Conurbation, urban and rural living are contributing determinants of allergic and infectious disease. Royal College of General Practitioners (RCGP) Research and Surveillance Centre (RSC) Annual Report 2016-2017

Simon de Lusignan 1,2 *
Professor of Primary Care & Clinical Informatics
Director RCGP Research and Surveillance Centre
* Corresponding author, email address: s.lusignan@surrey.ac.uk

Christopher McGee 1,2
c.mcgee@surrey.ac.uk
Research Assistant

Rebecca Webb 1
Becca.Webb@surrey.ac.uk
Primary Care Scientist

Mark Joy 3
m.joy@surrey.ac.uk
Senior Lecturer

Alex J Elliot 4
Alex.Elliot@phe.gov.uk
National Scientist Lead for Syndromic Surveillance

Gillian Smith 4
Gillian.Smith@phe.gov.uk
Consultant Epidemiologist

Rachel Byford 1
r.byford@surrey.ac.uk
Database developer

Ivelina Yonova 1,2
i.yonova@surrey.ac.uk
Practice Liaison Officer

Mariya Hrisko 1,2
m.hrisko@surrey.ac.uk
Practice Liaison Officer

Filipa Ferreira 1
f.ferreira@surrey.ac.uk
Programme Manager

Imran Rafi 5
imran.raf@rcgp.org.uk
Chair of Clinical Innovation and Research Centre (CIRC)

1 Department of Clinical and Experimental Medicine, University of Surrey, Guildford, UK
2 Royal College of General Practitioners Research and Surveillance Centre, London, UK
4 Public Health England, National Infection Service, Birmingham, UK
5 Royal College of General Practitioners Clinical Innovation and Research Centre, London, UK
Abstract

**Background:** Living in a conurbation, urban, or rural environment is an important determinant of health.

**Objective:** To report differences in incidence of allergic and infectious disease in those exposed to conurbation or urban living, compared with rural environments.

**Design and Setting:** A nationally representative sample of 175 English general practices covering a population of 1.6 million patients registered with sentinel network general practices.

**Method:** Incidence rates per 100,000 population were reported for allergic rhinitis (AR), asthma and infectious conditions grouped into upper and lower respiratory tract infections (URTI and LRTI), urinary tract infection (UTI) and acute gastroenteritis (AGE) by Office of National Statics urban-rural category. We used multivariate logistic regression adjusting for age, gender, ethnicity, deprivation, comorbidities and smoking status; reporting odds ratios (OR) with 95% confidence intervals (CI).

**Results:** The OR for AR if living in an urban area was 1.13 (95%CI: 1.04-1.23, \( P < 0.001 \)) and for conurbation 1.29 (95%CI: 1.19-1.41, \( P < 0.001 \)) compared to rural. Neither asthma nor LRTI had significantly different OR in urban compared to rural living, and both were associated with a lower odds compared to conurbations (OR 0.70, 95%CI: 0.67-0.73, \( P < 0.001 \) (asthma); OR 0.94, 95%CI: 0.90-0.98, \( P < 0.001 \) (LRTI)). The OR for URTI was greater in urban areas (OR 1.06 95%CI 1.03-1.08, \( P < 0.001 \)); but no different from rural in conurbation dwellers (OR 1.00, 95%CI: 0.97-1.03). AGE followed the same pattern, the OR was 1.13 (95%CI: 1.01-1.25, \( P = 0.03 \)) for those residing in urban areas and 1.04 (95%CI: 0.93-1.17) for conurbations. Finally, the OR for UTI was lower for those living in urban areas (OR 0.94, 95%CI: 0.89-0.99, \( P = 0.02 \)) but higher in conurbations (OR 1.06, 95%CI: 1.00-1.13; \( P = 0.04 \)).

**Conclusion:** Those living in conurbations or urban areas were more likely to consult for allergic rhinitis, URTI, and AGE. Both conurbation and rural living were associated with an increased risk of UTI. Living in rural areas was associated with an increased risk of asthma and LRTI. The data suggest living environment may impact on rates of consultations for certain conditions. Longitudinal analyses of these data would be useful in providing insights into important determinants.

**Key words:** Population Surveillance; Respiratory tract infections; Conjunctivitis, Allergic; Asthma; Urinary Tract Infections; Gastroenteritis; Healthcare Disparities; Socioeconomic Factors; Social Determinants of Health
Conurbation, urban and rural living are determinants of allergic and infectious disease: Royal College of General Practitioners (RCGP) Research and Surveillance Centre (RSC) Annual Report 2016-2017

Introduction
There are a wide range of social determinants of health; and conurbation, urban and rural living are important amongst these, though their different effects are still unclear [1]. Urbanisation is increasing and it is predicted by the United Nations that the world urban population will double between 2007 and 2050. Urbanisation is an important determinant of health [2] as it may create incubators for infectious disease [3].

Factors associated with urban and rural living are associated with differences in respiratory and allergic conditions. Pollution, climate change, and pollen exposure are all associated with increased respiratory and allergic conditions [4-6]. Farm and rural upbringing have been shown to be protective against allergic rhinitis compared with urban living [7, 8]. The same gradient has been reported for asthma in northern Europe [9]. However, asthma has also been shown to have an increasing incidence with higher levels of air pollution, but for there is inconsistency between age-groups for specific pollutants [10, 11]. Pollen levels may also be important in precipitating exacerbations of asthma [12] and there may be complex interaction between them and with the weather [13]. Much less is known about the impact of conurbation, urban and rural living on upper respiratory infection, gastroenteritis, or urinary infection.

The Royal College of General Practitioners (RCGP) Research and Surveillance Centre (RSC) is one of the oldest sentinel networks and is in its 50th season of reporting infections and respiratory conditions [14, 15]. This is a longstanding collaboration with Public Health England [16, 17]. The network is recruited to be nationally representative and at the time of this report comprised over 1.6 million registered patients. The network's capabilities include reporting whether patients live in a conurbation, urban, or rural areas.

We carried out this study to report whether exposure to living in a conurbation (high density living), urban (intermediate density, such as a city or town) or rural (least dense, such as the countryside) environment was associated with a greater incidence of allergic (allergic rhinitis and asthma) or common infective conditions. This investigation is the theme of the RSC’s annual report on diseases. The annual report also includes the annual weekly incidence of all our monitored conditions (Supplementary file A).

Methods
Design and setting
We extracted data from 175 volunteer practices who are members of the RCGP RSC; a cohort of 1,602,366 patients registered for the first 6 months of the period of 1 April 2016 – 31 March 2017. The data extracted are anonymised and encrypted. We only extract coded data, not free text. Data were coded with Read version 2, or Clinical Terms version 3 (CTv3) [18]. We do not process the data of patients who have an "opt out" code (2.2% of the RCGP RSC population).

Data quality in RCGP RSC for infections and allergic conditions is assured through a programme of training for each participating practice in routine primary care data. The RCGP RSC practices are encouraged to record the most likely diagnosis as a problem title; also assigning an "episode type" to differentiate first or new presentations from ongoing care. Most of the data quality feedback to RSC member practices focuses on data quality for acute respiratory infection, and respiratory conditions. More recently we have introduced financially incentivised training and practice specific comparative feedback via a dashboard [19], modelled on the principles of audit-based education [20].
**Data preparation**

We determined a patient’s urban classification by using an ONS lookup tool [21]. This was done on an individual patient level basis using their Lower Super Output Area, to estimate population density. Based on this lookup tool, if a patient’s population was classified as mainly rural or largely rural we classified them as living in a rural population. If a patient lived in urban with significant rural, urban with city and town or urban with minor conurbation we classified them as living in a city or town (referred to as rural throughout this paper). If a patient lived in urban with major conurbation we classified them as living in a conurbation. These were based on the ONS lower super output area (LSOA), which has a mean size in England and Wales of 1, 640, with population sizes ranging from 820 in South Cambridgeshire to 8,250 in Oxford [22].

Our outcome variables, allergic and infectious conditions, were a composite of similar conditions grouped together; a method we adopted for the 2016-2017 annual report. Allergic conditions were allergic rhinitis (including hay fever) and asthma. Infections were divided into: Lower respiratory infections (LRTI), comprised of people with acute bronchitis, pneumonia, and pleurisy; upper respiratory infection (URTI) including tonsillitis, common cold, sinusitis, conjunctivitis and otitis media; acute gastroenteritis (AGE) and urinary tract infection (UTI). We did not include influenza-like-Illness (ILI) in this analysis, though data about ILI are contained in the annual report (Supplementary File A); as we plan a separate analysis taking into account vaccine exposure. Similarly, less common conditions (e.g. measles, mumps, scabies), though their weekly incidence is included in the annual report.

In exploring the association between living area and allergic and infectious disease, we adjusted for age, gender, ethnicity and socioeconomic status (SES), using the Index of Multiple Deprivation (IMD). These variables were grouped as follows: Gender (female were the reference group); age-bands (1-4 years, 5-17 years, 18-64 years and 65+ years, reference as 18-64 years); ethnicity (white ethnicity (W) was reference, we divided the others into Asian (A), Black (B), mixed (M), other (O), and unclassified (U) ethnicities) using an ontological approach to maximise identification [23]; and deprivation. The latter was reported using the IMD divided into quintiles (quintile 1, most deprived, was used as reference).

From the cohort of 1,602,366 patients registered, we compiled and reported data on conurbation, urban and rural living by age, gender, ethnicity and IMD score. We also controlled for co-morbid disease. We grouped comorbidities into the following groups: 0 comorbidities (reference), 1-2 comorbidities and 3 or more comorbidities. We included the following as comorbidities: depression, hypertension, chronic obstructive pulmonary disease (COPD), rheumatoid arthritis, dementia, stroke or transient ischaemic attack (grouped as cerebrovascular disease), acute myocardial infarction, angina, and coronary artery disease (grouped as ischaemic heart disease), congestive cardiac failure, peripheral arterial disease, chronic kidney disease (CKD), diabetes mellitus and atrial fibrillation (AF). Smoking status was also included and controlled for in our analysis, grouping smokers into ‘Active smoker’ (reference), ‘Ex-smoker’, ‘Non-smoker’ and ‘Unknown,’ based on their latest recorded smoking habit.

**Statistical analyses**

To understand whether rural, urban or conurbation living was associated with certain allergic or contagious diseases we carried out a multivariate logistic regression, with rural, urban or conurbation as the predictor variables, and disease as the outcome variable. We report the odds ratio (OR) and 95% confidence interval (95%CI) from the multivariate logistic regression [24] for conurbation, or urban compared with rural (reference). An OR of >1 implies greater odds of a patient living in a conurbation or urban area presenting with the condition, an OR of <1 suggests lower odds of a
patient living in a conurbation or urban area presenting with a condition, adjusting for other variables in the model. We created an aggregated table showing those conditions with significant results highlighted (Table 1). Given the large number of models, we applied a Benjamini-Hochberg correction [25]. We also report probability (P) and this was calculated from the coefficients of the logistic regression.

In addition to the main effect of urban, rural and conurbation living on disease rates, we also looked at the interaction of age band/gender and urban, rural and conurbation on disease rates (see Supplementary file B for detailed results). Forest plots for age bands and each of the conditions were also created (Supplementary file C).

The analysis presented in the Annual Report (Supplementary file A) includes:

- Map of the National distribution of RCGP RSC practices
- Summary tables showing the conditions we monitor:
  - Median age (using horizontal box-whisker plots),
  - Gender distribution of our monitored conditions,
  - Ethnicity distribution, comparing white and non-white,
  - Median IMD (again using a horizontal box-whisker plot),
  - Conurbation, urban and rural distribution of our monitored conditions
- Weekly incidence of the conditions monitored by the RCGP RSC. Population denominators were based on the population registered in the participating practices in December. The weeks are numbered using the International Organisation for Standardization (ISO) system [26].

### Results

#### Population

The RCGP RSC network population consists of 1,602,366 people. Older, less deprived, and a less ethnically mixed population live in rural areas. In comparison a younger, ethnically mixed, and more deprived population live in conurbations (see Figures 1-3).
The minority of the RSC network population (19%) live in rural areas. White (20.8%) and undisclosed ethnicities (22.7%) are most likely to live in rural areas, compared to Black (1%) or Asian (2.5%) people. The population in rural areas is older than in conurbations, with 51.8% of this population aged over 45. Levels of deprivation are low in rural areas; only 34.2% of this population have an IMD score of 1-3 (most deprived).
The majority of the RSC network population in the network live in urban areas (48%). Individuals aged 18-64 years make up a large proportion of those living in urban areas (60.3%). White people (49.8%), followed by those with undisclosed ethnicities (54.4%) are most likely to live in urban areas. Those who live in urban areas have an even split of deprivation; 46.3% of the population have an IMD score of 1-3 (most deprived) and the remaining 53.6% have an IMD score of 4-5 (least deprived).

A third (32%) of the RSC network population live in a conurbation. Younger people aged 15-44 (49.2%), and Asian (67.4%), black (88.7%), mixed (63.6%) and other (67.4%) ethnicities are most likely to live in conurbations. Levels of deprivation are high in conurbations with 69.2% of this group obtaining a score of 1-3 on the IMD.

**Interaction effects**

No interactions were found between gender and living area. Four interactions were found for age band and living area, we used rural and working age (18-64 years) as reference groups. Children aged 0-4 years living in urban areas were more likely to present to general practice with asthma compared with adults aged 18-64 years living in rural areas (OR 1.42, 95% CI 1.20-1.68, \( P<0.001 \)). Children aged between 5 and 17 were more likely to consult for URTI than adults aged 18-64 living in rural areas (OR 1.06, 95% CI 1.02-1.11, \( P=0.01 \)). On the other hand, children aged 0-4 years living in urban areas were less likely to present with AGE compared to adults aged 18-64 living in rural areas (OR 0.84, 95% CI 0.72-0.98, \( P=0.03 \)). Over 65 year olds living in urban areas were less likely to consult for URTI (OR 0.92, 95% CI 0.88-0.97, \( P<0.001 \)) and AGE (OR 0.85, 95% CI 0.72-0.99, \( P=0.04 \)) compared to our reference group (Table 1).

<table>
<thead>
<tr>
<th>Age band and Urban vs Rural living</th>
<th>Allergic Rhinitis</th>
<th>Asthma</th>
<th>LRTI</th>
<th>URTI</th>
<th>AGE</th>
<th>URTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4yrs, Ref = 18-64yrs OR</td>
<td>0.81</td>
<td>1.42</td>
<td>0.99</td>
<td>1.03</td>
<td>0.84</td>
<td>1.100</td>
</tr>
<tr>
<td>95%CI</td>
<td>0.63-1.04</td>
<td>1.20-1.68</td>
<td>0.91-1.08</td>
<td>0.99-1.08</td>
<td>0.72-0.98</td>
<td>0.87-1.38</td>
</tr>
<tr>
<td>p-value</td>
<td>0.09</td>
<td>&lt;0.001</td>
<td>0.85</td>
<td>0.16</td>
<td>0.03</td>
<td>0.43</td>
</tr>
<tr>
<td>5-17yrs, Ref = 18-64yrs OR</td>
<td>0.93</td>
<td>1.05</td>
<td>1.11</td>
<td>1.06</td>
<td>1.01</td>
<td>1</td>
</tr>
<tr>
<td>95%CI</td>
<td>0.83-1.05</td>
<td>0.98-1.13</td>
<td>1.00-1.23</td>
<td>1.02-1.11</td>
<td>0.84-1.22</td>
<td>0.86-1.17</td>
</tr>
<tr>
<td>p-value</td>
<td>0.23</td>
<td>0.18</td>
<td>0.06</td>
<td>0.01</td>
<td>0.92</td>
<td>0.97</td>
</tr>
<tr>
<td>65+yrs, Ref = 18-64yrs OR</td>
<td>1.08</td>
<td>0.96</td>
<td>1.03</td>
<td>0.92</td>
<td>0.85</td>
<td>0.98</td>
</tr>
<tr>
<td>95%CI</td>
<td>0.94-1.25</td>
<td>0.91-1.02</td>
<td>0.99-1.09</td>
<td>0.88-0.97</td>
<td>0.72-0.99</td>
<td>0.91-1.05</td>
</tr>
<tr>
<td>p-value</td>
<td>0.29</td>
<td>0.18</td>
<td>0.17</td>
<td>&lt;0.001</td>
<td>0.04</td>
<td>0.58</td>
</tr>
</tbody>
</table>

**Table 1:** OR and 95% CI of the main effect of Urban (Rural is reference) and interaction terms of Urban area with age band (18-64yrs is reference) on the 6 conditions of interest. White text on dark shading illustrates OR > 1 and significant adjusted p-value, dark text or grey shading illustrates OR < 1 and significant adjusted p-value.

Children aged 0-4 years living in a conurbation were more likely to consult for URTI (OR 1.25, 95% CI 1.19-1.31, \( P<0.001 \)) compared to 18-64 year olds living in rural areas. Furthermore, children aged 5-17 living in conurbations were more likely to consult for asthma (OR 1.14, 95% CI 1.05-1.23, \( P=0.001 \)), LRTI (OR 1.32, 95% CI 1.18-1.47, \( P<0.001 \)), URTI (OR 1.25, 95% CI 1.20-1.31, \( P<0.001 \)) and AGE (OR 1.64, 95% CI 1.36-1.98, \( P<0.001 \)) compared with our reference group. Additionally, those aged over 65 living in conurbations were more likely to consult for asthma (OR 1.29, 95% CI 1.21-1.39, \( P<0.001 \)) and LRTI (OR 1.14, 95% CI 1.08-1.21, \( P<0.001 \)) in comparison to our reference group (Table 2).
<table>
<thead>
<tr>
<th>Age band and Conurbation vs Rural living</th>
<th>Allergic Rhinitis</th>
<th>Asthma</th>
<th>LRTI</th>
<th>URTI</th>
<th>AGE</th>
<th>UTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4yrs, Ref = 18-64yrs</td>
<td>OR 0.84</td>
<td>1.08</td>
<td>0.98</td>
<td>1.25</td>
<td>0.94</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>95%CI 0.65-1.07</td>
<td>0.90-1.29</td>
<td>0.90-1.07</td>
<td>1.19-1.31</td>
<td>0.80-1.10</td>
<td>0.89-1.43</td>
</tr>
<tr>
<td></td>
<td>p-value 0.16</td>
<td>0.43</td>
<td>0.68</td>
<td>&lt;0.001</td>
<td>0.45</td>
<td>0.31</td>
</tr>
<tr>
<td>5-17yrs, Ref = 18-64yrs</td>
<td>OR 0.94</td>
<td>1.14</td>
<td>1.32</td>
<td>1.25</td>
<td>1.64</td>
<td>1.04</td>
</tr>
<tr>
<td></td>
<td>95%CI 0.83-1.05</td>
<td>1.05-1.23</td>
<td>1.18-1.47</td>
<td>1.20-1.31</td>
<td>1.36-1.98</td>
<td>0.89-1.22</td>
</tr>
<tr>
<td></td>
<td>p-value 0.27</td>
<td>0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.61</td>
</tr>
<tr>
<td>65+yrs, Ref = 18-64yrs</td>
<td>OR 0.99</td>
<td>1.29</td>
<td>1.14</td>
<td>1.02</td>
<td>0.93</td>
<td>1.02</td>
</tr>
<tr>
<td></td>
<td>95%CI 0.85-1.17</td>
<td>1.23-1.39</td>
<td>1.08-1.21</td>
<td>0.97-1.08</td>
<td>0.78-1.12</td>
<td>0.94-1.10</td>
</tr>
<tr>
<td></td>
<td>p-value 0.94</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.40</td>
<td>0.45</td>
<td>0.63</td>
</tr>
</tbody>
</table>

Table 2: OR and 95% CI of the main effect of Conurbation (Rural is reference) and interaction terms of Conurbation with age band (18-64yrs is reference) on the 6 conditions of interest. White text on dark shading illustrates OR > 1 and significant adjusted p-value, dark text or grey shading illustrates OR < 1 and significant adjusted p-value.

**Main effect**

Those living in a conurbation, in comparison to a rural area, had greater odds of presenting to general practice with allergic rhinitis (OR 1.29, 95% CI 1.19-1.41, \(P<0.001\)) or a UTI (OR 1.06, 95% CI 1.00-1.13, \(P=0.04\)) but had lower odds of presenting with asthma (OR 0.70, 95% CI 0.67-0.73, \(P<0.001\)) and LRTI (OR 0.94, 95% CI 0.90-0.98, \(P=0.005\)).

Those living in urban, compared to rural areas, had greater odds of presenting to general practice with allergic rhinitis (OR 1.13, 95% CI 1.04-1.23, \(P=0.003\)), URTI (OR 1.06, 95% CI 1.03-1.08, \(P<0.001\)) and AGE (OR 1.13, 95% CI 1.01-1.25, \(P=0.003\)). On the other hand, they were less likely to present to practice with UTI (OR 0.94, 95% CI 0.89-0.99, \(P=0.02\)) (Table 3).

<table>
<thead>
<tr>
<th>Age band</th>
<th>Allergic Rhinitis</th>
<th>Asthma</th>
<th>LRTI</th>
<th>URTI</th>
<th>AGE</th>
<th>UTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conurbation, Ref = Rural</td>
<td>OR 1.29</td>
<td>0.70</td>
<td>0.94</td>
<td>1</td>
<td>1.04</td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td>95%CI 1.19-1.41</td>
<td>0.67-0.73</td>
<td>0.90-0.98</td>
<td>0.97-1.03</td>
<td>0.93-1.17</td>
<td>1.00-1.13</td>
</tr>
<tr>
<td></td>
<td>p-value &lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.93</td>
<td>0.46</td>
<td>0.04</td>
</tr>
<tr>
<td>Urban, Ref = Rural</td>
<td>OR 1.13</td>
<td>0.97</td>
<td>1</td>
<td>1.06</td>
<td>1.13</td>
<td>0.94</td>
</tr>
<tr>
<td></td>
<td>95%CI 1.04-1.23</td>
<td>0.93-1.01</td>
<td>0.96-1.04</td>
<td>1.03-1.08</td>
<td>1.01-1.25</td>
<td>0.89-0.99</td>
</tr>
<tr>
<td></td>
<td>p-value 0.003</td>
<td>0.11</td>
<td>0.89</td>
<td>&lt;0.001</td>
<td>0.03</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Table 3: OR and 95% CI of the main effect of Conurbation, Urban (Rural is reference) on the 6 conditions of interest. White text on dark shading illustrates OR > 1 and significant adjusted p-value, dark text or grey shading illustrates OR < 1 and significant adjusted p-value.

**Discussion:**

**Principal findings**

Those living in conurbations or urban areas were more likely to consult for allergic rhinitis, URTI, and AGE after adjusting for age, gender, ethnicity, socioeconomic status, co-morbid disease and smoking status. The OR of presenting with allergic rhinitis increased with population density. Whilst living in rural areas was associated with an increased risk of asthma and LRTI, both conurbation and rural living were associated with an increased risk of UTI.
Age and living environment interact when predicting the rates of these conditions. Children living in urban areas were more likely to consult for asthma (0-4 years) and URTI (5-17 years) compared to adults 18-64 year olds living in rural areas (our reference group). Additionally, children living in conurbations were more likely to consult for URTI (0-17 years), LRTI, asthma and AGE (5-17 years) compared to our reference groups. Over 65 year olds living in conurbations were also more likely to consult for asthma than our reference group. An increased risk of AGE was found in 18-64 year olds living in rural areas in comparison to 0-4 year olds and over 65 year olds living in urban areas. Rural living for 18-64 year olds was associated with an increased risk of URTI compared to over 65 year olds living in rural areas.

Comparison with the literature
Conurbation and urban living was associated with an increased presentation to general practice with allergic rhinitis, URTI and AGE, and this is consistent with previous research finding that allergic rhinitis and asthma are more common in urban areas and conurbations[8, 27]. As in previous research those living in conurbations had higher odds of consulting for UTI. The majority (49.2%) of people who live in conurbations within our population are young (15-44 years), and UTIs are more common in young sexually active women [28]. People living in rural areas were also more likely to consult for UTI than those living in urban areas. This finding may also be reflective of the age group within this population (51.8% were aged 45 year olds or over). Research suggests that UTI rates increase in people over the age of 65[29-31]. Therefore, the finding that UTIs are more common in conurbations (younger people) and rural areas (older people) is in line with previous research.

The results also show that those living in rural areas were more likely to present with LRTI and asthma. LRTI is more common in older people [29] and therefore this finding fits with previous research. However, it is not clear why asthma is more common in rural areas. Age does not appear to have a strong impact on the odds of presenting to general practice for asthma [29]. Previous research has found mixed results regarding the impact of living environment on asthma. Some studies have found that urban living is associated with increased odds of developing asthma [32], whereas others have found that rural living increases the odds[33].

Infectious diseases are associated with population density [3], therefore the increased odds of AGE and URTI in adults aged 18-64 living in rural areas does not fit with previous research. A possible explanation may be related to food-borne illness. For example, incidence of food poisoning caused by certain bacteria is increased in those with high SES[34]. Risk factors for these bacteria include eating restaurant-prepared food, eating undercooked food, drinking raw milk, having contact with farm animals, and travelling abroad[35, 36], factors that are associated with higher SES groups[37-39].

Implications of the findings
Living in a conurbation leads to an increased risk of allergic rhinitis, URTI and AGE in all people, and an increased risk of URTI, LRTI, asthma and AGE in children. These results are in line with previous research as densely populated areas have been associated with rapid spread of infectious diseases such as the SARS virus and avian flu [3]. Population density and traffic in conurbations may increase the rates of allergic rhinitis and asthma [4-6].

For allergic conditions such as rhinitis and asthma, pollution in conurbations may be important [4-6]. Increasing the number of green spaces may also be important[40] as they improve the environment[41], and can decrease rates of asthma[42, 43], and allergic rhinitis[44, 45].
Many of our findings are compatible with the Marmot review found that in England, people living in the poorest neighbourhoods will, on average, die seven years earlier than people living in the richest neighbourhoods[46]. Black and Asian people are more likely to report poorer health and have more long term health conditions than white British people [47].

**Strengths and Limitations**
The data are derived from a network of general practitioners where the population in question is large and is representative of the whole of England. This large and representative population allows us to link morbidity to ethnicity, living environment and SES. Patterns found from this dataset can be applied to the whole population.

Not everyone who has infectious or allergic diseases will go to their general practice. Although we work hard to ensure accuracy of our data, there will be investigable errors and failure to record.

**Conclusion**
Overall, we found different allergic and infectious conditions were associated with rural, urban and conurbation living. Longitudinal study of RCGP RSC data may provide insights, particularly around changes in emissions or other variations in exposure on the effect of environment on allergic and infectious conditions. Living in a conurbation is associated with increased rates of allergic rhinitis, URTI and AGE, though with the exception of allergic rhinitis the results our annual report data are not unequivocally tipped towards the health benefits of living at one level of population density.
### List of abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AF</td>
<td>Atrial fibrillation</td>
</tr>
<tr>
<td>AGE</td>
<td>Acute gastroenteritis</td>
</tr>
<tr>
<td>AR</td>
<td>Allergic rhinitis</td>
</tr>
<tr>
<td>CI</td>
<td>Confidence Interval</td>
</tr>
<tr>
<td>CIRC</td>
<td>Clinical Innovation and Research Centre</td>
</tr>
<tr>
<td>CKD</td>
<td>Chronic kidney disease</td>
</tr>
<tr>
<td>COPD</td>
<td>Chronic obstructive pulmonary disease</td>
</tr>
<tr>
<td>CTV3</td>
<td>Clinical Terms version 3</td>
</tr>
<tr>
<td>IMD</td>
<td>Index of Multiple Deprivation</td>
</tr>
<tr>
<td>LRTI</td>
<td>Lower respiratory tract infections</td>
</tr>
<tr>
<td>LSOA</td>
<td>Lower super output area</td>
</tr>
<tr>
<td>OR</td>
<td>Odds ratio</td>
</tr>
<tr>
<td>ONS</td>
<td>Office National Statistics</td>
</tr>
<tr>
<td>RCGP</td>
<td>Royal College of General Practitioners</td>
</tr>
<tr>
<td>RSC</td>
<td>Research and Surveillance Centre</td>
</tr>
<tr>
<td>SES</td>
<td>Socioeconomic Status</td>
</tr>
<tr>
<td>URTI</td>
<td>Upper respiratory tract infections</td>
</tr>
<tr>
<td>UTI</td>
<td>Urinary tract infection</td>
</tr>
</tbody>
</table>
Declarations

Ethical considerations:
Disease surveillance is part of standard health service activity, so no specific ethical approval was needed. Data are pseudonymised as close to source as possible and no personal identifiers are held on the RCGP RSC secure network at the University of Surrey. We do not process the data of patients who have an “opt out” code (2.2% of the RCGP RSC population).

Consent for publication:
Not applicable, this manuscript does not contain any individual person’s data.

Availability of data and materials:
All data generated or analysed during this study are included in this published article and its supplementary information files.

Competing interests:
Simon de Lusignan is the Medical Director of the RCGP Research and Surveillance Centre

Authors contributions:
1. Simon de Lusignan – Created the idea for the study, proof read the work. Director, guarantor for these data, assisted with clinical knowledge, system design and problem solving.
2. Chris McGee – Carried out data extraction and statistical analysis for this study and the supplementary report. Drafted the introduction, method and results section.
3. Rebecca Webb – Edited introduction, method, results sections and wrote the discussion. Formatted the manuscript.
4. Mark Joy – Designed the statistical analysis method to use for this study.
5. Alex Elliot – reviewed the manuscript
6. Gillian Smith – reviewed the manuscript
7. Rachel Byford – Designed and developed much of the database structure and carried out much of the data extraction for this report.
8. Ivelina Yonova – liaison with practices and co-ordination.
10. Filipa Ferreira – Project manager
11. Imran Rafi - Joint Medical Director RCGP Clinical Innovation and Research

Acknowledgements:
Patients who consented to providing virology and other specimens in RCGP RSC practices, our member practices, Apollo Medical Systems for managing secure data extraction. Professor Mitch Blair for encouragement and support. Nick Andrews for helpful comments on the manuscript.

Funding
Public Health England are the principal funders of the RCGP RSC.

Data Sharing Statement
Data is shared in a way which safeguards the confidentiality and anonymity of participants. Requests for access to data should be addressed to the data custodian of this study, Prof Simon de Lusignan
References


