

Monitoring epidemiological trends in back to school asthma among preschool and school-aged children using real-time syndromic surveillance in England, 2012–2016

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ABSTRACT

Background Back to school (BTS) asthma has been previously reported in children; however, its epidemiology and associated healthcare burden are unclear. We aimed to describe the timing and magnitude of BTS asthma using surveillance data from different health services in England.

Methods Asthma morbidity data from emergency department attendances and general practitioner (GP) consultations between April 2012 and December 2016 were used from national syndromic surveillance systems in England. Age-specific and sex-specific rates and time series of asthma peaks relative to school term dates were described. The timing of a BTS excess period and adjusted rates of asthma relative to a baseline period were estimated using cumulative sum control chart plots and negative binomial regression.

Results BTS asthma among children aged below 15 years was most pronounced at the start of the school year in September. This effect was not present among those aged 15 years and above. After controlling for sex and study year, the adjusted daily rate of childhood GP in-hours asthma consultations was 2.5–3 times higher in the BTS excess period, with a significantly higher effect among children aged 0–4 years. A distinct age-specific pattern of sex differences in asthma presentations was present, with a higher burden among males in children and among females aged over 15 years.

Conclusion We found evidence of a BTS asthma peak in children using surveillance data across a range of healthcare systems, supporting the need for further preventative work to reduce the impact of BTS asthma in children.

BACKGROUND

Asthma is a long-term condition that is typically characterised by chronic airway inflammation presenting with a range of respiratory symptoms including shortness of breath, wheeze, cough and tightness of the chest.¹ A peak in childhood asthma exacerbations that coincides with the start of the school year in September, known as ‘back to school’ (BTS) asthma, accounts for 20%–25% of all exacerbations requiring hospitalisation in many Northern Hemisphere countries² and a similar peak has been described in Australia in February following the long summer break.³ In Canada, the peak in school

age children has been shown to occur on average 2–3 weeks after the start of the autumn school term,^{2,4} and peaks in hospital admissions for asthma in Scotland have been observed 2 weeks earlier than in England, in line with the earlier start of the Scottish autumn term;⁵ evidence to suggest that the return to school itself may be significant. The detection of lesser peaks in preschool children and adults a few days after school-aged children fits with a hypothesis of possible within-family transmission of a communicable causative agent.^{2,4} Infection by respiratory viruses, in particular human rhinovirus, is thought to be the most important risk factor⁶ but does not fully explain the phenomenon.^{3,7} Seasonal variation in meteorological and other environmental factors known to be associated with asthma exceedances may also play a role.^{8–12}

Asthma prevalence, related mortality and healthcare utilisation in the UK are estimated to be among the highest in the world;¹³ however, to date there has been little description of the extent to which BTS asthma affects different parts of the English National Health Service (NHS). With the exception of a study in 2000 based on sentinel general practitioner (GP) data,¹⁴ BTS asthma has been largely investigated through hospital admission data, which are likely to represent the most severe cases only.^{5,15}

In this current study, we aimed to build a more complete picture of the epidemiology of BTS asthma in England by describing its timing and magnitude by age and gender across three different sources of syndromic surveillance data from primary and secondary healthcare presentations for acutely presenting asthma in the community.

METHODS

Data collection and management

Healthcare presentations

This study used data collected through the Public Health England national syndromic surveillance service,^{16,17} including consultation data from GP in-hours (GPIH) and out of hours (GPOOH) systems and emergency department (ED) attendances (EDSSS). Over the study period, the GPIH system covered approximately 50% of the English population, estimated through the registered patient denominator. The GPOOH system achieved approximately 60% national coverage estimated through the population coverage of out of hours

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service providers contributing to the GPOOH system. EDSSS is a sentinel surveillance system from which data were used from a subset of nine EDs who had reported consistently across the study period and was therefore not representative nationally. Indicator definitions varied between system: GPIH included diagnoses of acutely presenting asthma including asthma attack, excluding those consultations suggestive of routine asthma management consultations or prescription links; EDSSS included diagnoses that specified asthma and GPOOH included diagnoses that described acute asthmatic episodes (online Supplementary table).

School term dates

The English school year starts in September after the summer holiday, and for the vast majority of schools the year is divided into three terms and six half-terms, each with a holiday of at least a week between them. Half-terms 1, 3 and 5 corresponded to the return to school after the longer summer, Christmas and Easter holidays, respectively. We estimated the start and end date in England for each half-term in the study period as the median of the term dates identified from Local Educational Authorities (LEA) randomly sampled from each of the nine English Regions.

Statistical analysis

Overall differences in asthma presentations by age and sex

For each dataset, the age-specific and sex-specific counts and denominators across the study period were summed and crude rates of a presenting asthma episode calculated to facilitate a comparison of stratum-specific activity.

Trends in asthma relative to the school year

Age-specific and sex-specific time series of counts or rates were plotted using 7-day moving averages to smooth out short-term fluctuations. We used different scales for each age-group to best illustrate the timing and relative magnitude of peaks in relation to school term dates and described similarities and differences by age group, sex and year, both within and between datasets.

Timing and magnitude of the September back to school period

Analysis of the September BTS period was restricted to those age groups in which a BTS effect was most apparent in the time series plots, namely children aged 0–4 and 5–14 years. The period of interest spanned the last 4 weeks of the summer holiday, chosen to represent a baseline period of low activity, and the entire first half-term (duration range: 6.6–7.4 weeks) of the school year. To estimate the date at which the period of September excess activity ('BTS excess period') started we applied a logarithmic (GPIH 5–14 years, GPOOH 5–14 years and GPOOH 0–4 years) or square root (GPIH 0–4 years) transformation to the age-specific counts of asthma in each system so that they approximated a normal distribution. As this was not possible for EDSSS due to data sparsity, it was excluded from subsequent analysis. For each age group within GPOOH and GPIH, we calculated the sex-specific and year-specific mean and standard deviation (SD) of the transformed counts during the last 4 weeks of the summer holiday. These were used as inputs into cumulative sum control charts (CUSUM) using the 'QCC' package in R¹⁸ to plot the CUSUM of the deviation over time of the transformed counts away from the mean baseline value. CUSUM plots allow small consistent changes away from the mean to be detected.¹⁹ We were interested in identifying the date at which the CUSUM exceeded, and then continued to consistently deviate away from, an upper expected limit of two SD above the baseline mean.

This date was taken as the start of the BTS excess period and we assumed that this period continued until the last day of the first half-term. This was a pragmatic assumption, driven by a desire to keep school and holiday times separate and confirmed to be reasonable on inspection of the trends in the time series plots. The average age and sex-specific delay in days between the start of the school year and the BTS excess period was expressed using the median and range of this value from all years in the study period.

To quantify the magnitude of the BTS effect, we estimated adjusted rate ratios (aRR) for the daily rate of asthma for all years in the study, using negative binomial regression to model the variation in counts in the BTS excess period relative to the preceding non-excess baseline period, controlling for year, sex, and including an offset to account for variation in the denominator. Since asthma presentations on holidays (weekends and public holidays) were included in the GPOOH dataset, differences between periods in the number of holidays falling within them were a potential source of bias. To account for this, the proportion of working days in a period was included as an additional offset.

All sampling, data cleaning, visualisation and analysis were carried out in R V3.2.2.²⁰

RESULTS

Overall differences in asthma presentations by age and sex

Each system showed a similar age-sex distribution in the asthma burden, with rates of a presenting asthma episode that were between 1.6 and 2.4 times higher in males than females among the 0–4 and 5–14 years age groups. Among those aged 15 years and over, this pattern was reversed, with rates among females between 1.2 and 2.0 times higher than among males. The highest rate in each system was found in males aged 5–14 years (table 1).

Table 1 Rates of asthma presentation by sex and age group for general practitioner consultations (in hours and out of hours) and emergency department attendances, England, 2012–2016

System	Age group (years)	Sex	Count	Denominator*	Rate†
GPIH	0–4	Male	13 608	934 012 067	1.5
		Female	6745	912 975 053	0.7
	5–14	Male	63 633	1 778 290 845	3.6
		Female	26 272	1 741 689 822	1.5
	15+	Male	161 739	12 625 605 519	1.3
		Female	343 303	13 243 855 724	2.6
EDSSS	0–4	Male	2153	170 405	12.6
		Female	1062	132 570	8.0
	5–14	Male	2627	162 739	16.1
		Female	1500	130 579	11.5
	15+	Male	5936	1 366 846	4.3
		Female	10 256	1 376 582	7.5
GPOOH	0–4	Male	13 509	3 452 267	3.9
		Female	7156	2 998 175	2.4
	5–14	Male	20 445	1 679 463	12.2
		Female	12 589	1 664 809	7.6
	15+	Male	46 614	14 827 458	3.1
		Female	80 165	21 925 096	3.7

*Denominators: sum of registered population for all days in study period (GPIH), sum of coded attendances for any reason (EDSSS, GPOOH).

†Rates: per 100 000 registered population (GPIH) or 1000 attendances (EDSSS, GPOOH).

EDSSS, Emergency Department Syndromic Surveillance System; GPIH, general practitioner in hours; GPOOH, general practitioner out of hours.

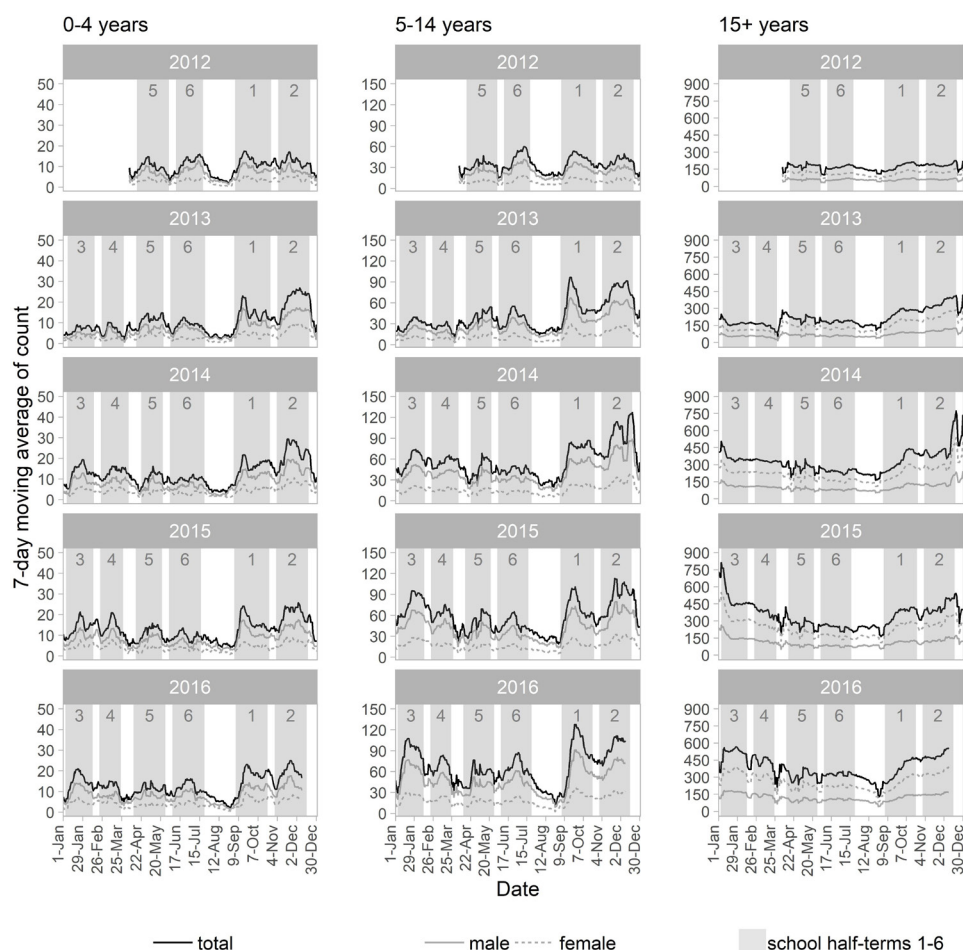


Figure 1 Count of general practitioner in-hours asthma consultations by sex and age group, England, 2012–2016.

Trends in asthma relative to the school year

For GPIH, there was evidence of a general BTS effect among children aged 0–4 and 5–14 years, characterised by falling rates during school holidays followed by an increase in the first 2–3 weeks of each half-term. This was not present among those aged 15 years and over (figure 1). Relative to the preceding summer holiday in July and August, the BTS effect tended to be most prominent at the start of the school year in September. A notable BTS effect was also present at the start of half-term 2. Timing of the peaks between the two younger age groups was very similar. A seasonal pattern of increased burden during November and December was present across all age groups.

EDSSS asthma attendances by children aged 0–4 and 5–14 years showed a reasonably clear BTS effect at the start of the school year (figure 2). BTS peaks were also present at the start of half-terms 2, 3, 5 or 6 in different years but with no consistency between the two age groups. There was considerable variation in attendances for asthma among those aged 15 years and over that did not appear to be closely correlated with school term dates. In contrast with GPIH and GPOOH, an increased burden in November and December was present only among the 15 years and over age group (figure 2).

GPOOH was similar to that of GPIH in terms of there being no clear temporal relationship between asthma presentations and school terms among the 15 years and over age group, as well as falling counts during school holidays and term time peaks among each of the 0–4 and 5–14 years age groups (figure 3). These groups showed considerable agreement in terms of overall

trends each year and their BTS effect was most pronounced and sudden at the start of the school year.

In all three systems, most of the peaks among children aged 0–4 and 5–14 years were driven by boys. Peaks in girls generally occurred at the same time but were of much smaller absolute magnitude.

Timing and magnitude of the September back to school period

The median delay between the start of the school year and the start of the September BTS excess period across all years in the study was shorter among males than females in both age groups in GPOOH, but varied little by age or sex in GPIH. There was considerable interyear variation, with the BTS excess period starting as late as 17 days after the start of the school year (0–4 years females in 2015, GPOOH) and as early as 7 days before (0–4 years males in 2016, GPOOH). All four instances of the excess period starting during the summer holiday were among children aged 0–4 years. After controlling for differences between sex and years in the study, the adjusted daily rate of GPIH asthma presentations was over three times higher in the BTS excess period compared with the non-excess baseline period among children aged 0–4 years (aRR 3.15, 95% CI 2.87–3.46) and two and a half times higher in the 5–14 years age group (aRR 2.58, 95% CI 2.43 to 2.75). In GPOOH, having controlled for differences between sex, years and the proportion of working days in each period, the adjusted daily rate of GPOOH asthma

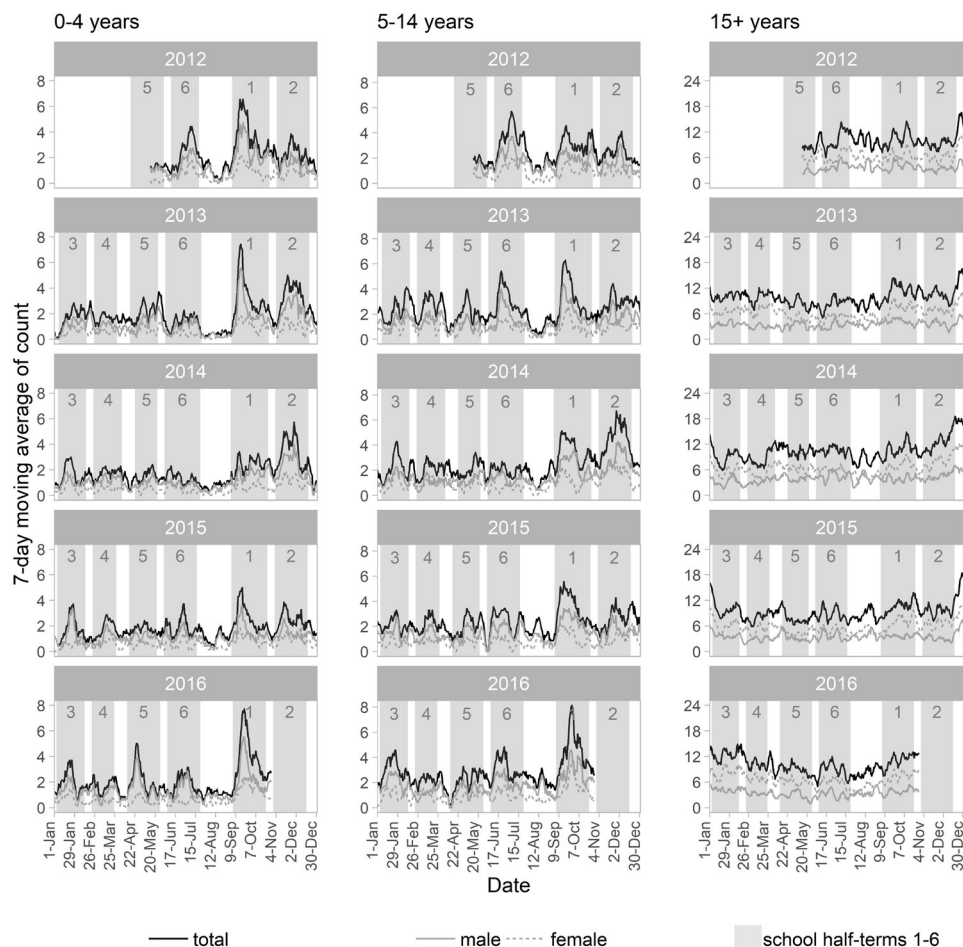


Figure 2 Count of emergency department asthma attendances by sex and age group, England, 2012–2016.

presentations was almost twice as high in the excess period than in the baseline period (0–4 years, aRR 1.74, 95% CI 1.60 to 1.90 and 5–14 years aRR 1.99, 95% CI 1.85 to 2.13; [table 2](#)).

DISCUSSION

Statement of principle findings

This study aimed to describe BTS asthma in England by using three sources of national syndromic surveillance data monitoring acutely presenting asthma. A general BTS asthma effect was observed in time series among children aged 0–4 and 5–14 years, which was most pronounced at the start of the school year in September. This general effect did not appear to be present among those aged 15 years and over. After controlling for differences between sex and years, the adjusted daily rate of childhood GPIH asthma consultations was 2.5–3 times higher in the BTS excess period than in the non-excess baseline period, with a significantly higher effect among children aged 0–4 years than those aged 5–14 years. A significant effect of smaller magnitude was observed for GPOOH for both 0–4 and 5–14 years age groups. Across all years in the study, the age-specific and sex-specific median delay between the start of the school year and BTS excess period ranged from 5 to 11 days. In some years, among children aged 0–4 years the BTS excess period began before the start of the school year.

Comparison with other studies

This is the first study to our knowledge that has used national syndromic surveillance data from a range of different health

systems to investigate this phenomenon and thus adds to the knowledge base. A distinct age-specific pattern of sex differences in overall asthma presentations was present, with a higher burden among males aged less than 15 years and among females aged 15 years and over. Although this finding contradicts the overall pattern of more females consulting GP services in England,²¹ it is consistent with existing literature regarding a young male consulting bias in respiratory and atopic conditions.²²

This study has not attempted to determine the underlying aetiology of BTS asthma peaks; however, some interesting observations emerge. The significant excess observed in children aged 0–4 years, below the age of compulsory schooling, and the start of the BTS excess period in this group, preceding the start of the school year in some study years, adds to the evidence that there are multiple factors contributing to the BTS asthma burden. The age-related pattern of BTS asthma peaks may somewhat challenge previous hypotheses of ‘within family’ transmission of infectious agents driving asthma exacerbations.^{15 23–26} However, the timing of the BTS asthma peak is concurrent with the starting of seasonal increases in a number of respiratory pathogens in the UK, including rhinovirus, a pathogen closely associated with asthma exacerbations in children.^{27 28} The underlying aetiology of BTS asthma is complex and in addition to the established contribution of respiratory infections, environmental determinants may be involved: the role of fungal spores (which show autumnal seasonality) could be an area for future research to investigate aetiology and thus determine potential future interventions.^{9 29} Additionally, the contribution of air pollution and

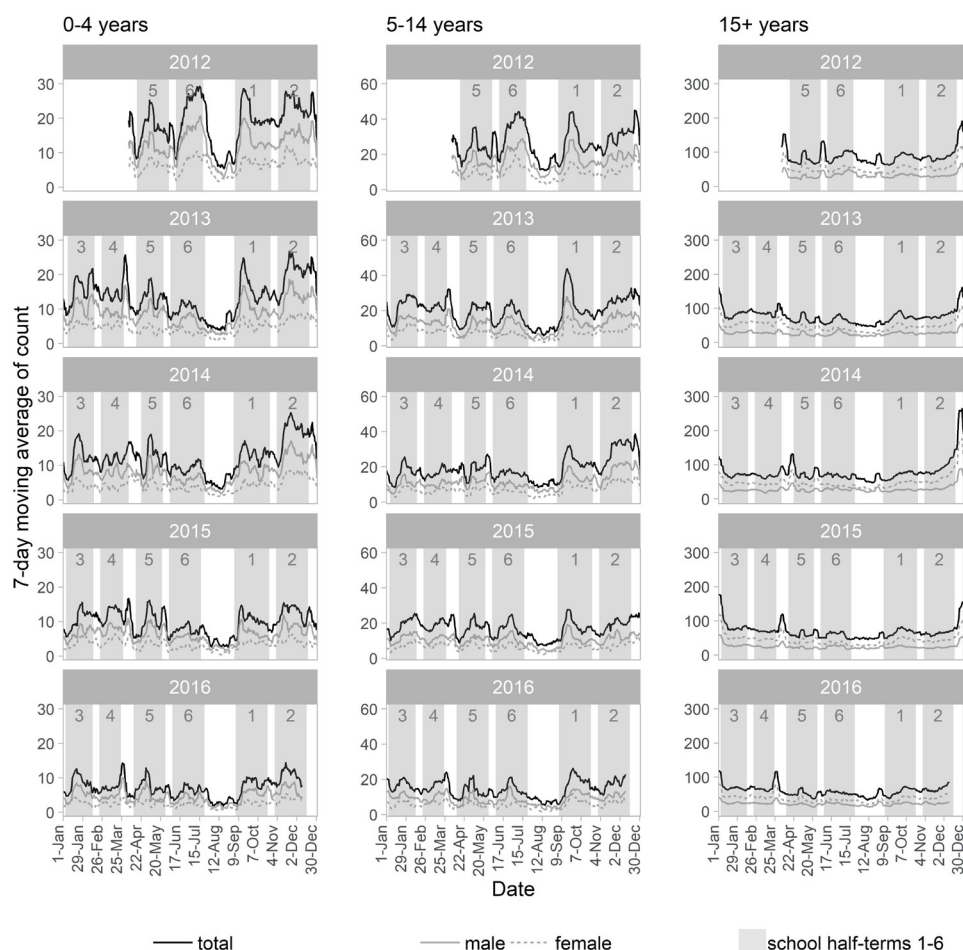


Figure 3 Count of general practitioner out of hours asthma consultations by sex and age group, England 2012–2016.

any associated exposure during school term time requires further research.^{11 30} Finally, an association between stress and asthma in children has been previously described and thus the return to school (which could be perceived as a stressful event for some children) could merit further investigation.^{31 32}

Strengths and limitations of study

A major strength of this study is the use of large population-level datasets of asthma activity covering GP consultations and ED attendances. Although this study has not used asthma hospital admissions, as used by a number of previous studies,^{5 14 15} admissions are a small proportion of the overall asthma healthcare events and therefore underestimate activity. The use of large population-level datasets also offset intrinsic issues with data quality that are often associated with syndromic surveillance:

missing variables, including age and sex, are often insignificant (approximately 0.02% of counts in this study) when the analysis involves such large numbers. Syndromic surveillance datasets are limited in the quality and validity of coded data: these data are taken as daily ‘snapshots’ of clinical activity for multipurpose syndromic surveillance, recording those diagnoses assessed by a healthcare professional as suggesting an acute presentation of asthma. Syndromic ‘asthma indicators’ are based on groups of clinical codes used by clinicians, which may vary according to the clinician and the clinical coding systems used. Furthermore, the varying population coverage of each national syndromic surveillance system must be considered when interpreting results.

Another potential limitation of this work is the reliability of asthma diagnoses in young children. Clinical guidelines recommend against making a formal diagnosis of asthma in children

Table 2 Timing and magnitude of excess September back to school asthma among school-aged children as monitored by general practitioner in hours and out of hours consultations, 2012–2016

System	Age group	Median (range) days from start of half-term 1 to excess period		Adjusted rate ratio* (95% CI)
		Male	Female	
GPIH	0–4 years	6 (–5 to 7)	6 (–1 to 8)	3.15 (2.87 to 3.46)
	5–14 years	6 (4 to 8)	8 (4 to 13)	2.58 (2.43 to 2.75)
GPOOH	0–4 years	5 (–7 to 9)	11 (6 to 17)	1.74 (1.60 to 1.90)
	5–14 years	8 (7 to 9)	11 (6 to 15)	1.99 (1.85 to 2.13)

*Adjusted rate ratio: the ratio of the adjusted daily rate of asthma presentation in the back to school excess period compared with the non-excess baseline period.
GPIH, general practitioner in hours; GPOOH, general practitioner out of hours.

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aged less than 5 years old due to the range of other factors that can cause the presentation of asthma-type symptoms.³³ This introduces a challenge in interpreting the results for children aged 0–4 years, although there was strong agreement between the findings for this age group and those of school-aged children (5–14 years) for whom this limitation was of less relevance. The age bands used in this study were determined by the standard reporting of age groups in the surveillance systems. This meant that it was not possible to investigate age effects beyond the age categories used; however, the 0–4 and 5–14 years age groups had real-world relevance as proxies for ‘preschool’ and ‘school-aged’ children. Finally, there were also limitations with deriving accurate estimates of historic school term dates with geographical representation. However, the use of multiple indicators fielding broadly consistent results across a number of national syndromic surveillance systems gives us confidence that the findings have national generalisability.

Conclusions and policy implications

A recent Cochrane review of a limited number of interventions for autumn exacerbations in children found no evidence that the use of a seasonal medication reminder letters reduced the number of autumn peak asthma exacerbations, and one study that showed seasonal omalizumab injections to be effective in reducing severe exacerbations.³⁴ The review further highlighted the need for a better understanding of BTS asthma in children to inform the planning and control of seasonal attacks. Our current study has contributed to this knowledge gap, quantifying the September BTS asthma peak in children aged 0–4 and 5–14 years using routinely available syndromic surveillance data accessed across a range of healthcare systems, thereby supporting existing public health messaging about the management of asthma in children at this time of year.^{35 36}

What is already known on this subject

- Asthma plays a significant role in the national health burden with particular impact in children. Previous studies have demonstrated a peak in asthma activity in school-aged children at the start of the September school term, but the magnitude and age-distribution of this effect have not been well described.

What this study adds

- This study describes a back to school (BTS) excess in asthma across multiple health systems, and in particular shows that general practitioner asthma consultations were 2.5–3 times higher in the BTS excess period, with a significantly higher effect among children aged 0–4 years than those aged 5–14 years. These results support the need for further preventative work to reduce the impact of BTS asthma in children.

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Contributors GS, OE and AJE conceived the study. NB, OE, GS and AJE developed the study protocol and NB undertook all data analysis and prepared the first draft of

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