental SES and different asthma or wheezing phenotypes in cousin comparison.

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CONFLICT OF INTEREST
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AUTHOR’S CONTRIBUTIONS
Study concept and design: C. A., T. G., C. L., E. C. O. and B. K. B. Data acquisition and funding: C. A. and H. L. Data analysis: E. C. O., T. G. and C. L. Data interpretation: C. A., E. C. O., B. K. B., C. L., T. G. and H. L. Drafting of the manuscript: E. C. O.

E. C. O., T. G., C. L. and C. A. had full access to all the data in the study and take responsibility for the integrity and the accuracy of the data. All authors critically reviewed and revised the manuscript and approved the final version. The corresponding author attest that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

ETHICAL APPROVAL
Ethical approval for the study was granted by the Regional Ethical Review Board in Stockholm, Sweden, DNR 2013/862-31/5.
DATA AVAILABILITY STATEMENT
All data relevant to the study are included in the article. No additional data available.

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