

BMJ Open Determinants of inter-practice variation in childhood asthma and respiratory infections: cross-sectional study of a national sentinel network

Uy Hoang,¹ Harshana Liyanage,¹ Rachel Coyle,¹ Charles Godden,² Simon Jones,^{1,3} Mitch Blair,⁴ Michael Rigby,⁵ Simon de Lusignan^{1,6}

To cite: Hoang U, Liyanage H, Coyle R, *et al*. Determinants of inter-practice variation in childhood asthma and respiratory infections: cross-sectional study of a national sentinel network. *BMJ Open* 2019;**9**:e024372. doi:10.1136/bmjopen-2018-024372

► Prepublication history for this paper is available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2018-024372>).

Received 29 May 2018
Revised 24 September 2018
Accepted 5 December 2018



© Author(s) (or their employer(s)) 2019. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

For numbered affiliations see end of article.

Correspondence to

Dr Uy Hoang;
u.hoang@surrey.ac.uk

ABSTRACT

Objectives Respiratory infections are associated with acute exacerbations of asthma and accompanying morbidity and mortality. In this study we explore inter-practice variations in respiratory infections in children with asthma and study the effect of practice-level factors on these variations.

Design Cross-sectional study.

Setting We analysed data from 164 general practices in the Royal College of General Practitioners Research and Surveillance Centres sentinel network in England.

Participants Children 5–12 years.

Interventions None. In this observational study, we used regression analysis to explore the impact of practice-level determinants on the number of respiratory infections in children with asthma.

Primary and secondary outcome measures We describe the distribution of childhood asthma and the determinants of upper/lower respiratory tract infections in these children.

Results 83.5% (137/164) practices were in urban locations; the mean number of general practitioners per practice was 7; and the mean duration since qualification 19.7 years. We found almost 10-fold difference in the rate of asthma (1.5–11.8 per 100 children) and 50-fold variation in respiratory infection rates between practices. Larger practices with larger lists of asthmatic children had greater rates of respiratory infections among these children.

Conclusion We showed that structural/environmental variables are consistent predictors of a range of respiratory infections among children with asthma. However, contradictory results between measures of practice clinical care show that a purely structural explanation for variability in respiratory infections is limited. Further research is needed to understand how the practice factors influence individual risk behaviours relevant to respiratory infections.

INTRODUCTION AND AIMS

Asthma is the most common long-term condition in children and young people in the UK. The British Lung Foundation estimates that there are 1.1 million children in

Strengths and limitations of this study

- This study used a large, nationally representative data set which allowed us to explore inter-practice variations in diagnosis of asthma among children and examine the determinants of a wide range of respiratory tract infections in these children than has previously been published.
- However, our first limitation is that we used routinely collected data from general practice which was not collected for clinical or epidemiological research.
- Second, our enumeration of practice structural variables relied on publicly available data about practices from their own websites, NHS Choices and the medical register held by the General Medical Council.
- Third, our study also lacked information on other structural and individual variables which may be important in the onset of respiratory infections in children with asthma, including exposure to smoking and pollution which may influence the risk of some respiratory infections in children.
- Finally, inference about the individual risk of respiratory infection in children with asthma is not straightforward from the results of our study, thus it is difficult to deduce changes to individual behaviours that may affect infection risk or make conclusions about changes in clinical practice for individual children.

the UK affected by the condition,¹ although recent evidence suggests that the prevalence of asthma is declining in certain Western countries.²

The condition is characterised by reversible airflow limitation experienced as coughing, wheezing, chest tightness and breathlessness, with symptoms often worse in the early morning and at night.³

Infections of the airways in children and adults with asthma may be associated with acute disease exacerbations and the development of chronic disease.⁴ In the UK, asthma

is among the most common reason for urgent admissions to hospital in young people with many admissions resulting from respiratory infections.⁵ Acute exacerbations of asthma are associated with decreased lung growth or accelerated loss of lung function,⁶ thus prevention and rapid treatment of respiratory infections in this group is crucial to acute and long-term management.

Paediatric asthma in the UK is predominantly managed by general practitioners (GPs) in primary care.⁷ Information collected for the National Health Service (NHS) showed widespread geographical variations, including variations at the practice level in the quality of care and outcomes experienced by people with respiratory disease including asthma in England.^{8–11} However, there is little information about how these geographical variations, especially variations at the practice level, affect the occurrence of respiratory infections in children with asthma.

In this study, we describe variations in respiratory infections among children with asthma registered with general practices who are members of the Royal College of General Practitioners Research and Surveillance Centre (RCGP RSC) network,¹² the English national sentinel system, and study the effect of practice-level factors on these variations.

METHODS

Subjects and setting

We used information from the RCGP RSC. It hosts data as a pseudonymised data set from a nationally representative sample of just under 2 million people registered with 164 of the network practices in the UK.¹² It has been involved in surveillance of influenza and respiratory disease for >50 years. Over this period practices have had feedback about their data quality around influenza and respiratory disease. In particular, the differentiation of first or new (incident) from follow-up consultations. Data quality is good for routine primary care.¹³

UK general practice is suitable for this type of study because it has a registration-based system with patients registered with a single practice. Practices have been computerised since the late 1990s, with pay-for-performance introduced in 2004 for chronic disease management including asthma.¹⁴ Key data are coded,¹⁵ which includes diagnoses, therapy, test results and other data.

Asthma was defined using an ontological approach.^{16 17} We combined clinician-assigned diagnostic codes relating to five supporting concepts: (1) diagnostic codes (including those referred to in Quality Outcomes Framework code lists); (2) symptoms of asthma (including wheeze, cough, shortness of breath and chest tightness); (3) diagnostic tests (including peak expiratory flow rates and spirometry); (4) therapies codes (including short-acting beta 2 agonists, inhaled corticosteroids, long-acting beta 2 agonists, leukotriene antagonists and oral steroids); and (5) Process of Care codes (codes for attending an

asthma clinic or an asthma medication review that imply a diagnosis of asthma).^{18 19}

The diagnosis of asthma in very young children under 5 years of age can be difficult.²⁰ Disease remission from adolescence also occurs in a significant proportion of children with asthma,²¹ thus we restricted our analysis to children with asthma aged between 5 and 12 years of age on 31st December 2016.

Respiratory infection outcomes

We conducted a cross-sectional study examining the distribution of both lower and upper respiratory tract infections in children with asthma between 1 January and 31 December 2016.

We extracted information on lower respiratory tract infections (LRTI) including acute bronchitis and bronchiolitis, pneumonia and pneumonitis, pleurisy and other LRTIs. Influenza-like-illness (ILI), which affects both upper and lower respiratory tracts, was grouped with LRTI. We extracted information on upper respiratory tract infections (URTIs) including common cold, streptococcal sore throat, scarlatina and other URTI.

General practice-level characteristics

We collected the following information about the primary care practices within the RCGP RSC sentinel practice network from the individual practice websites, the NHS Choices website²² and the General Medical Council (GMC) register²³ between 1 August and 31 August 2017 including the total number of GPs in the practice, the gender of the GPs in the practice, the average number of years since their medical and specialist general practice qualifications, the average number of qualifications of GPs in the practice and whether the practice was in an urban or rural location.

We collected information about childhood immunisation rates for each practice from the RCGP RSC in 2016, including (1) diphtheria; tetanus; whooping cough (pertussis); polio; *Haemophilus influenzae* type b (DTaP/IPV/HiB) vaccination rates for children under 12 months; (2) pneumococcal conjugate vaccination (PCV) rates for children under 12 months and (3) live-attenuated influenza vaccination rates for children between 2 and 17 years of age.

We collected information about respiratory care for each practice from the National General Practice Profiles published by Public Health England, including the total achievement score in the respiratory disease domain of the chronic disease pay-for-performance scheme (P4P)—the Quality and Outcomes Framework (QOF). Between 2015 and 2016 this included recording the percentage of practice patients aged 8 and over with asthma who have had an asthma review within the past 12 months including an assessment of their asthma control using the Royal College of Physicians three questions survey²⁴ and those over the age of 14 years with asthma who have had a record of their smoking status in the last 12 months.

General practice-level characteristics of children with asthma

The following information on the population of children with asthma within each general practice was collected including asthma prevalence, average age of children with asthma, percentage of female and percentage of non-white ethnicity.

The severity of the disease in the practice population of children with asthma was recorded from the proportion prescribed 6 or greater number of inhaled bronchodilators (relievers) in the past year and the proportion prescribed 12 or greater number of inhaled preventers in the past year.²⁵

Statistical analysis

Given the skewed distribution of respiratory infection rates in asthmatic children, we examined the effect of practice-level factors on the count of respiratory infections in children with asthma. Poisson, negative binomial and zero-inflated Poisson regression models of childhood respiratory infection counts in asthmatic children were examined.²⁶ Model goodness of fit was compared using the log likelihood ratio test.²⁷ All statistical analyses were undertaken using R.²⁸

RESULTS

Characteristics of practices within the RCGP RSC network

Information from 164 general practices in the RCGP RSC national sentinel practice network was included in the study. 83.5% (137/164) practices were located in an urban location. The mean number of GPs per practice was 7 (median=7), and the average number of years since GPs had qualified from medical school was 19.7 years (median=19). Each GP within the practice had on average more than two specialist qualifications in addition to their medical qualifications.

The GP practices within the network achieved on average 97.7% (95% CI 97.0 to 98.3) of the total P4P/QOF scores overall and 99.2% (95% CI 98.7 to 99.7) of the total P4P/QOF scores available for care of respiratory patients. This compares with an average total P4P/QOF score of 95.5% (95% CI 95.3 to 95.6) and average P4P/QOF scores for care of respiratory patients of 97.4% (95% CI 97.2 to 97.6) for all practices in England.

Asthmatic children within the RCGP RSC

In total, 6161 patients with asthma aged 5–12 years were included in the study. The rate of childhood asthma among practices within the network varied almost 10-fold between 1.5 per 100 children and 11.8 per 100 children with a mean of 4.1 per 100 children registered with the practice having a diagnosis of asthma (see figure 1).

Asthma rates varied by 2.6-fold when practice rates were grouped together into larger sustainability and transformation partnership (STP) areas (see figure 2). These larger geographical units encompass NHS organisations and local councils in England who are working together

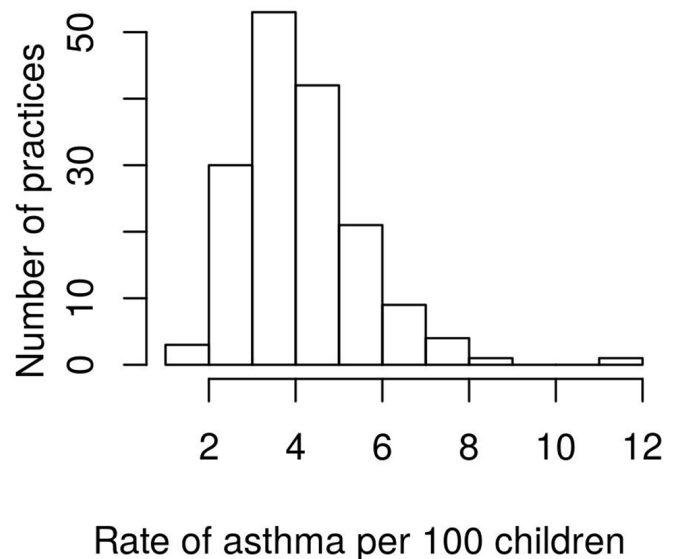


Figure 1 Rates of asthma among children aged 5–12 years.

to develop shared care pathways for people with chronic disease.²⁹

The severity of asthma among children within the RCGP RSC practices also varied widely as shown by the number that required >6 inhaled relievers or 12 inhaled preventers within the past year (see figure 3).

Respiratory infection rates in children with asthma

The rate of infections of the lower respiratory tract in children with asthma varied up to 50-fold between practices across the network, with rates of ILI showing the widest variation between 0–50 per 100 children with asthma. Also the rate of infections of the upper respiratory tract in children with asthma almost 20-fold between practices across the network, with rates of other URTIs showing the widest variation between 3.03 and 56.25 per 100 children with asthma. Table 1 shows the mean respiratory infection rates in children with asthma for practices across the network, the variance and median infection rates.

Determinants of respiratory infection in children with asthma

We present the negative binomial regression models which produced the most optimal fit for the data. The models showed that the most consistent predictor of both URTIs and LRTIs in children with asthma was the number of children registered with the practice, especially asthmatic children.

The relative risks indicates that as practice list size increased by 50 children there was a 4%–9% greater risk of respiratory infections in their population of asthmatic children.

Equally as the prevalence of children with asthma increased within practices the risk of respiratory infections increased between 19% and 46% (see tables 2 and 3).

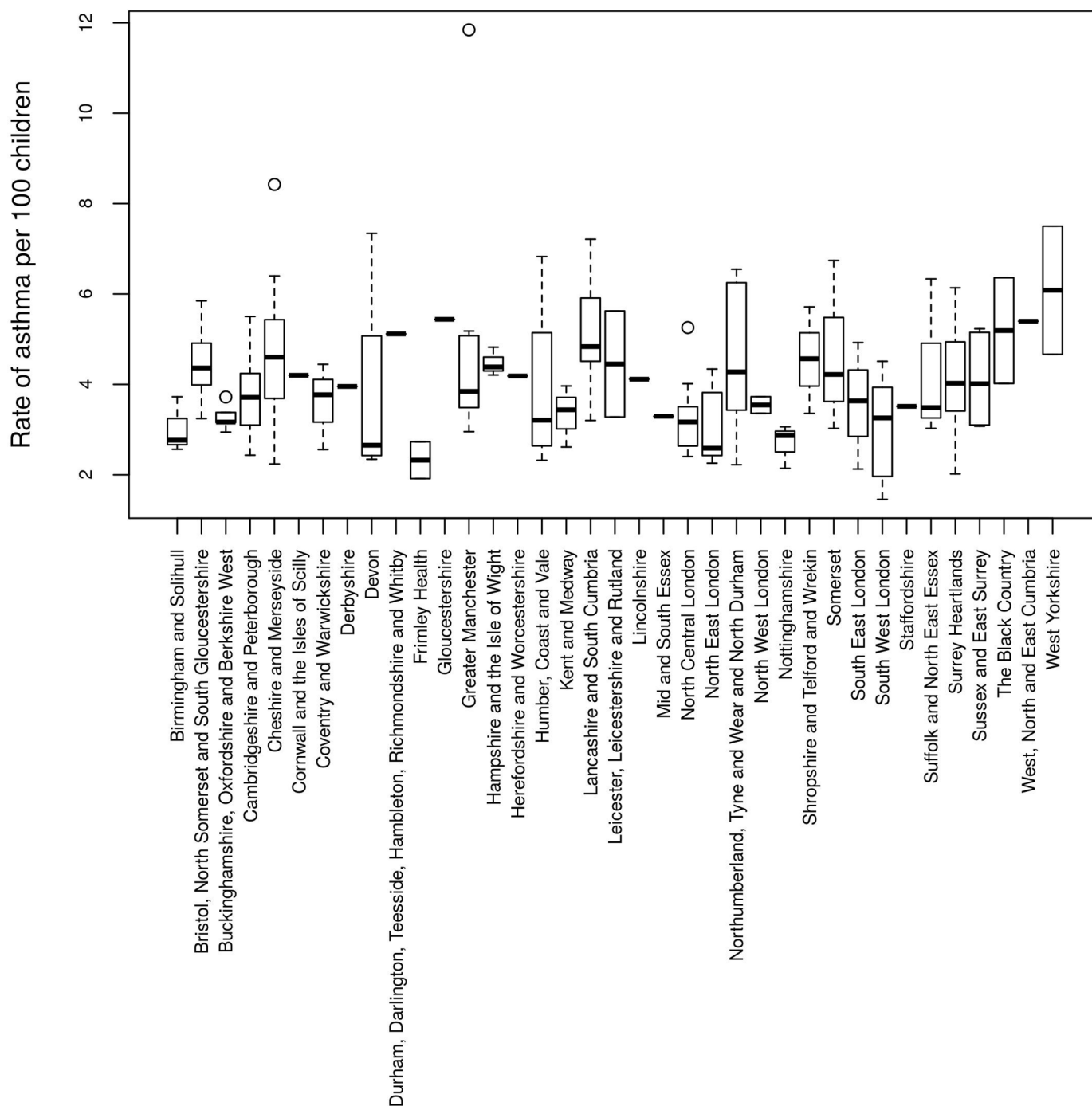


Figure 2 Asthma rates by sustainability and transformation partnership.

DISCUSSION

Summary of principal findings

Using data from a national sentinel network, we found wide variation in the prevalence of paediatric asthma in primary care, with almost 10-fold difference in the rate between practices and 2.6-fold variation between STP areas. We also found widespread variations in the respiratory infections among children with asthma, with an almost 50-fold difference in the rate between practices. Larger practices with larger lists of asthmatic children

tended to have greater rates of respiratory infections among these children.

Strengths and weaknesses of the study

There are a number of limitations to our study related to the use of routinely collected data from general practice, including the quality of data recording in primary care records. However, our sentinel network has been involved in monitoring ILI and respiratory infections for over 50 years and has had regular feedback on data quality.^{12 13} Our previous work has shown that an ontological approach

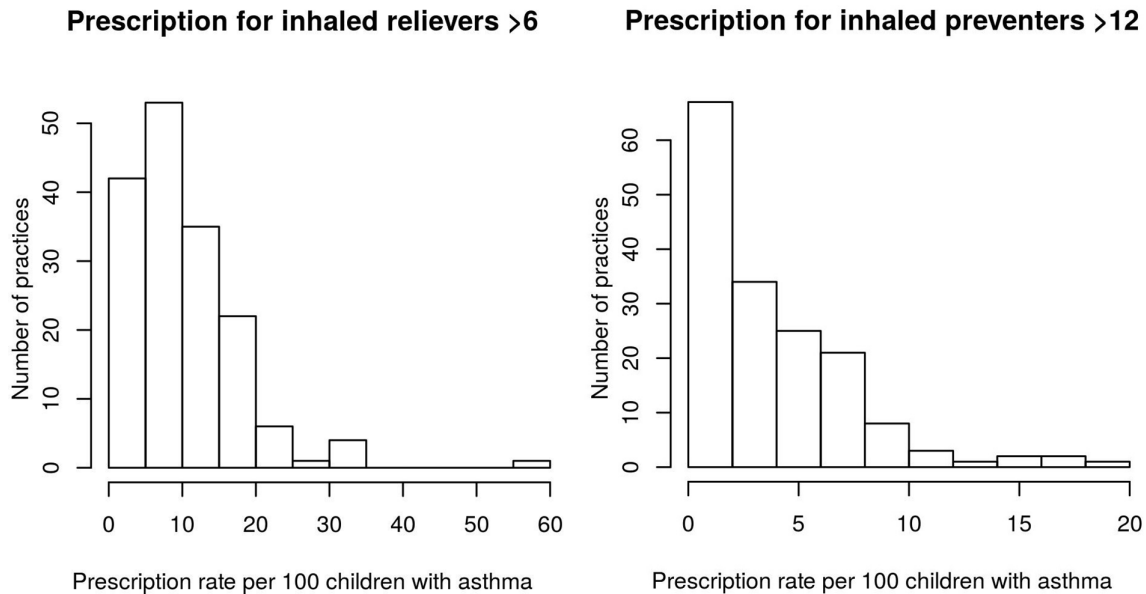


Figure 3 Severity of asthma among children aged 5–12 years in Royal College of General Practitioners Research and Surveillance Centre practices as indicated by rates of prescribing for >6 inhaled relievers or >12 inhaled preventers per year.

to asthma case definition combining clinician-assigned codes relating to five supporting concepts of asthma, namely diagnosis, symptoms, diagnostic tests, therapies and processes of care, accurately estimates the prevalence of asthma in a primary care data set compared with published data. However, the accuracy of our ontological definition of asthma has not been specifically tested in populations of children and young people.

An additional limitation relates to the enumeration of practice structural variables as this relied on the extraction of publicly available data about practices from their own websites, NHS Choices and the medical register held by the GMC. The quality of this information, especially its completeness, consistency, timeliness and accuracy, has not been validated in published data, and given

the number of practices involved in this study we did not attempt to validate the accuracy with individual practice staff.

Our study also lacked information on other structural and individual variables which may be important in the onset of respiratory infections in children with asthma, including exposure to smoking and pollution which may influence the risk of some respiratory infections in children.

Finally, inference about the individual risk of respiratory infection in children with asthma is not straightforward from the results of our study, thus it is difficult to deduce changes to individual behaviours that may affect infection risk or make conclusions about changes in clinical practice for individual children.

Table 1 Variation between practices in Royal College of General Practitioners Research and Surveillance Centre sentinel network in rates of respiratory infections among children with asthma

Respiratory infection	Mean infection rate per 100 children with asthma (95% CI)	Variance	Median rate
LRTIs			
Acute bronchitis and bronchiolitis	6.1 (5.3 to 7.0)	32.4	4.5
Pneumonia and pneumonitis	6.2 (5.3 to 7.1)	32.2	4.5
Pleurisy	0.9 (0.6 to 1.2)	3.1	0
Other LRTIs	0.5 (0.3 to 0.7)	2.1	0
Influenza-like Illness	15.7 (14.1 to 17.3)	107.5	14.8
URTIs			
Common cold	21.1 (19.4 to 22.8)	125.0	19.8
Streptococcal sore throat	0.1 (0.1 to 0.2)	0.3	0
Scarlatina	0.5 (0.3 to 0.7)	0.03	0
Other URTIs	24.5 (22.8 to 26.3)	129.7	23.4

LRTIs, lower respiratory tract infections; URTIs, upper respiratory tract infections.

Table 2 Relative risk (RR) of respiratory infection associated with practice-level determinants (95% CI)

RR* of respiratory infection	Urban location	Total number of children in the practice (RR per 50 children)	Total number of practice GPs	Mean years since medical qualification	Mean number of qualifications in the practice	DTaP/HIB vaccination rates	PCV vaccination rate	Influenza vaccination rate	Overall QoF achievement	QoF achievement for respiratory disease
Lower respiratory tract infections (LRTIs)										
Acute bronchitis and bronchiolitis	1.57 (1.06 to 2.38)	1.04 (1.02 to 1.05)	1.00 (0.97 to 1.04)	0.96 (0.92 to 0.99)	1.22 (1.02 to 1.47)	1.01 (1.00 to 1.02)	1.02 (0.98 to 1.07)	1.01 (0.98 to 1.04)	1.00 (0.96 to 1.04)	0.99 (0.94 to 1.06)
Pneumonia and pneumonitis	1.54 (1.05 to 2.32)	1.04 (1.02 to 1.06)	1.00 (0.96 to 1.04)	0.95 (0.92 to 0.99)	1.21 (1.01 to 1.44)	1.01 (1.00 to 1.02)	1.02 (0.98 to 1.07)	1.01 (0.98 to 1.03)	0.99 (0.96 to 1.03)	0.99 (0.94 to 1.06)
Pleurisy	0.54 (0.26 to 1.16)	1.05 (1.02 to 1.09)	1.00 (0.92 to 1.08)	1.07 (0.99 to 1.16)	0.83 (0.55 to 1.26)	0.99 (0.98 to 1.01)	1.06 (0.97 to 1.22)	0.98 (0.92 to 1.04)	1.00 (0.93 to 1.10)	0.93 (0.85 to 1.04)
Other LRTIs	1.16 (0.43 to 3.80)	1.04 (1.00 to 1.08)	1.03 (0.91 to 1.13)	0.94 (0.84 to 1.05)	1.16 (0.71 to 1.94)	1.00 (0.98 to 1.02)	0.94 (0.87 to 1.03)	0.96 (0.89 to 1.03)	1.16 (0.93 to 1.61)	1.44 (0.82 to ?)
Influenza-like illness	1.21 (0.90 to 1.63)	1.04 (1.03 to 1.05)	0.98 (0.95 to 1.01)	1.02 (0.99 to 1.04)	1.01 (0.89 to 1.15)	1.00 (1.00 to 1.01)	1.03 (1.00 to 1.07)	0.99 (0.97 to 1.01)	0.99 (0.96 to 1.02)	1.02 (0.97 to 1.07)
URTIs										
Common cold	1.13 (0.88 to 1.44)	1.04 (1.03 to 1.05)	0.98 (0.96 to 1.01)	1.01 (0.99 to 1.03)	0.98 (0.88 to 1.09)	1.00 (1.00 to 1.00)	1.03 (1.00 to 1.06)	0.98 (0.97 to 1.00)	1.00 (0.97 to 1.02)	1.01 (0.97 to 1.05)
Streptococcal sore throat	0.56 (0.07 to 6.35)	1.09 (1.01 to 1.19)	0.97 (0.78 to 1.18)	0.96 (0.78 to 1.16)	0.47 (0.17 to 1.20)	1.01 (0.98 to 1.10)	0.89 (0.71 to 1.22)	0.98 (0.85 to 1.12)	0.87 (0.71 to 1.03)	1.00 (0.79 to 1.47)
Scarlatina	1.12 (0.41 to 3.66)	1.04 (1.00 to 1.09)	1.01 (0.90 to 1.13)	0.94 (0.84 to 1.05)	1.22 (0.74 to 2.11)	1.00 (0.98 to 1.02)	0.95 (0.87 to 1.03)	0.97 (0.90 to 1.05)	1.18 (0.94 to 1.68)	1.41 (0.81 to ?)
Other URTIs	1.04 (0.83 to 1.31)	1.04 (1.03 to 1.05)	0.99 (0.96 to 1.01)	1.01 (0.99 to 1.03)	1.00 (0.90 to 1.11)	1.00 (1.00 to 1.00)	1.04 (1.01 to 1.07)	0.98 (0.97 to 1.00)	1.00 (0.98 to 1.03)	1.01 (0.97 to 1.05)

Bolded results are statistically significant. DTaP/HIB, *Haemophilus influenzae* type b; GP, general practitioner; LRTIs, lower respiratory tract infections; PCV, pneumococcal conjugate vaccination; URTIs, upper respiratory tract infections.

Table 3 Relative risk of respiratory infection associated the characteristics of children with asthma at practice level (95% CI)

Relative risk of respiratory infection	Practice child asthma prevalence rates	Average age of children with asthma	% female	% non-white	% prescribed >6 inhaled relievers in last year	% prescribed >12 inhaled preventers in last year
LRTIs						
Acute bronchitis and bronchiolitis	1.22 (1.12 to 1.33)	0.82 (0.60 to 1.13)	1.01 (0.99 to 1.02)	1.00 (0.99 to 1.00)	1.03 (1.01 to 1.05)	1.01 (0.97 to 1.05)
Pneumonia and pneumonitis	1.22 (1.12 to 1.33)	0.83 (0.60 to 1.13)	1.01 (0.99 to 1.02)	1.00 (0.99 to 1.00)	1.03 (1.01 to 1.05)	1.01 (0.97 to 1.05)
Pleurisy	1.24 (0.98 to 1.53)	0.64 (0.30 to 1.35)	0.99 (0.96 to 1.03)	0.99 (0.97 to 1.01)	1.00 (0.95 to 1.04)	1.03 (0.93 to 1.12)
Other LRTIs	1.38 (1.03 to 1.83)	0.45 (0.16 to 1.18)	1.02 (0.98 to 1.07)	0.99 (0.96 to 1.01)	1.00 (0.93 to 1.07)	0.83 (0.70 to 0.96)
Influenza-like illness	1.19 (1.12 to 1.28)	0.90 (0.71 to 1.14)	1.00 (0.99 to 1.02)	1.01 (1.00 to 1.01)	1.00 (0.99 to 1.01)	1.00 (0.97 to 1.03)
URTIs						
Common cold	1.22 (1.15 to 1.29)	0.96 (0.78 to 1.16)	1.01 (1.00 to 1.01)	1.00 (1.00 to 1.01)	1.00 (0.99 to 1.02)	1.00 (0.97 to 1.02)
Streptococcal sore throat	1.46 (0.82 to 2.53)	0.32 (0.04 to 2.12)	1.05 (0.97 to 1.15)	0.99 (0.95 to 1.02)	1.02 (0.89 to 1.14)	0.70 (0.45 to 0.98)
Scarlatina	1.34 (0.98 to 1.81)	0.44 (0.16 to 1.19)	1.02 (0.98 to 1.07)	0.99 (0.96 to 1.01)	0.99 (0.92 to 1.06)	0.85 (0.72 to 0.99)
Other URTIs	1.23 (1.17 to 1.30)	0.97 (0.80 to 1.17)	1.00 (0.99 to 1.01)	1.00 (1.00 to 1.01)	1.01 (0.99 to 1.02)	0.99 (0.97 to 1.02)

Bolded results are statistically significant. LRTIs, lower respiratory tract infections; URTIs, upper respiratory tract infections.

However, our study has a number of strengths including the fact that we used a large, nationally representative data set¹² which allowed us to examine a wide number of URTIs and LRTIs in this group of children compared with previously published research.

Strengths and weaknesses in relation to other studies, discussing important differences in results

Our study shows widespread inter-practice variations in asthma prevalence and variations in respiratory infections. These variations could indicate variations in the recording of asthma and respiratory infections in primary care, although we have previously shown that the prevalence of asthma in our database is in line with previously published data which suggest that recording of cases in the RCGP RSC network is in line with other general practices.

While our study looked at the effect of variations in clinical care provided for children with asthma, the indicators of the quality of clinical care provided for children with asthma used in this study, namely the P4P/QOF indicators, do not specifically include measures of respiratory care in children and showed little variability. In fact practice measures of clinical care either showed no or contradictory results such as the practice vaccination rates of PCV and influenza which showed increase or decrease in respiratory infections, respectively. These practice measures of clinical care may only be partially capturing changes in individual behaviours that change risk of respiratory infections and there is a need for a better understanding of how structural/environmental factors influence individual risk and vice versa.

Meaning of the study: possible explanations and implications for clinicians and policymakers

Previous studies have shown that asthma is familial and that the genetic makeup of stable populations suggests that the probable cause of variations in asthma prevalence must lie in the environment.³⁰

Various environmental exposures have been posited as causally related to asthma prevalence including air pollution, airborne allergens, house dust mite and smoking.³¹ There is also some evidence that these exposures may be causally related to respiratory infections.³²

An alternative explanation for our findings may be the result of population-level variations in genetic susceptibility causing both asthma and asthma-related infections.³¹

In such a scenario, temporal and geographical variations in asthma rates would closely mirror respiratory infection rates with little influence from changes in environmental exposures over time or geography.

Lastly our findings suggest the need for the improved monitoring of respiratory infections in children with asthma, especially those from large urban practices who are at increased risk of infections that could result in acute exacerbations or chronic disease.

Unanswered questions and future research

The findings from our study raise a number of important questions for further research. First, are the variations in asthma rates and respiratory infection rates between practices also seen over time and are structural factors equally important in determining temporal variations in these rates?

Second, what other structural and environmental variables or individual exposures are important determinants of variations in asthma prevalence and respiratory infection rates in this population? For example, are there important genetic variations between populations that could result in these variations in asthma and asthma-related respiratory infections? How do the structural/environmental factors influence individual children with asthma or the clinicians caring for them to change the risk of infection and vice versa?

Author affiliations

¹Department of Clinical and Experimental Medicine, University of Surrey, Guildford, UK

²St Mary's Hospital, Isle of Wight, UK

³Division of Healthcare Delivery Science/ Center for Healthcare Innovation and Delivery Science (CHIDS), Department of Population Health, New York University, Langone Medical Centre, New York, USA

⁴Department of Paediatrics and Child Health, Northwick Park Hospital, Harrow, UK

⁵Section of Paediatrics, School of Medicine, Imperial College London, St. Mary's Hospital, London, UK

⁶Research and Surveillance Centre, Royal College of General Practitioners, London, UK

Contributors UH, SdL, MB, SJ and HL were responsible for the conception or design of the work. UH and HL were responsible for data analysis and writing the initial draft manuscript. UH, HL, RC, CG, SJ, MB, MR and SdL were responsible for interpretation of data, revising the manuscript critically for important intellectual content and final approval of the version to be published.

Funding This study was based on work as part of the Models of Child Health Appraised (MOCHA) project. This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement No. 634201.

Disclaimer The funders did not have any role in study design, analysis or interpretation of data, in the writing of the report or in the decision to submit the article for publication.

Competing interests None declared.

Patient consent Not required.

Ethics approval All data used in this study had been anonymised at the point of data extraction. No clinically identifiable information was used. The study received ethical approval from the South West Central Bristol Research Ethics Committee (REC reference number: 17/SW/0137, approval granted 16 June 2017).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Additional data are available by emailing Dr Uy Hoang, u.hoang@surrey.ac.uk.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

REFERENCES

1. Asthma statistics: British Lung Foundation. <https://statistics.blf.org.uk/asthma>
2. Anderson HR, Gupta R, Strachan DP, et al. 50 years of asthma: UK trends from 1955 to 2004. *Thorax* 2007;62:85–90.
3. Martinez FD, Vercelli D. Asthma. *The Lancet* 2013;382:1360–72.
4. Pelaia G, Vatrella A, Gallelli L, et al. Respiratory infections and asthma. *Respir Med* 2006;100:775–84.
5. Saxena S, Bottle A, Gilbert R, et al. Increasing short-stay unplanned hospital admissions among children in England; time trends analysis '97-'06. *PLoS One* 2009;4:e7484.
6. Ahanchian H, Jones CM, Chen YS, et al. Respiratory viral infections in children with asthma: do they matter and can we prevent them? *BMC Pediatr* 2012;12:147.
7. Abdelhamid AS, Maisey S, Steel N. Predictors of the quality of care for asthma in general practice: an observational study. *Fam Pract* 2010;27:186–91.
8. Garbutt JM, Yan Y, Strunk RC. Practice Variation in Management of Childhood Asthma Is Associated with Outcome Differences. *J Allergy Clin Immunol Pract* 2016;4:474–80.
9. Finkelstein JA, Lozano P, Fuhlbrigge AL, et al. Practice-level effects of interventions to improve asthma care in primary care settings: the pediatric asthma care patient outcomes research team. *Health Serv Res* 2005;40(6 Pt 1):1737–57.
10. Chamberlain JM, Teach SJ, Hayes KL, et al. Practice pattern variation in the care of children with acute asthma. *Acad Emerg Med* 2016;23:166–70.
11. NHS Atlas of Variation in Healthcare for People with Respiratory Disease. 2012.
12. Correa A, Hinton W, McGovern A, et al. Royal College of General Practitioners Research and Surveillance Centre (RCGP RSC) sentinel network: a cohort profile. *BMJ Open* 2016;6:e011092.
13. de Lusignan S, Correa A, Smith GE, et al. RCGP Research and Surveillance Centre: 50 years' surveillance of influenza, infections, and respiratory conditions. *Br J Gen Pract* 2017;67:440–1.
14. de Lusignan S, van Weel C. The use of routinely collected computer data for research in primary care: opportunities and challenges. *Fam Pract* 2006;23:253–63.
15. de Lusignan S. Codes, classifications, terminologies and nomenclatures: definition, development and application in practice. *Inform Prim Care* 2005;13:65–9.
16. de Lusignan S, Shinneman S, Yonova I, et al. An ontology to improve transparency in case definition and increase case finding of infectious intestinal disease: database study in english general practice. *JMIR Med Inform* 2017;5:e34.
17. Liaw ST, Rahimi A, Ray P, et al. Towards an ontology for data quality in integrated chronic disease management: a realist review of the literature. *Int J Med Inform* 2013;82:10–24.
18. McNulty R, Liyanage H, Arrowsmith B, et al. Time to present the ontological basis of disease prevalence: Asthma as an exemplar, in: Health-exploring complexity: an interdisciplinary systems approach HEC 2016: 28 August-2 September 2016, Munich, Germany. *Eur J Epidemiol* 2016;131:1–239.
19. McNulty R, Liyanage H, Arrowsmith B, et al. Asthma Ontology: National Center for Biomedical Ontology BioPortal. 2017 <http://bioportal.bioontology.org/ontologies/AO/>
20. Pedersen SE, Hurd SS, Lemanske RF, et al. Global strategy for the diagnosis and management of asthma in children 5 years and younger. *Pediatr Pulmonol* 2011;46:1–17.
21. Bronnimann S, Burrows B. A prospective study of the natural history of asthma. Remission and relapse rates. *Chest* 1986;90:480–4.
22. NHS Choices. <https://www.nhs.uk/pages/home.aspx>
23. General Medical Council. List of registered medical practitioners. <http://www.gmc-uk.org/doctors/register/LRMP.asp>
24. Steven K, Neville RG, Hoskins G, et al. The RCP's 'Three Key Questions' for asthma: review of practical use. *Br J Community Nurs* 2002;7:300–3.
25. Hoskins G, Williams B, Jackson C, et al. Assessing asthma control in UK primary care: use of routinely collected prospective observational consultation data to determine appropriateness of a variety of control assessment models. *BMC Fam Pract* 2011;12:105.
26. Jones A, Rice N, d'Uva T, et al. *Models for count data*. Applied Health Economics. London: Routledge, 2013:295–341.
27. Wilks SS. The large-sample distribution of the likelihood ratio for testing composite hypotheses. *Ann Math Statist* 1938;9:60–2.
28. RStudio. RStudio, new open-source IDE for R. <https://blog.rstudio.com/2011/02/28/rstudio-new-open-source-ide-for-r/>
29. *Delivering the forward view: NHS planning guidance 2016/17 – 2020/21*. London: NHS England, 2015.
30. Cookson WO, Moffatt MF. Asthma: an epidemic in the absence of infection? *Science* 1997;275:41–2.
31. Seaton A, Godden DJ, Brown K. Increase in asthma: a more toxic environment or a more susceptible population? *Thorax* 1994;49:171–4.
32. Rylander R, Mégevard Y. Environmental risk factors for respiratory infections. *Arch Environ Health* 2000;55:300–3.