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Early family socioeconomic status and asthma-related outcomes in school-aged children: Results from seven birth cohort studies

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ABSTRACT

Objective To examine the associations between maternal education and household income during early childhood with asthma-related outcomes in children aged 9–12 years in the UK, the Netherlands, Sweden, Australia, the USA and Canada.

Methods Data on 31 210 children were obtained from 7 prospective birth cohort studies across six countries. Asthma-related outcomes included ever asthma, wheezing/asthma attacks and medication control for asthma. Relative social inequalities were estimated using pooled risk ratios (RRs) adjusted for potential confounders (child age, sex, mother ethnic background and maternal age) for maternal education and household income. The Slope Index of Inequality (SII) was calculated for each cohort to evaluate absolute social inequalities.

Results Ever asthma prevalence ranged from 8.3% (Netherlands) to 29.1% (Australia). Wheezing/asthma attacks prevalence ranged from 3.9% (Quebec) to 16.8% (USA). Pooled RRs for low (vs high) maternal education and low (vs high) household income were: ever asthma (education 1.24, 95% CI 1.13 to 1.37; income 1.28, 95% CI 1.15 to 1.43), wheezing/asthma attacks (education 1.14, 95% CI 0.97 to 1.35; income 1.22, 95% CI 1.03 to 1.44) and asthma with medication control (education 1.16, 95% CI 0.97 to 1.40; income 1.25, 95% CI 1.01 to 1.55). SIIs supported the lower risk for children with more highly educated mothers and those from higher-income households in most cohorts, with few exceptions.

Conclusions Social inequalities by household income on the risk of ever asthma, wheezing/asthma attacks, and medication control for asthma were evident; the associations were attenuated for maternal education. These findings support the need for prevention policies to address the relatively high risks of respiratory morbidity in children in families with low socioeconomic status.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Wide variations exist in the prevalence of childhood asthma worldwide. Evidence is limited regarding the association of socioeconomic status and asthma-related outcomes using comparable measures of socioeconomic status across countries. There has been a lack of research examining absolute inequality in child asthma-related outcomes.

WHAT THIS STUDY ADDS

⇒ This project examines social inequalities in asthma-related outcomes in school-aged children both in relative and absolute terms across seven birth cohort studies. For the three outcomes (ever asthma, wheezing/asthma attacks, medication control for asthma), pooled estimates are consistent with increased relative risk among low-income households. The pooled estimate for ever asthma was consistent with increased relative risk by maternal education. Except for wheezing/asthma attacks by maternal education in the UK cohort and by income in the Swedish cohort, absolute risk by income and maternal education is in the expected direction for all outcomes and complements the findings for relative risk.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Healthcare professionals should be aware of the relatively high risks of respiratory morbidity in children in families with low socioeconomic status at an early time. Prevention policies are needed to address the social inequalities in asthma-related outcomes among school-aged children.

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INTRODUCTION

Asthma is one of the most common chronic conditions in childhood.[1] Respiratory symptoms such as wheezing, shortness of breath and cough are recognised as indicative of asthma. Of these, the most common and important symptom for the identification of asthma in epidemiological studies is wheezing.[2] Wide variations exist in the prevalence of childhood asthma worldwide. Between 2000 and 2003, among children aged 13–14 years, the prevalence rate of children ever having asthma was 16.3% in Western Europe, 22.5% in North America and 32.4% in Oceania.[1] Similar variation was observed in the prevalence rate of child wheezing in the previous 12 months (15.2% Western Europe; 21.5% North America; 26.7% Oceania).[1]

A child's socioeconomic status (SES) can be measured by household income, caregiver employment or parental education status.[3] Each of these SES variables has been previously linked with childhood asthma-related outcomes.[4–6] However, results are inconsistent, as both low and high SES have been reported as risk factors.[7] Some of these inconsistencies may be accounted for by the SES indicators used. The definitions of SES vary across studies which makes it challenging to compare the socioeconomic inequalities between countries.[8] Evidence is limited regarding the association of SES and asthma-related outcomes using comparable measures of SES across countries; one study comparing 10 European cohorts used maternal education and observed mixed results among the included cohorts.[9] In addition, compared with relative inequality, absolute inequality in child asthma-related outcomes provides valuable insights from public health perspectives by accounting for the overall level of asthma prevalence; yet there has been a lack of research examining this aspect.[10]

Current global treatment guidelines emphasise the use of controller medications, such as inhaled corticosteroids or long-acting bronchodilator inhalers for asthma control.[11] Disadvantaged SES has been associated with not only the development of asthma during childhood but also poor compliance with asthma treatment and increased prescription dispensation of controller medication.[12 13] In addition to ever asthma, wheezing/asthma attacks and the use of medication can provide information regarding current symptoms and severity of asthma.

The Elucidating Pathways Of Child Health inequalities (EPOCH) study draws on data from seven birth cohort studies from six countries to explore the pathways from early SES to child health outcomes in later childhood. Outcomes investigated include attention-deficit/hyperactivity disorder,[14] overweight/obesity[15] and chronic conditions[16] among others. The impact of early SES on adult health has been extensively studied,[17] but less attention has been given to its impact across childhood and adolescence.[8] The EPOCH study aims to address this gap. The current paper reports the associations both in relative and absolute terms between maternal education and household income during early childhood and the presence of ever asthma, wheezing/asthma attacks, and asthma with medication control later when the children were aged 9–12 years in six countries.

METHODS

Data sources

Drawing on the EPOCH research collaboration, the current study derived data from pre-existing birth cohort studies (online supplemental table 1). In total, data were available for 31 210 children born between 1988 and 2006. The study included data from seven prospective cohorts conducted in the UK (Millennium Cohort Study, MCS[18], n=13 354), The Netherlands (Generation R Study, GenR[19], n=4277), Sweden (All Babies in Southeast Sweden, ABIS[20], n=4026), Australia (Longitudinal Study of Australian Children B-Cohort, LSAC[21], n=3759), USA (National Longitudinal Survey of Youth, Children and Young Adults, USNLSY[22], n=3104), Canada (National Longitudinal Survey of Children and Youth, NLSCY[23], n=1356) and the province of Québec in Canada (Québec Longitudinal Study of Child Development, QLSCD[24], n=1334). All cohorts enrolled population-based samples of children at birth or within the first 2 years of life. The participating cohort profiles are shown in online supplemental table 1.

Ethics

All original birth cohorts complied with the ethical standards of their relevant institutional and/or national committees and with the Declaration of Helsinki of 1964, and its later amendments. Ethical approval and participant consent were undertaken by the research ethics committees in the respective participating countries (online supplemental table 1). Concordia University Human Research Ethics Committee certified the ethical acceptability for EPOCH's secondary data use (#2011028).

Socioeconomic status

Maternal education and household income were obtained by questionnaire of children aged 0–5 years. Self-reported maternal education levels across cohorts were harmonised using the 1997 International Standard Classification of Education (ISCED 97).[25] The highest level of education completed was categorised into three groups: low (ISCED I–II), middle (ISCED III–IV) and high (ISCED V–VII). Self-reported household income was collected in local currency and harmonised using $purchasing power parity 2000 ($PPP) (https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm) to facilitate comparison of ranges and means across cohorts. To assess the social inequalities in asthma with equal importance of the upper and lower end of the distribution, participants were categorised into three groups according to their household income: low (1st quintile), middle (2nd–4th quintile) and high (5th quintile). Details of income data collection are shown in table 1.

Ever asthma, wheezing/asthma attacks and medication control for asthma

In all cohorts, childhood asthma and wheezing/asthma attacks were obtained by parent-reported questionnaire. Data were collected at age 10–11 years for all cohorts, except the Netherlands (GenR, 9–10 years) and Sweden (ABIS, 10–12 years). Ever asthma (yes/no) was defined as a parent endorsement of whether their child had ever received a diagnosis of asthma by a health professional. Wheezing/asthma attacks in the past 12 months (yes/no) was defined as a parent endorsement of whether their child had 'attacks/illness of wheezing' (Netherlands and Australia), 'wheezing or whistling' (UK, Sweden and Canada) or 'wheezing or an attack of asthma' (USA and Quebec). Medication control for asthma (yes/no) was defined as ever diagnosis of asthma and asthma-related medication use (yes/no) in the past 12 months. Information on medication use in the past 12 months was obtained by parent questionnaire for all cohorts, except the Netherlands (GenR), which collected information during the child's visit to the research centre. The USA cohort inquired about medication use over the past 30 days. The Swedish cohort cross-linked information on asthma medication prescription with the National Prescribed Drug Register. Information on medication use was not available in the Australian cohort. Online supplemental table 2 describes the measurement specifications for each cohort.

Potential confounders

Child age, sex, mother ethnic background and maternal age at birth were included as covariates in all models. Mother ethnic background was dichotomised using 'majority/minority' or 'born inside country/born outside country' designations. Aboriginal and Torres Strait Islander (Australia) and First Nations (Québec) mothers were classified as 'born inside country' in these cohorts. Mother ethnic background was based on the country of birth of the mother and of her parents for the Netherlands cohort

Table 1 Household income ranges and means data harmonisation by cohort*

Cohort	Annual income (gross or net)	Child age at baseline income assessment	Equivalised (yes or no)	Annual household Income† range and mean (local currency) and $PPP (purchasing power parities)		
				High–richest (quintile 1)	Middle (quintiles 2–4)	Low—poorest (quintile 5)
GenR Rotterdam, Netherlands	Net	5–6 years	No	Range (€ Euro)		
				>€57 600 (>$PPP49 133)	€24 000–€57 600 ($PPP 20 472–$PPP49 133)	<€24 000 (<$PPP20 472)
LSAC B Australia	Gross	Birth to 1 year	No	Range (AUD$ Australian dollar)		
				>$A86 164 ($PPP>65 676)	$A32 240–$A86 216 ($PPP24 544–$PPP65 624)	<$A32 240 ($PPP<24 596)
				Mean (AUD$)		
				$A131 438 ($PPP100 181)	$A55 864 ($PPP42 579)	$A22 014 ($PPP16 779)
ABIS‡ Southeast Sweden	Net	1–3 years	No	Range (SEK Swedish Krona)		
				>SEK346 663 (>$PPP37 845)	SEK235 853–SEK346 650 ($PPP 25 748–$PPP37 844)	<SEK235 850 ($PPP25 749)
				Mean (SEK Swedish Krona)		
				Mean SEK479 928 ($PPP52 394)	Mean SEK290 077 ($PPP31 668)	Mean SEK177 139 ($PPP19 338)
MCS§ UK	Net	9 months	Yes (OECD‡‡)	Range (£ pound sterling)		
				>£23 452 ($PPP>33 265)	£6708–£23 452 ($PPP9515–$PPP33 265)	<£6682 (<$PPP9478)
				Mean (£)		
				£34 008 ($PPP48 238)	£14 783 ($PPP20 969)	£5148 ($PPP7302)
QLSCD¶ Quebec, Canada	Gross	Before birth (−1 year before maternity leave)	Yes (OECD)	Range ($CAD Canadian dollar)		
				>$C34 444 ($PPP>28 679)	$C10 769–$C34 285 ($PPP8967–$PPP28 547)	<$C10 714 (<$PPP8921)
				Mean ($CAD Canadian dollar)		
				$C49 321	$C21 291	$C6889
				($PPP41 067)	($PPP17 727)	($PPP5736)
NLSCY** †† Canada	Gross	0–11 months	No	Range ($CAD Canadian dollar)		
				>$C80 000 (>$PPP66 225)	$C30 000–$C79 999 ($PPP24 834–$PPP66 224)	<$C30 000 (<$PPP24 834)
USNLSY USA	Net	0–2 years	No	Range (US$)		
				>US$86 065	US$21 968–US$86 064	<US$21 967
				Mean (US$)		
				US$89 369	US$22 585–US$35 375	US$10 521

*Factual content regarding cohort profiles is similarly provided across all EPOCH Collaborative Group publications.
†Household income grouped into high (5th quintile, richest), middle (2nd–4th quintile), low (1st quintile, poorest).
‡$PPP conversion rate year 2000; kr9.16/US$.
§$PPP conversion rate year 2000; £0.705/US$.
¶Average $PPP conversion rate of 1997; $C1.201/US$.
**Average $PPP conversion rate of 1994 and 1995; $C1.208/US$. Source: https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm.
††NLSCY restricts data release; mean data cannot be released.
‡‡OECD: Modified OECD scales were used for equivalisation.
ABIS, All Babies in Southeast Sweden; EPOCH, Elucidating Pathways Of Child Health inequalities; LSAC, Longitudinal Study of Australian Children B-Cohort; MCS, Millennium Cohort Study; NLSCY, National Longitudinal Survey of Children and Youth; QLSCD, Québec Longitudinal Study of Child Development; USNLSY, US National Longitudinal Survey of Youth, Children and Young Adults.

(GenR). Potential mediators identified in published literature (parental smoking,[26] poor quality housing,[27] maternal history of asthma[28]) that partly explain the associations between SES and asthma-related outcomes were not included in the regression models to prevent potential obstruction in the pathways of interest and avoid biased results caused by conditioning on colliders. A directed acyclic graph is presented in online supplemental figure 1.

Statistical analysis

Frequency tables report the unweighted characteristics of the cohort samples. To facilitate comparison across cohorts, weights accounting for differential attrition were applied in all cohorts except ABIS (Sweden). In GenR (Netherlands), this was done by constructing inverse probability weights using the original cohort's information on maternal education and household income. In the remaining cohorts, complex weights using additional variables were used which allowed for comparisons with reference populations (see online supplemental table 1). For interpretability, risk ratios (RRs) were estimated using a generalised linear model with a log link and robust variance estimation in bivariate and multivariate analyses.[29] Individual-level data were used to estimate RRs and 95% confidence interval (95%CI) in each cohort. Pooling of RRs from all cohorts and estimation of the I^2 and Q statistic ranges to evaluate heterogeneity were carried out using meta-analysis procedures (Metafor package in R).[30] Finally, to evaluate the associations between SES and asthma-related outcomes on the absolute scale, the Slope Index of Inequality (SII) was calculated for each cohort. SII represents the absolute difference in prevalence between the most advantaged and the least advantaged groups in a population.[31] SIIs in this study were calculated using regression with the weighted prevalence of ever asthma, wheezing/asthma attacks and medication control for asthma as the dependent variables.[32]

Table 2 Sample characteristics by cohort

Variables		GenR Netherlands n=4277	LSAC B Australia n=3759	ABIS Sweden n=4026	MCS UK n=13 354	QLSCD Quebec n=1334	NLSCY Canada n=1356	US NLSY USA n=3104*
Asthma (ever)	Yes	357 (8.3)	1095 (29.1)	528 (13.1)	2401 (18.0)	302 (22.6)	234 (17.3)	491 (15.8)
(n, %)	No	3537 (82.7)	2664 (70.9)	3498 (86.9)	10 951 (82.0)	1032 (77.4)	1073 (79.1)	2613 (84.2)
	Missing	383 (9.0)	0 (0)	0 (0)	2 (0)	0 (0)	49 (3.6)	0 (0)
Wheezing or asthma attack (past year)	Yes	178 (4.2)	387 (10.3)	424 (10.5)	1590 (11.9)	52 (3.9)	183 (13.5)	227 (16.8)
(n, %)	No	3818 (89.3)	3304 (87.9)	3602 (89.5)	11 762 (88.1)	1282 (96.1)	123 (82.8)	1126 (83.2)
	Missing	281 (6.6)	68 (1.8)	0 (0)	2 (0.0)	0 (0)	50 (3.7)	0 (0)*
Medication control (past year)	Yes	186 (4.3)	n/a	176 (4.4)	610 (4.6)	157 (11.8)	94 (7.0)	84 (6.2)
(n, %)	No	3430 (80.2)	n/a	3840 (95.4)	12 744 (95.4)	1177 (88.2)	1213 (89.0)	1269 (93.8)
	Missing	661 (15.5)	3759 (100)	10 (0.2)	0 (0)	0 (0)	49 (4.0)	0 (0)*
Household income	High (Q5)	683 (16.0)	831 (22.1)	985 (24.5)	2299 (17.2)	286 (21.4)	365 (26.9)	570 (18.4)
(n, %; by quintile groups)	Middle (Q2–4)	2823 (66.0)	2352 (62.6)	2468 (61.3)	7714 (57.8)	782 (58.6)	874 (64.5)	1581 (50.9)
	Low (Q1)	771 (18.0)	576 (15.3)	569 (14.1)	2829 (21.2)	210 (15.7)	117 (8.6)	731 (23.6)
	Missing	0 (0)	0 (0)	4 (0.1)	512 (3.8)	56 (4.2)	0 (0)	222 (7.2)
Maternal educational	High	2440 (57.0)	1796 (47.8)	1705 (42.8)	4175 (31.3)	463 (34.7)	567 (41.8)	902 (29.1)
(n, %; by three categories)	Middle	1224 (28.6)	1624 (43.2)	2107 (52.9)	5545 (41.5)	536 (40.2)	568 (41.9)	1670 (53.9)
	Low	613 (14.3)	337 (9.0)	174 (4.4)	3135 (23.5)	335 (25.1)	187 (13.8)	528 (17.0)
	Missing	0 (0)	2 (0.05)	40 (1.0)	499 (3.7)	0 (0)	34 (2.5)	4 (0.1)
Child age (mean, SD)	Years	9.7 (0.3)	10.9 (0.01)	10.6 (0.3)	10.7 (0.5)	10.1 (0.3)	10.1 (0.3)	10.5 (0.7)
Child sex	Male	2120 (49.6)	1928 (51.3)	2044 (50.8)	6730 (50.4)	635 (47.6)	687 (50.7)	1599 (51.5)
(n, %)	Female	2157 (50.4)	1831 (48.7)	1982 (49.2)	6624 (49.6)	699 (52.4)	669 (49.3)	1505 (48.5)
	Missing	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mother ethnicity	Ethnic majority/born in country	2873 (67.2)	2453 (65.3)	3790 (94.1)	10 747 (80.5)	1224 (91.8)	1196 (88.0)	1627 (52.4)
(n, %)	Ethnic minority/born out country	1404 (32.8)	1297 (34.5)	195 (4.8)	2104 (15.8)	109 (8.2)	116 (9.0)	1477 (47.6)
	Missing	0 (0)	9 (0.2)	41 (1.0)	503 (3.8)	1 (0.1)	44 (3.0)	0 (0)
Maternal age at birth†	<25 years	383 (9.0)	436 (11.6)	400 (9.9)	3158 (23.7)	310 (23.2)	310 (22.9)	113 (3.6)
(n, %)	25–29 years	1020 (23.8)	986 (26.3)	1594 (39.6)	3577 (26.8)	420 (31.5)	451 (33.3)	1364 (43.9)
	30–34 years	1976 (46.2)	1490 (39.6)	1407 (34.9)	4502 (33.7)	446 (33.4)	435 (32.1)	1411 (45.5)
	≥35 years	898 (21.0)	844 (22.5)	596 (14.8)	1638 (12.3)	157 (11.8)	145 (10.7)	216 (7.0)
	Missing	0 (0)	3 (0.1)	29 (0.7)	478 (3.6)	1 (0.1)	15 (1.1)	0 (0)

Sample size may differ from baseline N reported in online supplemental table 1 due to missing data for SES exposure in early childhood or asthma in late childhood or cohort attrition.
*USNLSY included detailed questions about wheezing and asthma medications starting in 2004; subsample (n=1353) restricted to children born 1992 or later was used for these two variables.
†Mother age at child birth categories differed for NLSCY (Canada): 15–24, 25–29, 30–34, 35+, missing.
ABIS, All Babies in Southeast Sweden; LSAC, Longitudinal Study of Australian Children B-Cohort; MCS, Millennium Cohort Study; NLSCY, National Longitudinal Survey of Children and Youth; QLSCD, Québec Longitudinal Study of Child Development; SES, socioeconomic status; USNLSY, US National Longitudinal Survey of Youth, Children and Young Adults.

RESULTS

Table 2 presents the characteristics of the study population. Of the 31 210 children, 49.6% were female, and 16.4% of mothers were younger than 25 years at their child's birth. The proportion of mothers with minority ethnic background ranged from 4.8% (Sweden) to 47.6% (USA). Levels of maternal education varied widely by cohort: the UK and Quebec cohorts had the highest proportion of low maternal education (23.5% and 25.1%, respectively), while Sweden and Australia had the lowest proportions (4.4% and 9.0%, respectively). Alternatively, the proportions of high maternal education were highest in the Netherlands (57.0%), Australia (47.8%) and Sweden cohorts (42.8%), compared with the remaining cohorts. The proportions of children who had ever experienced asthma in the participating cohorts ranged from 8.3% (Netherlands) to 29.1% (Australia). Prevalence of wheezing/asthma attacks ranged from 3.9% (Quebec) to 16.8% (USA). Prevalence of medication control was higher in Quebec (11.8%), Canada (7.0%) and the USA cohorts (6.2%), than in the remaining cohorts.

Ever asthma

The RRs and 95% CI for each asthma-related outcomes by maternal education and household income are summarised in table 3. After adjustment for confounding variables, cohort-specific analyses showed that social inequalities by maternal education were present in the UK, Netherlands and Australia cohorts. Children of mothers with lower educational attainment had higher risk for ever asthma compared with those of mothers with higher educational attainment. Social inequalities by household income were observed in the UK and Australia cohorts, such that lower household income was associated with an increased risk of ever asthma. Pooled analyses of effect estimates indicated increased risk of ever asthma for children of mothers with lower educational attainment (RR 1.24, 95% CI 1.13 to 1.37) and from lower-income households (RR 1.28, 95% CI 1.15 to 1.43). Heterogeneity among cohorts was low (Q range 1.88–3.72; see figure 1A).

Absolute inequalities (SIIs) are illustrated for each cohort in figure 1B,C. Absolute inequalities in ever asthma across cohorts indicate the lower risk for children with more highly educated mothers and those from higher-income households. Absolute inequality by maternal educational level for asthma was the highest in Australia (−9.76) and lowest in the USA (−1.25). For absolute inequality by income, Australia (−9.09) had the highest inequality and Sweden (−1.29) had the lowest.

Table 3 Risk ratios for asthma-like outcomes in late childhood by income and education at baseline using adjusted multivariate regression (weighted)

Exposure	GenR (Netherlands)	LSAC B (Australia)	ABIS (Sweden)	MCS (UK)	QLSCD (Quebec)	NLSCY (Canada)	USNLSY (USA)
				Asthma (ever) Risk ratio (95% CI)			
Maternal education							
High	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Middle	1.06 (0.83 to 1.34)	1.18 (0.98 to 1.41)	1.10 (0.93 to 1.31)	1.04 (0.94 to 1.16)	1.05 (0.80 to 1.38)	1.13 (0.74 to 1.72)	0.96 (0.65 to 1.41)
Low	**1.52 (1.15 to 1.99)**	**1.38 (1.06 to 1.79)**	1.18 (0.80 to 1.75)	**1.20 (1.06 to 1.37)**	1.11 (0.79 1.57)	1.14 (0.70 to 1.87)	1.12 (0.65 to 1.91)
Household income							
High	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Middle	0.92 (0.68 to 1.23)	1.16 (0.94 to 1.43)	1.10 (0.90 to 1.34)	1.10 (0.97 to 1.25)	0.98 (0.73 to 1.31)	1.32 (0.86 to 2.03)	0.95 (0.58 to 1.55)
Low	1.31 (0.92 to 1.87)	**1.39 (1.05 to 1.83)**	1.04 (0.79 to 1.38)	**1.33 (1.14 to 1.56)**	1.28 (0.84 to 1.94)	1.35 (0.67 to 2.71)	1.29 (0.72 to 2.32)
				Wheezing or asthma attack (past year) Risk ratio (95% CI)			
Maternal education							
High	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Middle	**1.61 (1.16 to 2.23)**	1.17 (0.98 to 1.41)	1.08 (0.80 to 1.17)	0.96 (0.84 to 1.09)	0.79 (0.34 to 1.85)	1.12 (0.70 to 1.78)	1.11 (0.80 to 1.53)
Low	1.47 (0.94 to 2.29)	**1.38 (1.06 to 1.80)**	0.86 (0.52 to 1.42)	1.01 (0.86 to 1.19)	1.03 (0.46 to 2.30)	1.25 (0.69 to 2.26)	1.14 (0.72 to 1.81)
Household income							
High	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Middle	1.11 (0.71 to 1.76)	1.62 (0.94 to 1.43)	1.21 (0.96 to 1.52)	0.98 (0.85 to 1.15)	1.16 (0.50 to 2.70)	1.23 (0.78 to 1.94)	**1.75 (1.09 to 2.83)**
Low	1.52 (0.89 to 2.60)	**1.39 (1.05 to 1.83)**	0.90 (0.64 to 1.26)	1.11 (0.91 to 1.35)	1.45 (0.53 to 3.98)	1.75 (0.86 to 3.58)	1.42 (0.80 to 2.51)
				Asthma medication control (past year)* Risk ratio (95% CI)			
Maternal education							
High	Reference		Reference	Reference	Reference	Reference	Reference
Middle	1.09 (0.78 to 1.52)	*N/A*	0.87 (0.64 to 1.18)	0.87 (0.69 to 1.09)	0.90 (0.60 to 1.35)	1.23 (0.62 to 2.43)	0.90 (0.52 to 1.56)
Low	1.46 (0.99 to 2.16)		1.00 (0.49 to 2.05)	1.13 (0.87 to 1.48)	1.05 (0.65 to 1.70)	1.21 (0.48 to 3.05)	0.89 (0.38 to 2.07)
Household income							
High	Reference		Reference	Reference	Reference	Reference	Reference
Middle	0.76 (0.52 to 1.11)	*N/A*	1.27 (0.88 to 1.83)	1.07 (0.83 to 1.38)	0.93 (0.61 to 1.41)	**2.08 (1.02 to 4.22)**	1.11 (0.54 to 2.29)
Low	1.16 (0.72 to 1.86)		0.94 (0.55 to 1.62)	1.30 (0.94 to 1.81)	1.23 (0.69 to 2.20)	**4.33 (1.55 to 12.1)**	1.14 (0.45 to 2.88)

Risk ratios adjusted for child age, child sex, maternal ethnicity, maternal age at birth for all cohorts. Sample sizes may differ from baseline N reported in online supplemental table 2 or table 2 due to missing data for SES exposure in early childhood or asthma in late childhood or cohort attrition.
Bold typeface indicates statistical significance at P<0.05.
Values for 95% CIs vary slightly versus those in the pooled forest plots due to rounding.
*In USNLSY (USA), medication use information was collected regarding last 30 days.
ABIS, All Babies in Southeast Sweden; LSAC, Longitudinal Study of Australian Children B-Cohort; MCS, Millennium Cohort Study; N/A, not available; NLSCY, National Longitudinal Survey of Children and Youth; QLSCD, Québec Longitudinal Study of Child Development; SES, socioeconomic status; USNLSY, US National Longitudinal Survey of Youth, Children and Young Adults.

Wheezing/asthma attacks

Cohort-specific analyses showed that social inequalities in maternal education for wheezing/asthma attacks in children were present in the Netherlands and Australia cohorts. Pooled estimates indicated increased risk of wheezing/asthma attacks for children of mothers with lower educational attainment (RR 1.14, 95% CI 0.97 to 1.35) and from lower-income households (RR 1.22, 95% CI 1.03 to 1.44). Heterogeneity ranged from low to moderate (Q range 6.61–17.29), with higher estimates among the middle categories of household income. Forest plot is shown in figure 2A.

Absolute inequalities in wheezing/asthma attacks varied across cohorts (see figure 2B,C). In the UK and Sweden cohorts, children of higher maternal education had a greater risk for wheezing/asthma attacks (SII: 0.55 and 0.99, respectively); although, these values are small. Among the remaining cohorts, absolute inequality by maternal educational level for wheezing/asthma attacks the highest in Australia (−10.71) and lowest in

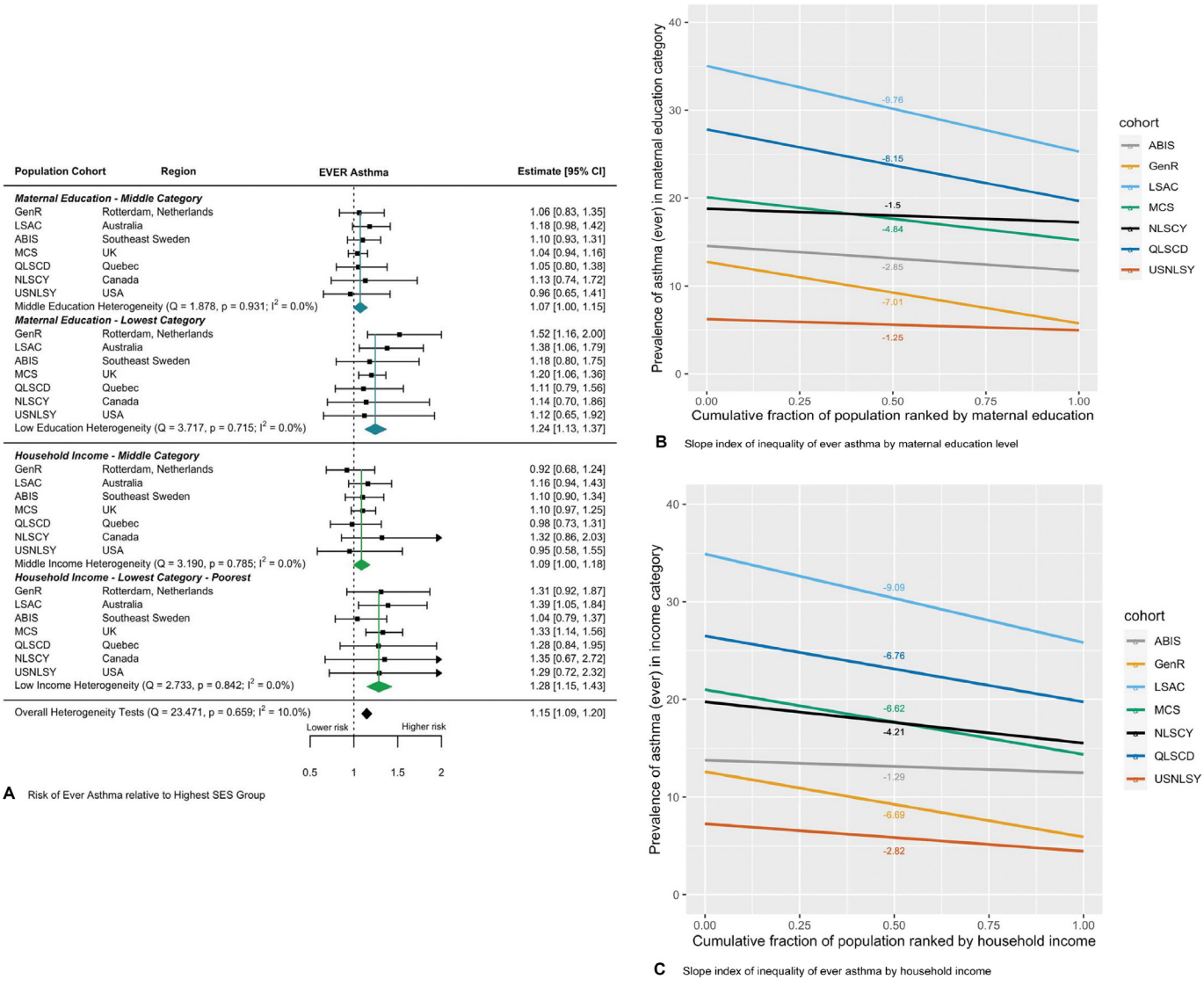

Figure 1 Relative and absolute association between maternal education, household income and ever asthma. ABIS, All Babies in Southeast Sweden; LSAC, Longitudinal Study of Australian Children; MCS, Millennium Cohort Study; NLSCY, National Longitudinal Survey of Children and Youth; QLSCD, Québec Longitudinal Study of Child Development; SES, socioeconomic status; USNLSY, US National Longitudinal Survey of Youth, Children and Young Adults.

Quebec (−1.36). For absolute inequality by income, the USA cohort (−6.38) had the highest inequality and Sweden (−0.44) had the lowest.

Medication control for asthma

Regarding medication control for asthma, associations of social inequalities by household income were only observed in Canada (see table 3). No association was observed between maternal education and medication control for asthma in any cohort. Pooled analyses of effect estimates across cohorts showed that children from lower-income households had an increased risk of asthma with medication control (RR 1.25, 95% CI 1.01 to 1.55). Similarly, children of mothers with low educational attainment had an increased risk, although estimates crossed unity (RR 1.16, 95% CI 0.97 to 1.40; see figure 3A). Absolute inequalities in asthma with medication control were lower than in ever asthma. In Sweden, children of higher maternal education had a greater risk for medication control (SII: 0.98). Among the remaining cohorts, the highest absolute inequality by maternal education for medication control was in Quebec (−2.67) and lowest in the UK (−0.47). For absolute inequality by income, Canada had the highest inequality (−9.52) and Sweden had the lowest (−0.1; see figure 3B,C).

DISCUSSION

We examined relative and absolute risks of three asthma-related outcomes (ever asthma, wheezing/asthma attacks, asthma with medication control) in later childhood by household income and maternal education in early childhood in six high-income countries. For all three outcomes, pooled estimates were consistent with increased relative risk among low-income households. The pooled estimate for ever asthma was consistent with increased relative risk by maternal education while pooled estimates for wheezing/asthma attacks and asthma medication control were in the expected direction, their CIs crossed unity. The reported trends for these outcomes were significant in the UK, Netherlands and Australian cohorts. Except for wheezing by maternal education in the UK cohort and by income in the Swedish cohort, absolute risk by income and maternal education was in

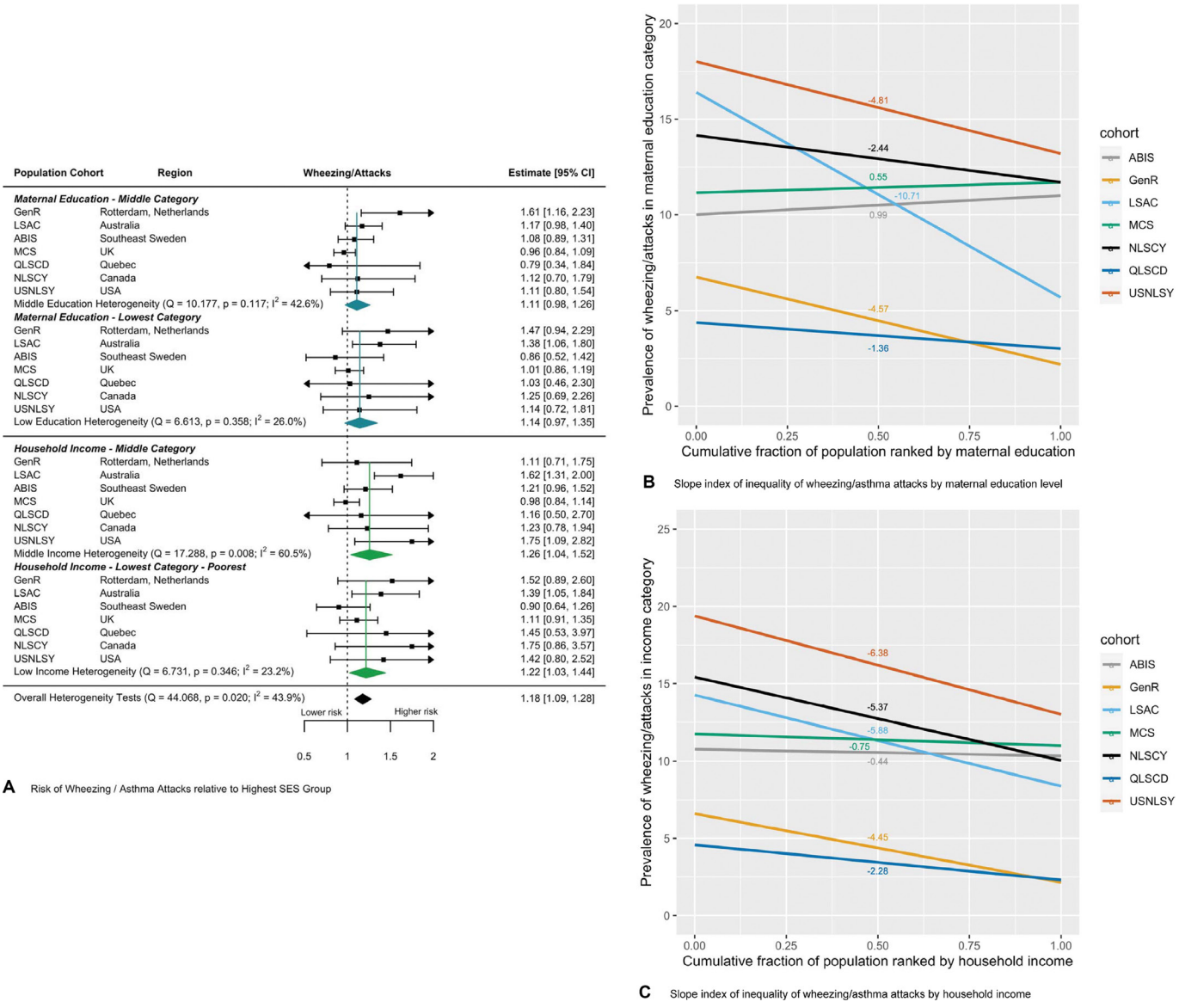

Figure 2 Relative and absolute association between maternal education, household income and wheezing/asthma attacks. ABIS, All Babies in Southeast Sweden; LSAC, Longitudinal Study of Australian Children; MCS, Millennium Cohort Study; NLSCY, National Longitudinal Survey of Children and Youth; QLSCD, Québec Longitudinal Study of Child Development; SES, socioeconomic status; USNLSY, US National Longitudinal Survey of Youth, Children and Young Adults.

the expected direction for all outcomes and complemented the findings for relative risk.

The prevalence of child asthma ranged from 8.3% to 29.1% in the participating cohorts, which was generally lower than the findings of phase III (2000–2003) of the International Study of Asthma and Allergies in Childhood (ISAAC), the latest worldwide data on school-aged children.[1] A possible explanation could be that data for all cohorts were collected after the ISAAC phase III period, except for the USA cohort that had overlapping years (age 10 was collected 1998–2006). A previous study reported that asthma prevalence has plateaued or even decreased in recent years.[33] In our study, the highest prevalences of ever had asthma were observed in Australia, the UK and Canada, which is comparable with the results from phase III study. The 'hygiene hypothesis' has been suggested as a partial explanation for the elevated symptom prevalence in English-speaking countries. It is noteworthy that despite the decline trend in recent years, the prevalence remains notably high in these regions.[1 34]

Overall, social inequalities by maternal education were found for risk of ever experiencing asthma, but not on asthma with medication control. Children with a history of asthma diagnosis and recent medication use within the last 12 months from the measurement time were considered as having active asthma.[35] The absence of a significant association between maternal education and active asthma at the age of 9–10 years aligns with a systematic review's conclusion, which reported that the traditional relation between lower SES and higher asthma prevalence is evident until children are age 9 years.[36] Among older children and adolescents, mixed results were reported. As children grow older, a larger portion of their day will be spent in school and the neighbourhood. Thus, the impact of poor housing conditions, to which children from lower SES families tend to be exposed, may be a less salient risk factor during later childhood.[37]

The associations between lower household income and higher asthma prevalence were found in all cohort studies; noteworthy, the CIs of many crossed unity. Lower prevalence of wheezing/

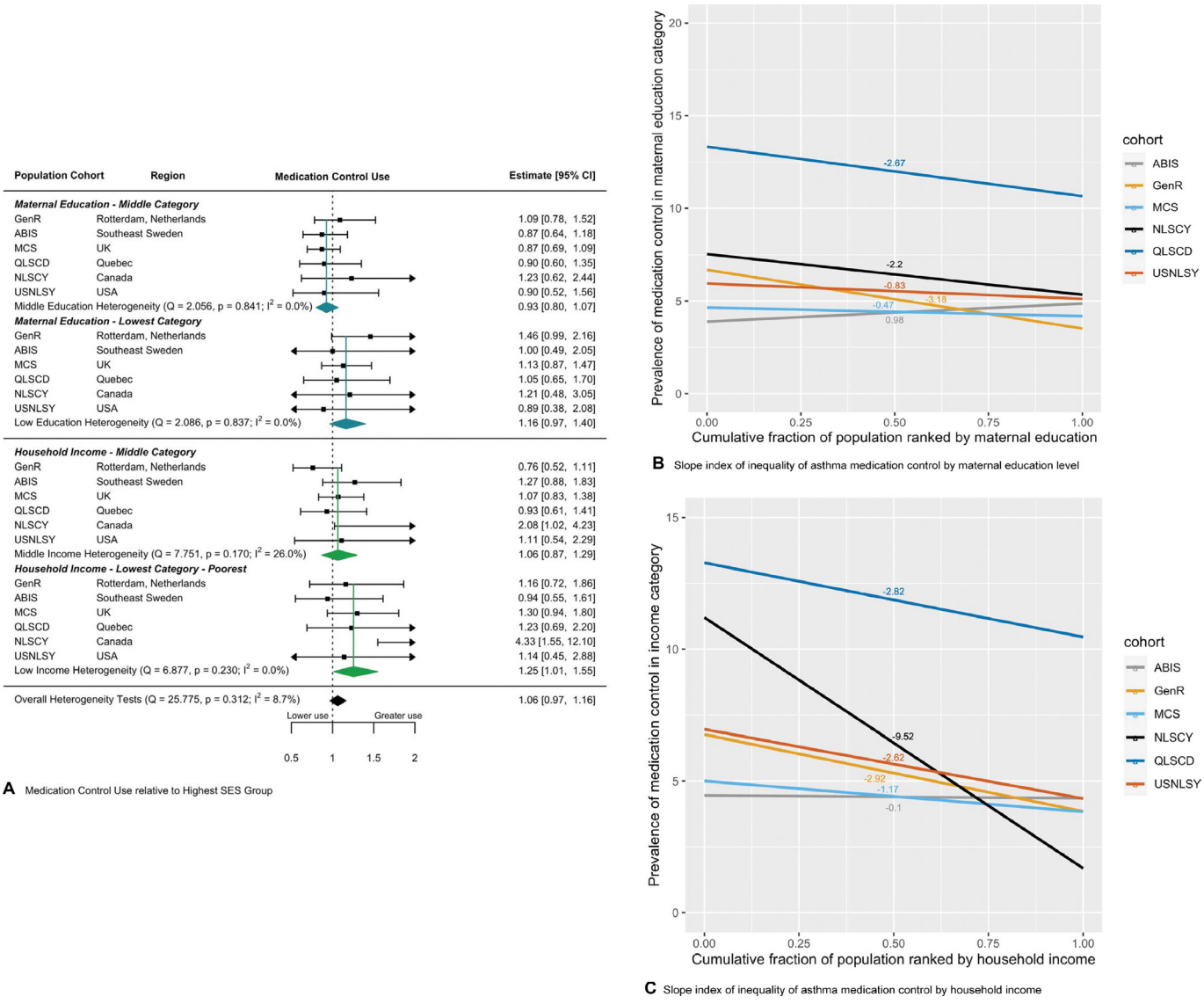

Figure 3 Relative and absolute association between maternal education, household income and asthma with medication control. ABIS, All Babies in Southeast Sweden; LSAC, Longitudinal Study of Australian Children; MCS, Millennium Cohort Study; NLSCY, National Longitudinal Survey of Children and Youth; QLSCD, Québec Longitudinal Study of Child Development; SES, socioeconomic status; USNLSY, US National Longitudinal Survey of Youth, Children and Young Adults.

asthma attacks in lower-income groups was reported in the UK and Sweden cohorts. Overall, social inequalities by household income were observed for ever asthma and wheezing/asthma attacks, which is incongruent with some studies in the literature. A prior systematic review[8] reported inconsistent results for lower-income/SES and asthma: negative associations were reported in two out of five studies.[38 39] One possible reason for the incongruent findings may be that differing income variables (ie, parental occupational status, cumulative poverty, poverty at early age) and definitions of asthma indicators (ie, ever asthma, wheezing/asthma attacks, lung function measurements) were assessed in the prior studies. Another possible explanation could be that the prevalence of self-reported symptoms was higher in people of higher SES while the clinical diagnose did not reach statistical significance.[7] Future studies are needed to identify how the timing and/or accumulation of low household income are associated with various asthma-related outcomes in high-income country settings.

Absolute inequality measured by SII showed consistent social inequalities for maternal education and household income across the cohort populations. The absolute risks in ever asthma were less marked than the risk in medication control for asthma, which strengthens our findings in multivariable analyses. The absolute risks also highlighted the differences in prevalence between countries and showed that the largest potential reduction in asthma prevalence, according to higher maternal educational levels, would be observed in Australia and the Netherlands (reduction in asthma: 10% and 8%, respectively), while higher household income would be associated with the largest reductions in Australia (reduction in asthma: 9%) as well as Quebec, the Netherlands and UK (similar reduction in asthma: all 7%). These findings were consistent with RRs from each cohort, except those from Sweden and Canada were not statistically significant. It should be noted that while RRs were adjusted for confounders (child age, sex, mother ethnic background, maternal age at birth), the SIIs were not. Caution is warranted

when attempting to draw a causal interpretation in relation to the reported SIIs.

The higher relative and absolute risks for asthma with medication control by lower-income in Canada were unexpected and not seen in the remaining cohorts. This could be driven by higher prevalence of asthma with medication control in the Canada cohort and a very low prevalence of asthma with medication control in the highest-income group (3.3%). The prevalence represents children who may still have asthma that requires ongoing management. Future studies are needed to validate the findings in our study.

Among the Sweden cohort, no significant association was found for maternal education nor household income on any of the three outcomes, and, relatively low prevalence of ever asthma and wheezing/asthma attacks were reported. Absolute inequalities for both SES variables on ever asthma and wheezing/asthma attacks were quite low in Sweden. One possible explanation could be Sweden's low level of income inequality. The ratio of the mean $PPP in the highest to lowest income quintile was lowest for Sweden, compared with the other cohorts. Alternatively, Sweden's access to specialised asthma nurses may facilitate greater asthma control by increasing parental knowledge and improving child asthma care, which may explain the relatively low absolute risk of asthma with medication control in the ABIS cohort.[40]

Methodological considerations

Strengths of this study include the large pooled sample of children from seven cohort studies in six high-income country settings, which compared 31 210 children over several years of life. The prospective design of the original cohorts and the harmonised definitions applied across all secondary datasets enabled the rigorous investigation of SES of the families in early childhood and its association with later childhood risk of asthma, wheezing/asthma attacks and asthma with medication control.

Several limitations merit consideration when interpreting results. The prevalence of asthma and wheezing/asthma attacks may not be fully representative of the entire country in which each cohort study was based. Certain cohorts (ie, GenR, QLSCD) used population-representative sampling for only one major geographical area (ie, Rotterdam, Quebec, respectively); regional differences in the prevalence of asthma and wheezing/asthma attacks in the rest of the country may be expected. Although the consistent use of parent-reported asthma diagnosis across all cohorts made asthma measurement method comparable, misclassification due to recall bias or inadvertent parental awareness might be present. Asthma medication control was employed to represent population with active asthma given the absence of questions on asthma attacks in the past 12 months across all cohorts. This method aligns with established practices in other epidemiological studies and it represents the most suitable approximation within the scope of our research. Household income was collected as gross income in three cohorts (Australia, Canada, Quebec) and income net of tax and transfers in the other four (UK, Sweden, Netherlands, USA). A standardised adjustment was used to account for this; nevertheless, misclassification may occur attributable to change in income percentile when tax was applied. In addition, household income was obtained at a range of 5 years in early childhood in each cohort. The interpretation of the results needs to take into account that the effect of low household income on child development may differ across early childhood.[41] Birth year ranged from 1988 to 1996 (USNLSY, USA) to 2002–2006 (GenR, Netherlands) across the cohorts, adding time-varying factors to the findings. Given the trend in child asthma with increasing prevalence over that period of time, this difference may misconstrue the comparison of prevalence across cohorts.

CONCLUSIONS

Pooled estimates indicate that the risk of poorer asthma-related outcomes at age 9–12 years was associated with lower household income in early childhood; significant associations with lower maternal education were found for ever asthma. Social inequalities in asthma during later childhood observed in this study emphasise the need for public policies and prevention policies to address the relatively higher risks of respiratory morbidity in children in families with lower SES.

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