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ASTHMA AND PAEDIATRICS

# Educational and health outcomes of children treated for asthma: Scotland-wide record linkage study of 683 716 children

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**Asthmatic children experience significant disadvantage in addition to poor health. Adverse effects on other aspects of their life, such as education, need to be recognised and addressed.** bit.ly/2W5K4Nib

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ABSTRACT

**Background:** The global prevalence of childhood asthma is increasing. The condition impacts physical and psychosocial morbidity; therefore, wide-ranging effects on health and education outcomes are plausible.

**Methods:** Linkage of eight Scotland-wide databases, covering dispensed prescriptions, hospital admissions, maternity records, death certificates, annual pupil census, examinations, school absences/exclusions and unemployment, provided data on 683 716 children attending Scottish schools between 2009 and 2013. We compared schoolchildren on medication for asthma with peers, adjusting for sociodemographic, maternity and comorbidity confounders, and explored effect modifiers and mediators.

**Results:** The 45 900 (6.0%) children treated for asthma had an increased risk of hospitalisation, particularly within the first year of treatment (incidence rate ratio 1.98, 95% CI 1.93–2.04), and increased mortality (HR 1.77, 95% CI 1.30–2.40). They were more likely to have special educational need for mental (OR 1.76, 95% CI 1.49–2.08) and physical (OR 2.76, 95% CI 2.57–2.95) health reasons, and performed worse in school exams (OR 1.11, 95% CI 1.06–1.16). Higher absenteeism (incidence rate ratio 1.25, 95% CI 1.24–1.26) partially explained their poorer attainment.

**Conclusions:** Children with treated asthma have poorer education and health outcomes than their peers. Educational interventions that mitigate the adverse effects of absenteeism should be considered.

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## Introduction

Asthma is the most common chronic disease of childhood in developed countries [1], affecting 1.1 million children in the UK [2]. Global prevalence is approximately 11% and 14% in children aged 6–7 and 13–14 years, respectively [1], and is increasing due to urbanisation of developing countries leading to environment and lifestyle changes [3]. Prevalence between countries [1, 4] varies from 2% to 20% among school-aged children through differing case ascertainment [5–13]. Asthma causes physical morbidity through breathlessness, sleep disturbance, reduced exercise capacity and psychosocial morbidity. Mood disorders are common through shared genetic and lifestyle risk factors, common disease pathways, and treatment side-effects [14]. Asthma accounts for 1% of disability-adjusted life-years lost and 1 in 250 deaths worldwide [15]. Annual per capita health service and societal burden is estimated at USD3000–3500 in the USA and USD2000 in Europe [16].

Potential adverse effects on educational performance are less well understood. Asthma commonly results in school absence [6, 17–23]; however, consensus lacks on whether this translates into reduced academic attainment [6, 19–21] and employment [23, 24]. We linked Scotland-wide administrative health and education databases to undertake a large-scale, general population cohort study comparing education and health outcomes in children treated for asthma *versus* peers. We questioned whether children treated for asthma suffer increased absenteeism, exclusion, special educational need, unemployment, hospital admission, mortality and poorer attainment compared with peers. We hypothesised that asthmatic children perform poorer than peers across all outcomes.

## Methods

### *Databases*

We linked Scotland-wide individual-level data from four health databases, held by the Information Services Division (ISD) of NHS Scotland (Edinburgh, UK), and four education databases, held by the Scottish Exchange of Educational Data (ScotXed) of the Scottish Goverment (Edinburgh, UK). Linkage methodology has been described previously [25, 26]. The Prescribing Information System (PIS) collects information on all prescriptions dispensed to Scottish residents by community pharmacies or primary care. The Scottish Morbidity Record (SMR) 02 maternity database collects data on maternal, obstetric and child factors. SMR01 and SMR04 record acute and psychiatric hospital admissions, respectively, including dates of admission and discharge and International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) diagnostic codes. The National Records of Scotland collects data from death certificates, including date and cause of death.

The pupil census, conducted annually by all Scottish local authority run primary, secondary and special schools, records whether a child has a special educational need, including type. Absences and exclusions, collected prospectively, are appended at the end of each school year. The Scottish Qualifications Authority collects examination attainment data for all Scottish schoolchildren. The school leaver database collects pupil information 6 months after leaving school: paid/voluntary employment, higher/further education, training or unemployment.

### *Inclusion criteria, definitions and outcomes*

Our cohort included individual records from pupil censuses recorded between 2009 and 2013 that successfully linked to health datasets via the Community Health Index (CHI) database. Mean number of observed school years per pupil was 3.65 (range 1–5 years). We excluded records where age was <4 or >19 years or pupil stage at school was outside the first (P1) to seventh (P7) year of primary (elementary) school and first (S1) to sixth (S6) year of secondary (high) school. For same-sex multiple births we cannot be certain that the correct child has linked; therefore, this study was restricted to singleton children. We used PIS data to ascertain asthma, described previously [26] and defined as an inhaled corticosteroid and β-agonist both dispensed more than once over a school year. Children dispensed one or more of these medications who did not meet the definition were excluded from the study (figure 1).

We studied six school outcomes: annual number of days absent, annual number of school exclusions for challenging/disruptive behaviour, annual record of special educational need, type of special educational need, final academic achievement and subsequent unemployment. The latter two outcomes were restricted to school leavers during the study period. Absence and exclusion data were only available for 2009, 2010 and 2012.

Special educational need is defined as inability to benefit from school education without help beyond that normally given to schoolchildren of the same age. We included special educational need attributed to intellectual disabilities, learning difficulties, dyslexia, language or speech disorder, physical, motor or sensory impairment, autistic spectrum disorder, social, emotional and behavioural difficulties, physical health conditions, and mental health conditions. Children could have more than one type. Academic

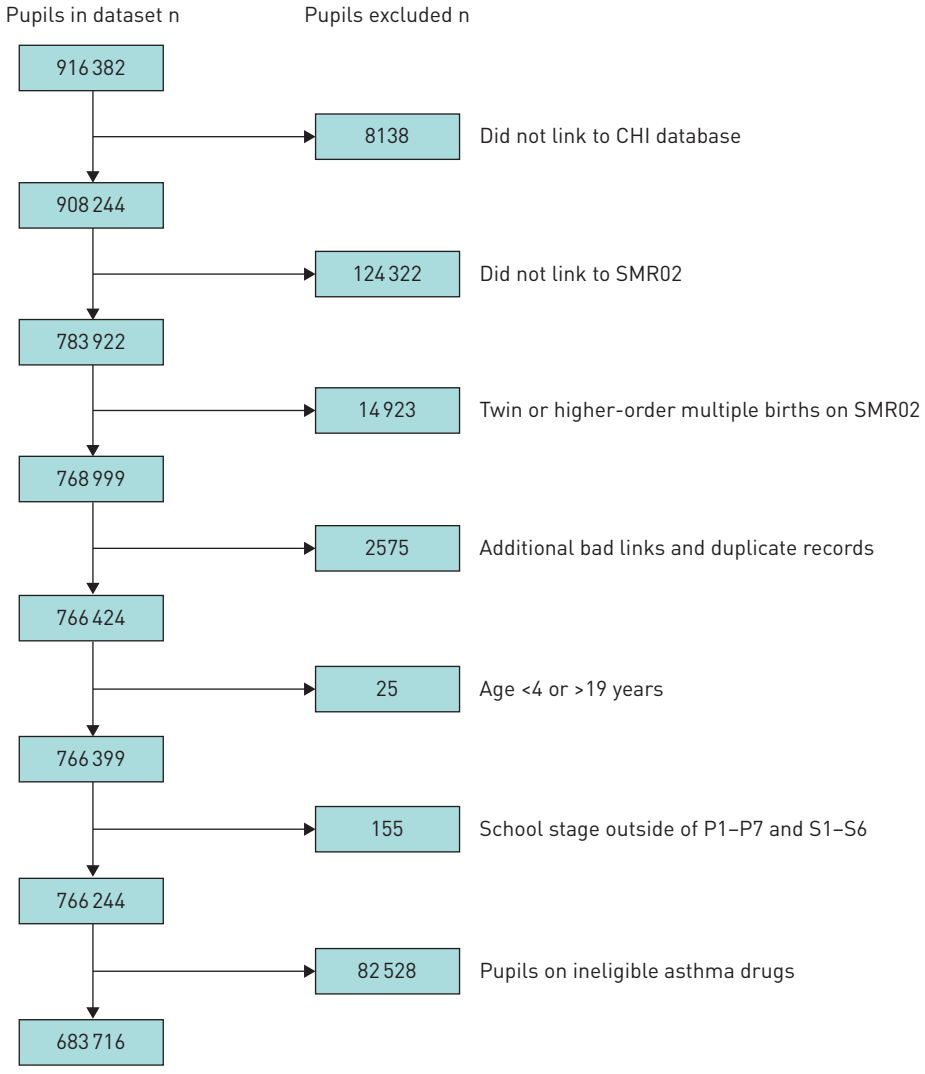


FIGURE 1 Flow diagram illustrating the number of pupils included and excluded from the cohort at each stage of data cleaning. CHI: Community Health Index; SMR: Scottish Morbidity Record; P1–P7: first year through to seventh year of primary (elementary) school; S1–S6: first year through to sixth year of secondary (high) school. The CHI database contains CHI numbers (unique identifiers used on health records) and identifiers for patients registered with a general practitioner.

achievement across the last 3 years of secondary (high) school (fourth, fifth and sixth year) was derived using total number of awards attained at each level of the Scottish Credit Qualifications Framework (http://scqf.org.uk) and converted into an ordinal variable: low, basic, broad/general and high attainment. Destination 6 months after leaving school was collapsed into a dichotomous variable: education/employment/training or unemployment. We studied three health outcomes: all-cause hospital admission, admission due to respiratory disease (ICD-10 codes J00–J99) and all-cause mortality. We also reported deaths due to suicide. Hospitalisation and death data were available until September 2014, providing a mean follow-up of 4.3 years (maximum 5 years).

The pupil census provided data on sex, age and ethnicity. Area socioeconomic deprivation was derived from postcode of residence using the Scottish Index of Multiple Deprivation (SIMD) 2012, with children allocated to general population quintiles. The SIMD is derived from 38 indicators across seven domains (income, employment, health, housing, geographic access, crime, and education, skills and training) using information from datazones of residence (median population 769). Retrospective linkage to SMR02 provided maternal age at delivery, parity, maternal smoking, gestation at delivery, mode of delivery and 5-min Apgar score. We derived sex-gestation-specific birthweight centiles as a measure of intra-uterine growth.

### *Statistical analyses*

Statistical analyses were undertaken using Stata/MP version 14.1 (StataCorp, College Station, TX, USA).

Characteristics of asthmatic children were compared with peers using Chi-squared tests for categorical data and Chi-squared tests for trend for ordinal data. Special educational need, absences and exclusions, recorded annually, were analysed as yearly outcomes using population-averaged generalised estimating equations (GEEs) [27] adjusting for correlations between measurements on the same pupil across different census years. We used the user-written Stata QIC statistic to compare different correlation structures, selecting the structure with the lowest trace QIC as most appropriate [28]. Number of days absent and number of school exclusions were modelled using longitudinal GEE analyses with a negative binomial distribution and log link function to produce incidence rate ratios (IRRs). Number of possible annual attendances was used as an offset variable adjusting for individual exposure time. Special educational need was modelled using GEE analyses with a binomial distribution and logit link function to produce odds ratios. Logistic regression (ordinal and binary) modelled attainment and unemployment, respectively, while subsequent hospitalisation and mortality were modelled using Cox proportional hazards. These four longer-term end-outcomes were summarised and modelled on a pupil, rather than yearly, basis dependent on children having previously been prescribed asthma medication at any point within the study period. Therefore, with no repeated measures, longitudinal methods were not required. In the Cox models, children prescribed relevant asthma medication were followed from the date of their first asthma prescription during the study period. The pupil census is recorded each September, a few weeks after the start of the school year. Children who did not receive any asthma prescriptions during the study period were followed from the date of their first pupil census within the study period. This methodology has been described previously [26]. Proportionality was tested using the estat phtest command within Stata. Where the assumption did not hold, Poisson piecewise regression models were used.

All models were unadjusted and then adjusted for sociodemographic and maternity confounders exploring age, sex and deprivation as potential effect modifiers by testing for statistical interactions and undertaking subgroup analyses. We re-ran the academic attainment and unemployment models including absenteeism to explore whether it was a mediator. We then performed formal mediation analyses using the user-written Stata paramed command to decompose the total effect of asthma on attainment (recoded into a binary variable: low/basic *versus* broad/general/high attainment) and unemployment into a direct effect (not mediated through absenteeism) and an indirect effect (mediated through absenteeism) adjusted for sociodemographic and maternity factors. We also re-ran these models excluding children with special educational needs. To test the robustness of our asthma definition, children omitted because they had been dispensed one or more asthma medications but fell short of our definition were re-included in the asthma group. We re-analysed the main educational and health outcomes to observe whether original associations remained.

### *Approvals*

The study was approved by the NHS National Services Scotland Privacy Advisory Committee. A data processing agreement was drafted between Glasgow University (Glasgow, UK) and ISD, and a data sharing agreement was drafted between Glasgow University and ScotXed.

## Results

Records pertaining to 916 382 children attending Scottish schools between 2009 and 2013 were supplied by ScotXed, of which 2 793 185 pupil records pertaining to 766 244 singleton children were analysed having succesfully linked to health data and met the study inclusion criteria. Of these, 82 528 (10.8%) children received inhaled asthma medication but did not satisfy our definition for treatment of asthma and were excluded from the study (figure 1). Of the 683 716 children remaining, 45 900 (6.0%) were asthmatic according to our study definition. Asthmatic children were more likely to be male, Asian and live in deprived areas (table 1). They were of lower gestation, smaller for gestational age, more likely to have required operative deliveries and had lower 5-min Apgar scores. Their mothers were younger, more likely to have smoked during pregnancy and more likely to have been nulliparous.

### *School attendance*

Analyses of absence and exclusion included 1 415 923 pupil records for 624 573 children. Asthmatic children experienced more absenteeism (table 2). There were interactions with age ($p<0.001$) and deprivation ($p<0.001$). The relative association was stronger in younger age groups and among children in less deprived areas (table 2). Among nonasthmatic children, absenteeism was higher in the most deprived quintile than in the least deprived quintile (median 11 *versus* 5 days). Among asthmatic children, absences were still more common in the most deprived quintile (median 14 *versus* 7 days).

TABLE 1 Characteristics of schoolchildren by presence or not of treated asthma

| | No asthma | Asthma | p-value |
|---|---|---|---|
| **Subjects** | 637 816 | 45 900 | |
| **Sociodemographic factors** | | | |
| Sex | | | |
| Male | 318 360 (49.9) | 26 806 (58.4) | <0.001 |
| Female | 319 456 (50.1) | 19 094 (41.6) | |
| Missing | 0 | 0 | |
| Deprivation quintile | | | |
| 1 (most deprived) | 141 585 (22.2) | 12 357 (26.9) | <0.001 |
| 2 | 126 279 (19.8) | 9941 (21.7) | |
| 3 | 122 827 (19.3) | 8917 (19.4) | |
| 4 | 126 335 (19.8) | 7985 (17.4) | |
| 5 (least deprived) | 120 288 (18.9) | 6667 (14.5) | |
| Missing | 502 | 33 | |
| Ethnic group | | | |
| White | 606 601 (96.3) | 43 388 (95.5) | <0.001 |
| Asian | 14 222 (2.3) | 1364 (3.0) | |
| Black | 1634 (0.3) | 126 (0.3) | |
| Mixed | 5471 (0.9) | 439 (1.0) | |
| Other | 1732 (0.3) | 125 (0.3) | |
| Missing | 8156 | 458 | |
| **Maternity factors** | | | |
| Maternal age years | | | |
| ⩽24 | 171 602 (26.9) | 13 868 (30.2) | <0.001 |
| 25–29 | 187 171 (29.4) | 13 516 (29.5) | |
| 30–34 | 182 432 (28.6) | 12 209 (26.6) | |
| ⩾35 | 96 600 (15.2) | 6307 (13.7) | |
| Missing | 11 | 0 | |
| Maternal smoking | | | |
| No | 411 276 (72.8) | 28 269 (69.2) | <0.001 |
| Yes | 153 337 (27.2) | 12 595 (30.8) | |
| Missing | 73 203 | 5036 | |
| Parity | | | |
| 0 | 284 289 (44.8) | 21 760 (47.7) | <0.001 |
| 1 | 221 459 (34.9) | 15 205 (33.3) | |
| >1 | 128 980 (20.3) | 8673 (19.0) | |
| Missing | 3088 | 262 | |
| Mode of delivery | | | |
| Spontaneous vaginal delivery | 552 730 (67.8) | 29 750 (62.4) | <0.001 |
| Assisted vaginal | 75 713 (11.9) | 5587 (2.4) | |
| Breech vaginal | 1825 (0.3) | 154 (12.2) | |
| Elective Caesarean section | 48 267 (7.7) | 3700 (0.3) | |
| Emergency Caesarean section | 79 325 (12.4) | 6700 (8.1) | |
| Other | 141 (0.0) | 9 (0.0) | |
| Missing | 2 | 0 | |
| Gestation weeks | | | |
| <24 | 17 (0.0) | 3 (0.0) | <0.001 |
| 24–27 | 753 (0.1) | 178 (0.4) | |
| 28–32 | 5338 (0.8) | 719 (1.6) | |
| 33–36 | 28 351 (4.5) | 2836 (6.2) | |
| 37 | 30 587 (4.8) | 2613 (5.7) | |
| 38 | 79 248 (12.4) | 6058 (13.2) | |
| 39 | 132 322 (20.8) | 9448 (20.6) | |
| 40 | 193 364 (30.3) | 13 103 (28.6) | |
| 41 | 143 715 (22.6) | 9451 (20.6) | |
| 42 | 22 979 (3.6) | 1416 (3.1) | |
| 43 | 542 (0.1) | 32 (0.1) | |
| >43 | 120 (0.0) | 9 (0.0) | |
| Missing | 480 | 34 | |
| Sex-gestation-specific birthweight centile | | | |
| 1–3 | 25 763 (4.0) | 2153 (4.7) | <0.001 |
| 4–10 | 56 669 (8.9) | 4308 (9.4) | |

Continued

TABLE 1 Continued

| | No asthma | Asthma | p-value |
|---|---|---|---|
| 11–20 | 75 633 (11.9) | 5582 (12.2) | |
| 21–80 | 375 540 (59.0) | 26 539 (57.9) | |
| 81–90 | 54 540 (8.6) | 3758 (8.2) | |
| 91–97 | 34 407 (5.4) | 2490 (5.4) | |
| 98–100 | 14 266 (2.2) | 1000 (2.2) | |
| Missing | 810 | 70 | |
| 5-min Apgar score | | | |
| 1–3 | 3044 (0.5) | 264 (0.6) | <0.001 |
| 4–6 | 5864 (0.9) | 565 (1.2) | |
| 7–10 | 622 502 (98.6) | 44 568 (98.2) | |
| Missing | 6406 | 503 | |

Data are presented as n or n (%); percentages may not add up to 100 due to rounding.

Asthma was associated with increased school exclusion on univariate analysis (IRR 1.16, 95% CI 1.08–1.24) but decreased exclusion after adjusting for sociodemographic (IRR 0.90, 95% CI 0.84–0.96) and maternity (IRR 0.91, 95% CI 0.85–0.97) factors. There was an interaction with deprivation (p=0.012). The protective association between asthma and exclusion was greatest among children in the most deprived areas (fully adjusted IRR 0.88, 95% CI 0.79–0.97). Compared with children in the least deprived quintile, those in the most deprived quintile had more exclusions whether on asthma medication (7.6% *versus* 1.9%) or not (7.1% *versus* 1.3%).

### *Special educational need*

On analysing 2 472 798 school records for 683 716 children, asthmatic children had greater special educational need on univariate analysis (OR 1.47, 95% CI 1.43–1.50) and after adjustment for sociodemographic (OR 1.31, 95% CI 1.28–1.35) and maternity (OR 1.28, 95% CI 1.25–1.32) factors. There were interactions with sex (p<0.001) and age (p<0.001). The association was stronger in girls (OR 1.39, 95% CI 1.33–1.46) than boys (OR 1.24, 95% 1.20–1.28) and strongest among children aged >14 years (OR 1.40, 95% CI 1.35–1.46) (figure 2). Asthma was associated with all types of special educational need. Strongest associations were with physical (fully adjusted OR 2.76, 95% CI 2.57–2.95) and mental health (fully adjusted OR 1.76, 95% CI 1.49–2.08) conditions.

TABLE 2 Association between treatment for asthma and annual absenteeism by sex, age and area deprivation

| | Univariate IRR (95% CI) | Multivariate[#] IRR (95% CI) | Multivariate[¶] IRR (95% CI) |
|---|---|---|---|
| **Overall** | 1.30 (1.28–1.31) | 1.25 (1.24–1.26) | 1.25 (1.24–1.26) |
| **Sex** | | | |
| Boys | 1.28 (1.27–1.30) | 1.24 (1.23–1.26) | 1.25 (1.23–1.26) |
| Girls | 1.32 (1.30–1.35) | 1.26 (1.24–1.28) | 1.26 (1.24–1.28) |
| **Age** | | | |
| <11 years | 1.38 (1.36–1.40) | 1.32 (1.31–1.34) | 1.32 (1.30–1.33) |
| 11–14 years | 1.29 (1.26–1.31) | 1.24 (1.22–1.26) | 1.26 (1.24–1.28) |
| >14 years | 1.17 (1.15–1.19) | 1.14 (1.12–1.16) | 1.15 (1.13–1.17) |
| **Area deprivation** | | | |
| 1 (most deprived) | 1.19 (1.17–1.21) | 1.19 (1.17–1.21) | 1.21 (1.19–1.23) |
| 2 | 1.25 (1.23–1.28) | 1.26 (1.23–1.28) | 1.26 (1.23–1.28) |
| 3 | 1.26 (1.24–1.29) | 1.26 (1.23–1.29) | 1.25 (1.23–1.28) |
| 4 | 1.30 (1.27–1.33) | 1.29 (1.26–1.32) | 1.28 (1.25–1.31) |
| 5 (least deprived) | 1.32 (1.28–1.36) | 1.31 (1.27–1.35) | 1.29 (1.26–1.33) |

IRR: incidence rate ratio (the annual incidence in children treated for asthma divided by the annual incidence among children not treated for asthma). [#]: adjusted for age, sex, deprivation quintile and ethnic group (as appropriate); [¶]: also adjusted for maternal age, maternal smoking, parity, mode of delivery, gestation at delivery, sex-gestation-specific birthweight centile and 5-min Apgar score.

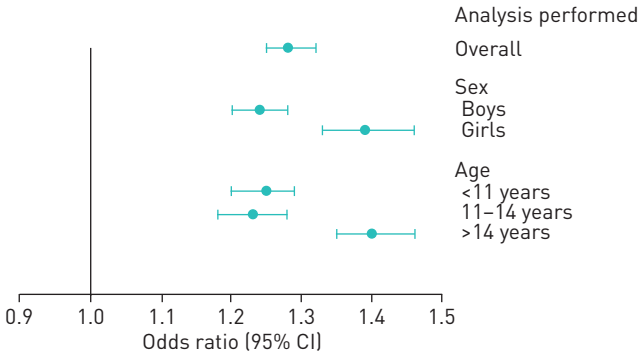


FIGURE 2 Forest plot of the association between treatment for asthma and special educational need by sex and age. Adjusted for age, sex, deprivation quintile, ethnic group, maternal age, maternal smoking, parity, mode of delivery, gestation at delivery, sex- gestation-specific birthweight centile and 5-min Apgar score.

### *Academic attainment and subsequent unemployment*

Of 125 211 children with attainment data, asthmatic children had poorer attainment on univariate analysis (OR 1.09, 95% CI 1.04–1.13) and after adjustment for sociodemographic (OR 1.10, 95% CI 1.05–1.16) and maternity (OR 1.11, 95% CI 1.06–1.16) factors. There were no interactions with age, sex or deprivation. On excluding children with special educational need, the association attenuated slightly (fully adjusted OR 1.08, 95% CI 1.03–1.14). The association disappeared after adjusting for absenteeism (OR 0.96, 95% CI 0.91–1.01). A formal mediation analysis on all pupils suggested that the effect of asthma on attainment (OR 1.14, 95% 1.05–1.22) was likely to be an indirect effect mediated by absenteeism (OR 1.15, 95% 1.13–1.18) rather than a direct effect (OR 0.98, 95% 0.92–1.05).

Of 197 430 children who left school during the study period, 3915 (32.7%) asthmatic children left school before 16 years of age compared with 52 654 (28.4%) of their peers. On univariate analysis, asthma was associated with increased unemployment overall (OR 1.11, 95% CI 1.05–1.18) and among girls (OR 1.18, 95% CI 1.07–1.29). These associations disappeared after adjusting for sociodemographic and maternity factors (OR 1.00, 95% CI 0.95–1.07). However, when children with special educational need were excluded from the analyses, the association in girls remained in the fully adjusted model (OR 1.14, 95% CI 1.03–1.27). Including absenteeism as a covariate made the association disappear (OR 1.07, 95% CI 0.96–1.19). A formal mediation analysis among girls with no recorded special educational need suggested that the effect of asthma on unemployment (OR 1.13, 95% CI 1.02–1.26) was likely to be an indirect effect mediated by absenteeism (OR 1.04, 95% CI 1.03–1.05) rather than a direct effect (OR 1.09, 95% CI 0.98–1.20).

### *Hospitalisation and mortality*

Linkage to hospital records provided 2.94 million person-years of follow-up. Mean follow-up time was 4.29 years. Of 683 716 pupils followed up, 135 482 experienced 260 705 hospital admissions. In Cox proportional hazards models, asthmatic children experienced increased risk of hospitalisation for any cause and for respiratory disease. However, the proportionality assumption was not met ($p<0.001$) for either model. Figure 3a shows fully adjusted IRRs for all-cause hospitalisation for each year of follow-up using a Poisson piecewise regression model. Asthmatic children were more likely to be hospitalised over all 5 years of the study. However, the IRR was greatest in the first year after treatment was recorded (IRR 1.98, 95% CI 1.93–2.04) and fell over time (figure 3a). There was an interaction with sex ($p<0.001$) whereby the association between asthma and admission for respiratory disease was stronger for boys than girls, especially over the first 2 years (figure 3b).

There were few deaths (n=437). However, asthmatic children were more likely to die over follow-up, on univariate analysis (HR 1.92, 95% CI 1.42–2.60), and following adjustment for sociodemographic (HR 1.83, 95% CI 1.35–2.48) and maternity (HR 1.77, 95% CI 1.30–2.40) factors. Percentage of deaths attributed to suicide (ICD-10 codes X60–X84 and Y87.0) was comparable among children with (10.6%) and without (10.8%) asthma.

### *Sensitivity analyses*

Re-including children previously omitted, because they were dispensed one or more asthma medications but did not meet our definition, and categorising them as asthmatic did not substantially alter the effect sizes of the respective associations with the main outcomes. After adjusting for sociodemographic and maternity factors, asthmatic children still experienced increased risk of absenteeism (IRR 1.20, 95% CI

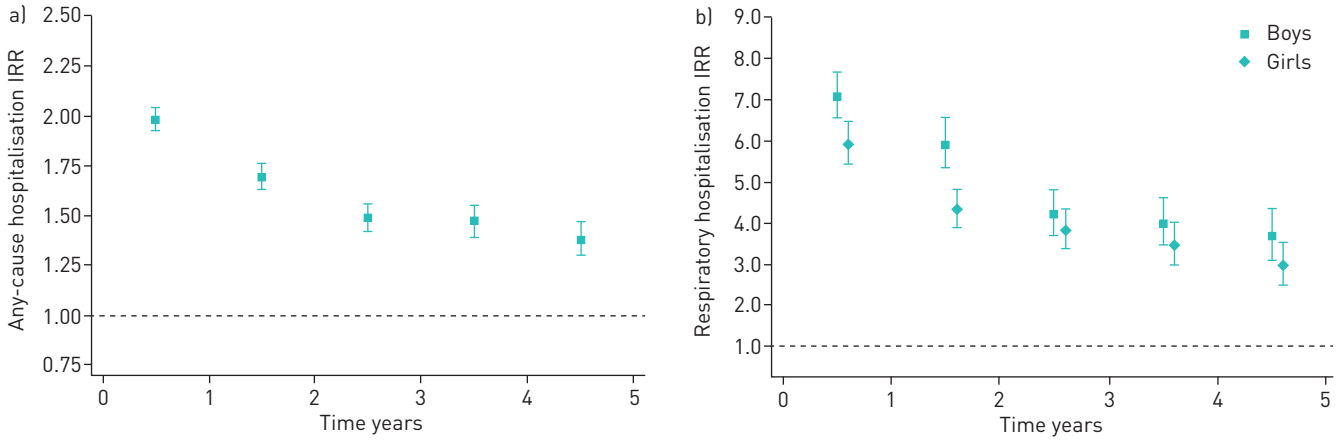


FIGURE 3 Poisson piecewise regression model of the risk of hospitalisation over 5 years follow-up from first record of treatment: a) any-cause hospitalisation and b) respiratory hospitalisation by sex. IRR: incidence rate ratio. Adjusted for age, sex, deprivation quintile, ethnic group, maternal age, maternal smoking, parity, mode of delivery, gestation at delivery, sex-gestation-specific birthweight centile and 5-min Apgar score.

1.19–1.21), special educational need (OR 1.19, 95% CI 1.17–1.21), hospitalisation (HR 1.47, 95% CI 1.45–1.48), mortality (HR 1.44, 95% CI 1.15–1.80) and poorer attainment (OR 1.07, 95% CI 1.04–1.10). There remained decreased risk of exclusion for asthmatic children compared with peers (fully adjusted IRR 0.94, 95% CI 0.90–0.98) and no association with unemployment (fully adjusted OR 0.97, 95% CI 0.94–1.02).

## Discussion

Asthmatic children experienced increased absenteeism and increased special educational need, for mental and physical health reasons. They left school earlier and achieved lower examination grades, even with no identified special educational need. Poorer exam grade attainment was attributable to higher school absence. However, reassuringly, poorer grades did not translate into subsequent higher unemployment, after adjusting for sociodemographic and maternity factors. Developing interventions to improve attendance or mitigate the impact of missed school days could improve grades of asthmatic children. Teachers were less likely to exclude asthmatic children compared with peers. Asthmatic children experienced increased risk of hospitalisation and mortality, particularly within 1 year of first recorded use of asthma medication. Associations with special educational need and unemployment were greater in girls, despite boys being more likely to be hospitalised for respiratory problems.

Previous studies investigating health outcomes of asthmatic children have used hospitalised cohorts or no comparison group. Ours was a large, nonselective study including children across the whole of Scotland. Because the sampling frame was mainstream and special schools, rather than hospital clinics, inclusion was not restricted to the most severe asthma cases and we adjusted for sociodemographic and maternity factors. The large cohort provided sufficient power to test for statistical interactions and undertake subgroup analyses, and we analysed a range of educational and health outcomes within the same study. Our proxy for asthma using prescriptions has previously been used and validated, showing a high positive predictive value of 0.75–0.9 in children aged 4.5–17 years [29, 30]. We previously validated this definition [31] consistent with the Scottish Intercollegiate Guideline Network/British Thoracic Society guidelines [32] recommending that all children diagnosed with asthma be prescribed a short-acting β-agonist alongside their inhaled corticosteroid or leukotriene antagonist.

Our study included children attending local authority maintained schools; however, in Scotland, <5% of children attend private schools. According to the 2011 Scottish Census, 11% of Scottish residents aged 5–19 years were born outside of Scotland, consistent with 12.3% of Scottish children we could not link to Scottish maternity records. Prevalence of asthma medication was lower (4.24%) in pupils who did not link *versus* those who did (5.99%). We used existing, administrative databases established for other purposes. However, they undergo regular quality assurance checks. Linkage of education and health records utilised probabilistic matching, validated to be 99% accurate for singletons [25].

Ours is the largest study, to date, to evaluate educational outcomes of asthmatic children and, to the best of our knowledge, the first countrywide study to investigate outcomes of asthmatic children covering both education and health. Previous studies reported that asthmatic children have more absences from school [19]; however, few have examined special education need and consensus is lacking on possible lower academic achievement [19]. One study of 9014 schoolchildren reported moderately increased absenteeism but no deficit in standardised test scores [18], while a larger study reported increased absenteeism and lower grades

[20]. Fowler *et al.* [21] demonstrated increased absenteeism, learning disability and use of educational services, but comparable rates of grade failure in asthmatic children compared with peers. Kohen [6] found that, compared with children with no chronic conditions, asthmatic children had more absences, increased use of education services, poorer standardised test scores and poorer maternal ratings of school performance. Increased distress and anxiety [22], and poorer wellbeing, decreased happiness and increased mental health issues [23], have been observed in asthmatic children. Kuo *et al.* [33] reported no increase in all-cause mortality but higher risk of suicide. In our study, 1.91% of asthmatic girls were also prescribed antidepressants compared with 0.84% of girls without asthma. However, there was no evidence of increased suicide among asthmatic children.

### *Conclusions*

Asthmatic children have worse educational and health outcomes than their peers. In addition to poorer health outcomes, adverse effects on educational performance should be recognised and addressed. Increased absenteeism appears to mediate some of these educational outcomes. Educational interventions that mitigate the adverse effects of absenteeism, especially in girls, should be considered.

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