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Early View

Original article

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Changing prevalence of current asthma and inhaled corticosteroid treatment in the UK: population based cohort 2006 to 2016

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Abstract

BACKGROUND:

Asthma is the most common respiratory disorder in the UK, yet we have incomplete knowledge on the prevalence of current disease, treatment and exacerbations.

METHODS:

We used UK electronic healthcare records, 2006 to 2016, to estimate the prevalence of current asthma by year, gender and age (<5, 5-11, 12-17, 18-24, 25-54 and ≥55 years), and the proportion prescribed inhaled corticosteroids (ICS) and additional asthma-therapy, treated for exacerbations and other asthma care markers.

RESULTS:

Overall current asthma prevalence was 6.5% in 2016 (7.2% in 2006). Prevalence fell in those under 45 years. The lowest prevalence and largest absolute decrease was in children under 5-years. In 2016, 80% of current asthma patients were managed on ICS, (65% in 2006); this increase occurred in all ages, primarily due to an increase in low-dose ICS. During this time there was an increase in all age-groups in the proportion prescribed additional asthma-therapy, treated for an exacerbation within primary care, given an annual asthma review or management plan. Hospitalised exacerbations showed minimal change over time.

CONCLUSION:

Asthma remains highly prevalent and a significant healthcare burden. In those with a diagnosis, there was an increase in ICS prescriptions and treatment of exacerbations across all age-groups. This may reflect a trend towards more aggressive asthma management within primary care. An apparent decline in prevalence was observed in those aged under 45 years, particularly in children under 5 years.

Introduction

Surveys of asthma prevalence have shown the UK has one of the highest national rates of self-reported adult and childhood asthma in Europe (1,2). Due to the considerable cost of treatment (inhalers are some of the most expensive drugs in the National Health Service budget), and high prevalence, asthma causes a significant healthcare burden in the UK (3,4). To understand the current

healthcare burden of asthma, and the projected future burden, it is important to capture recent temporal trends in prevalence of current disease, exacerbations and disease management. There are several methods that have been used to estimate asthma prevalence, each with their own strengths and limitations. One commonly used method is surveys, but these usually only cover geographically discrete areas, are relatively small in size, focus on specific age groups and rely on self-reporting of symptoms or doctor diagnoses. Many global surveys include a few specific locations in the UK (for example, the International Study of Asthma and Allergies in Childhood) but the only surveys explicitly carried out across the UK are the National Health surveys (including Health Survey for England, and the Scottish, Welsh and Northern Ireland Health Surveys).

An alternative source from which to estimate prevalence is to use routinely collected electronic healthcare records (EHR); providing data on doctor-diagnosed asthma. This resource is potentially useful to generate estimates of current asthma prevalence as information on doctor diagnosis of symptoms was recorded at the time of the GP consultation. It is less suitable for estimates of lifetime ('ever') prevalence due to lack of complete lifetime data. As many children with asthma go into remission, and some adults develop asthma *de novo*, this distinction is relevant in respect of current healthcare burden (5–10). Another advantage of EHR is that it can provide accurate data on GP prescriptions.

The aim of this study was to use longitudinal EHR to estimate the prevalence of doctor-diagnosed current asthma, asthma medication prescriptions and asthma exacerbations, between 2006 and 2016. To the authors' best knowledge this study involves the single largest database used to estimate prevalence, and treatment, of asthma in the UK.

Methods

Data sources

Clinical Practice Research Datalink (CPRD) is one of the world's largest databases of longitudinal healthcare records, collecting patient data from a network of general practitioner practices across the UK. It covers approximately 9% of the population and is nationally representative for age, gender, ethnicity and body mass index (11–13); just over 60% of practices have patient-level linkage to Hospital Episode Statistics (HES) data. HES contains data (collected during a visit to an English NHS hospital) on admission date and reason for admission, using ICD-10 codes; in this study data on all hospital admissions for asthma were collected.

Study population to determine prevalence denominator

Population was the whole of CPRD that had research acceptable healthcare records according to CPRD quality control, contributing data on a specific date in each year between 1st January 2006 and 31st December 2016. Of the 727 practices contributing data, 325 (45%) continuously contributed throughout the study period, these practices have been termed 'loyal practices'.

Asthma population

Asthma patients were identified using validated asthma Read Codes (the clinical terminology system used by GP practices and CPRD)(14); infants with preschool wheeze were therefore not included as having asthma unless specifically labelled as asthma. Asthma patients' with a co-diagnosis of COPD were identified using validated Read codes and excluded (15). Patient data were only eligible at the latest date of: becoming research acceptable according to CPRD quality control, being continuously

in a CPRD practice, or having their first asthma Read code. Patients' stopped contributing data at the earliest of the date of death, transfer out of CPRD practice, practice's last collection date or their 'last current asthma date'. An age-dependent assumption was made to define when a patient no longer had current asthma, based on their last contact with the GP practice in respect of their asthma, and their last asthma prescription date (if receiving medication). Therefore, the 'last current asthma date' was defined as the latest of either (a) the patient's last specific asthma Read code date (+ 12 months if aged 5 to 18 years; + 24 months if aged ≥18 years) or (b) the patient's last asthma medication prescription date (+ 6 months if aged <5 years; + 12 months if aged ≥5 years). Asthma medications included were short-acting beta-agonist (SABA), inhaled corticosteroid (ICS), long-acting beta2-agonist (LABA), combination LABA-ICS, leukotriene receptor antagonist (LTRA) or theophylline.

Other variables

The main asthma guidelines used in the UK are the BTS/SIGN British Guideline on the Management of Asthma (16). Age-groups were divided according to the categories used in these guidelines, under 5 years old, 5–12 years old, adolescents, and adults; adults were further divided into two due to the possible impact from COPD after 55 years old. For more detailed prevalence estimates the adult cohort was further broken down by 10-year age groups.

ICS included single component ICS or LABA-ICS combinations; the dose was defined as the maximum inhaler dose prescribed. The 2016 BTS asthma guidelines were used to define the categorisation of ICS dosage; categories were fine dose beclometasone dipropionate equivalent: very low dose (<200mcg), low dose (200-400mcg for children, ≤799mcg for adolescents/adults), medium dose (800-1599mcg) and high dose (≥1600 mcg) (Table 9, adults and adolescents inhaler doses, & Table 10, children under 10 years old inhaler doses) (16). The cut-off for an infrequent ICS prescription was arbitrarily defined as ≤2 prescriptions/year. Add-on therapy was defined as any of the following: LABA, LTRA, long-acting muscarinic antagonist (LAMA) or theophylline. An annual asthma review and asthma management plan were identified using relevant Read codes (available on request).

Asthma exacerbations were categorised as (a) treated within primary care with a short course of oral corticosteroids (not during an annual review or rescue packs) (b) required an over-night hospital stay (identified using HES data). Asthma patients only seen in Accident & Emergency were not included as this data was not complete during the study period.

Prevalence calculation

Point prevalence was calculated by dividing the numerator by the denominator. The annual numerator was the total number of patients' at a randomly set date (1st February) that had (a) their first validated asthma Read code on or before that date and (b) their 'last current asthma date' was on or after that date and (c) did not have COPD on or before that date. The denominator was all research acceptable patients in CPRD on that set date. A sensitivity analysis was performed including patients with a COPD diagnosis. A sensitivity analysis was performed including only loyal GP practices. Confidence intervals were calculated and are shown in the supplementary tables. Linear regression was used to test the statistical significance of change in annual prevalence. All analyses were conducted using Stata version 14 (Texas).

Ethical approval

The protocol for this research was approved by the Independent Scientific Advisory Committee (ISAC) for MHRA Database Research (protocol 18_055R), the approved protocol was made available during peer review. Generic ethical approval for observational research using the CPRD with

approval from ISAC has been granted by a Health Research Authority Research Ethics Committee (East Midlands – Derby, REC reference number 05/MRE04/87). Linked pseudonymised data were provided for this study by CPRD. Data is linked by NHS Digital, the statutory trusted third party for linking data, using identifiable data held only by NHS Digital. Select general practices consent to this process at a practice level with individual patients having the right to opt-out.

Results

Prevalence of current asthma

The prevalence of current asthma was 7.2% in 2006, gradually falling to 6.5% in 2016 (Figure 1 & Supplementary Table 1). The overall prevalence was lower in males than in females (2016: males=5.8%, females=7.2%); and decreased in both gender over the study period. Differences in prevalence by gender were dependent on age; prevalence was higher in males until adolescence, thereafter it was higher in females (Figure 2).

In 2016, the under 5-years had the lowest prevalence of current asthma (1.6%), and the 13-17 year olds had the highest prevalence of current asthma (8.0%) (Figure 3 & Supplementary Table 2). Prevalence gradually fell over the 10 year period in all age groups, except in those ≥55 years where it slightly increased. The trend over time was similar in male and female asthma patients in all age groups (Supplementary Figure 1). Further breakdown, into 10-year age groups, showed that the prevalence declined in each age-group over time, until the 45-54 years age-group; in all age-groups thereafter prevalence slightly increased (Supplementary Figure 2). The steepest decline occurred in the under 5-years age group, the decline in the 25-55 years age group was minimal (Figure 3).

Prevalence estimates in only loyal GP practices exhibited the same magnitude and trends as estimates in all GP practices (Supplementary Tables 1-2). Including patients with a COPD diagnosis, as would be expected, exhibited a higher prevalence; the temporal trend declined, therefore, the opposite of when COPD patients were excluded (2006: ≥55 years=8.6%; 2016: ≥55 years=8.3%, Supplementary Table 3).

Changes in asthma management

The percentage of current asthma patients prescribed an ICS in 2006 was 65%, compared to 80% in 2016. Throughout follow-up, the under 5-years and ≥55 years, had the highest proportion managed on an ICS, whereas, the 12-17 year olds had the lowest proportion. The proportion prescribed an ICS increased over time most markedly in the under 5-year, and least in the ≥55 years (relative increase, between 2006 and 2016: <5 years=47.5%; 5-11 years=30%; 12-17 years=27.7%; 18-54 years=26.5%; ≥55 years=20.7%) (Figure 4 & Supplementary Table 4). There was very little difference between percentages from patients in loyal GP practices, compared to those in all GP practices (Supplementary Table 4). Gender had little effect on receiving ICS or not, or the dose prescribed (data not shown).

The proportion of patients receiving infrequent ICS prescriptions (≤2 per year) fell over time and was highest in the 12-17 year olds and 5-11 year olds (Supplementary Figure 3).

The proportion being prescribed asthma add-on therapy increased in all age groups; this increase occurred for all add-on therapies, except theophylline, which remained stable (Supplementary Figure 4).

There was a gradual increase in all age groups in the percentage having an annual asthma review or receiving an asthma management plan (annual asthma review: 2006=38.6%, 2016=43.7%; asthma management plan 2006=6.2%, 2016=19.7%; Supplementary Figure 5).

Temporal changes in exacerbations

The proportion of exacerbations treated in primary care increased over time, the biggest rise occurred in the under 5-years and smallest increase in those over 55-years; results were comparable between all GP practices and only loyal GP practices (Figure 5 & Supplementary Table 5). There was little change in the proportion of over-night hospitalised exacerbations, except for an increase in children aged under-5 years (Supplementary Figure 6).

Discussion

Our study shows that in 2016, just under 6.5% of the CPRD population excluding COPD patients had current asthma (7.1% including COPD patients). The prevalence had declined slightly over the previous 10-years and was most notable in patients aged under 5-years old, with little change over time in patients aged between 25 and 55 years. In keeping with previous findings, we also found that asthma is more prevalent in males up until around puberty, after which it is more prevalent in females (17,18,20,21).

Comparing findings to previous studies

Similar studies, conducted using primary care EHR data, estimated the lifetime ('ever') prevalence of doctor-diagnosed asthma in England (2001 to 2005) and the UK (2004 to 2012) (18,19). Both these studies reported a steady increase in lifetime prevalence in those aged over 16 years, but a decrease in incident asthma in all ages. These studies used information from databases that were unlikely to cover the entire lifetime of individuals included, so are likely to have under-estimated the true lifetime prevalence which might explain why their lifetime estimates were only 3 to 4% higher than our current prevalence estimates.

Survey data (using self-reports of symptoms, doctor-diagnosis and treatment) from the UK have found approximately double the prevalence of 'asthma', in all age groups, compared to our estimates (3,19,20,22–27). However, the four established asthma surveys that have been used in the UK defined asthma by the presence of self-reported wheeze, which over-estimates the presence of clinical asthma, which may be related to other factors (interpretation of 'wheeze') and other pathologies. Furthermore, changes in prevalence of wheeze may be correlated with increased symptom awareness, better education or augmented readiness to report wheeze (31). Surveys, may also overestimate the prevalence of disease because of low response rates which may bias the study (patients with symptoms may be more likely to respond to a survey) (33).

Unlike surveys, which are often only collected from specific centres, and therefore not generalisable to the whole of the UK (20,22,23,25,27), this study has wide national geographical coverage with prevalence estimates based on large samples. Lastly, previous surveys and EHR data that included older patients, did not address the difficulty of misclassification with COPD. Interestingly, we found an increasing prevalence of asthma only diagnoses in older patients, whereas prevalence of asthma with or without COPD diagnosis showed a decreasing prevalence. One explanation might be that primary care physicians are less likely now to label all obstructive airways disease in older patients as COPD, perhaps due to increasing awareness of late-onset adult asthma or increased use of the lower limit of predicted normal in spirometry (34).

Comparison to recent European estimates

Unlike this study, other studies with up-to-date estimates of prevalence in Western European countries have found a rise in current asthma prevalence over the past 10-years. The latest estimates for Sweden were derived from repeated cross-sectional self-reporting surveys, and found an increase from 9.9% to 10.6% in adult asthma, between 2006 and 2016, although it is notable that only around half of those surveyed responded (35). The most recent prevalence estimates for Finland, of persistent asthma only, obtained from a social insurance registry, showed an increase between 2000 and 2013, of 3.6% to 4.4%, this could be related to the increased recognition of disease due to their national-asthma program (32).

Strengths and limitations of EHR data

Studies using survey data of asthma symptoms as compared to EHR data of doctor-diagnosed asthma provide information on different aspects, each with their own advantages and disadvantages. Two key advantages of EHR is the probable increase in diagnostic accuracy and reduction of recall bias, although there still remains potential for misclassification due to the clinical difficulty in diagnosing asthma in primary care, particularly in young children and adult smokers. Another limitation of EHR is that some people may not report their symptoms to their doctor, due to an unwillingness or a lack of perception of the meaning of their symptoms; a distinct advantage of self-reporting of wheeze in survey data. Due to the complexity of defining asthma, and lack of a gold-standard diagnostic test, patients may be under or over-diagnosed. Factors associated with under-diagnosis in primary care include underreporting of symptoms, poor diagnostic sensitivity of spirometry and lack of access to high specificity diagnostic tests (34); this diagnostic challenge is potentially most apparent in the youngest and oldest populations.

Limitations of this study

We have used a validated definition of asthma, but had to make assumptions to define current asthma (based on the patient's last Read Code and asthma medication prescription). It is probable our case definition did not identify all individuals with current asthma; missed individuals were likely to have such mild current asthma that little doctor-contact had occurred. In the UK, the Quality and Outcomes Framework (QOF) is a system used to financially reward GPs for implementing good practice; changes in these QOFs over time could influence GP coding, fortunately, the QOFs for asthma did not change over the study period. Reassuringly, prevalence and treatment trends were the same for practices continuously in CPRD to those that entered CPRD later during the study period; however, it is possible CPRD practices in general are more up-to-date in terms of clinical practice and following of guidelines recommendations, than non-CPRD practices.

Another potential limitation was the assumption that all courses of oral corticosteroids prescribed during an annual asthma review (accounting for <2% of short course of corticosteroids) were kept for rescue packs, and therefore excluded in our analysis. It is also not known if any of the prescriptions were actually dispensed, and even less is known if they were adhered to or not; the increase in ICS frequency could suggest an increase in adherence or a change in prescription patterns.

Potential explanations for the observed findings

Our observation that the proportion of patients managed on an ICS has increased, alongside an increase in more regular ICS prescriptions, add-on asthma therapy and asthma management plans, suggests more aggressive management of disease within primary care. This is also supported by the increase in treatment for exacerbations in primary care. Alternatively, alongside the decrease in

prevalence in children and adults aged up to 45 years, these findings could suggest that there has been increasing reticence to give a diagnosis of asthma. Diagnostic pathways in UK asthma guidelines (BTS/SIGN British Guideline on the Management of Asthma) did not change during the time period of the study, but rely greatly upon clinical judgement, and cultural changes may have led to an increasing reluctance to formally diagnose asthma without higher clinical certainty. The reduction of infrequent ICS prescriptions conceivably has several factors at play, including changes over time in adherence or diagnostic improvements, alternatively, it is also in keeping with the other changes observed to suggest alterations in the primary care management of disease, and/or labelling of mildly symptomatic patients. The most rapid increase in ICS use was in children aged under 5 years, predominantly the increase was in low dose ICS; this supports the concept that doctors have become disinclined to give a diagnosis to pre-schoolers with wheeze (perhaps using terms such as 'preschool wheeze' instead), thus those that actually receive a formal diagnosis are more likely to require pharmacological treatment. A seemingly less likely explanation for this pattern is that the natural history of asthma has changed in the UK over the past 10 years, such that it now presents in a more severe form.

In 2016, the BTS/SIGN guidelines changed to recommend starting low dose ICS in newly diagnosed asthma patients, previously patients were commenced on SABA as needed. Our findings indicate this new approach was starting to infiltrate primary care even before the release of the latest guidelines.

Implications of these findings

Globally, survey data has been instrumental in our appreciation of asthma epidemiology, but with the availability of large volume EHR data we can now obtain an alternative, and arguably more relevant estimation of prevalence when such data is sufficiently and accurately recorded. In this study we have used the largest source of EHR data from the UK to describe changes in asthma prevalence and management over the past 10 years. We have shown that the prevalence of current disease is decreasing in the younger age-groups. Overall, patients are increasingly managed with inhaled corticosteroids and add-on therapies; concurrently, the number of exacerbations treated in primary care has risen. These findings suggest a trend towards more aggressive asthma management, and may indicate a reticence to give a formal asthma diagnosis until a certain level of disease severity.

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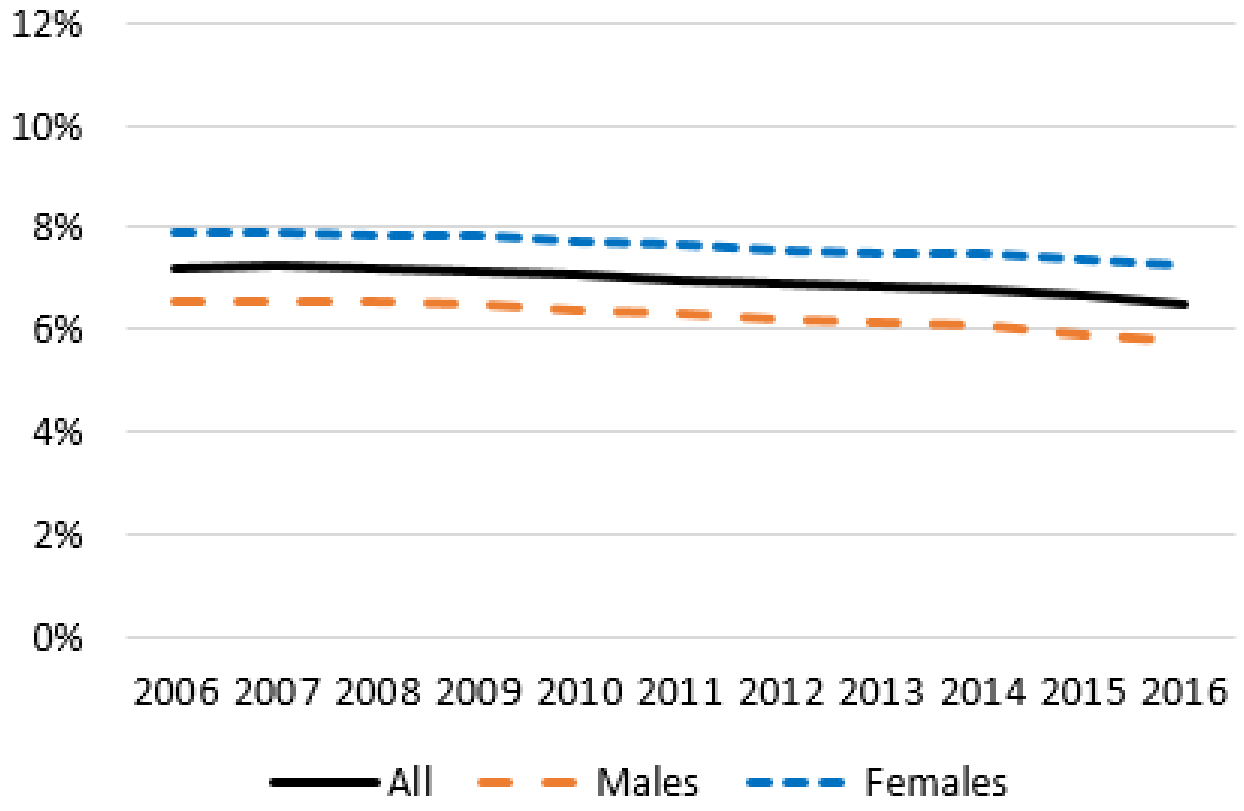
Figure 1. UK current asthma prevalence

Figure 2. Prevalence by age and gender, in 2006 (full bars) and 2016 (spotted bars)

Figure 3. Asthma prevalence by age groups

Figure 4. Temporal changes of proportion in each ICS dose category by age. ICS = inhaled corticosteroid, VLD = very low dose (<200mcg), LD = low dose (200-400mcg for children, <800mcg for adolescents/adults), MD = medium dose (800-1599mcg), HD = high dose (≥1600 mcg).

Figure 5. Temporal changes of exacerbations over time and by age. Proportion of patients with at least 1 exacerbation treated within primary care in the year shown.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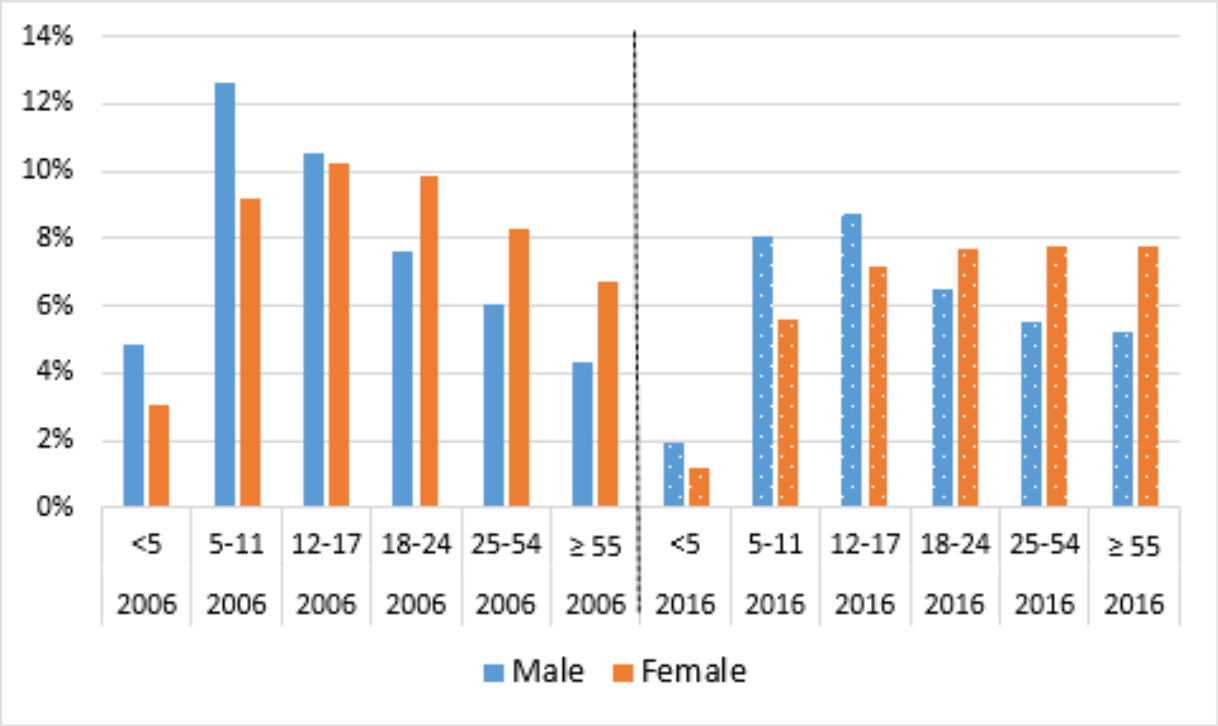
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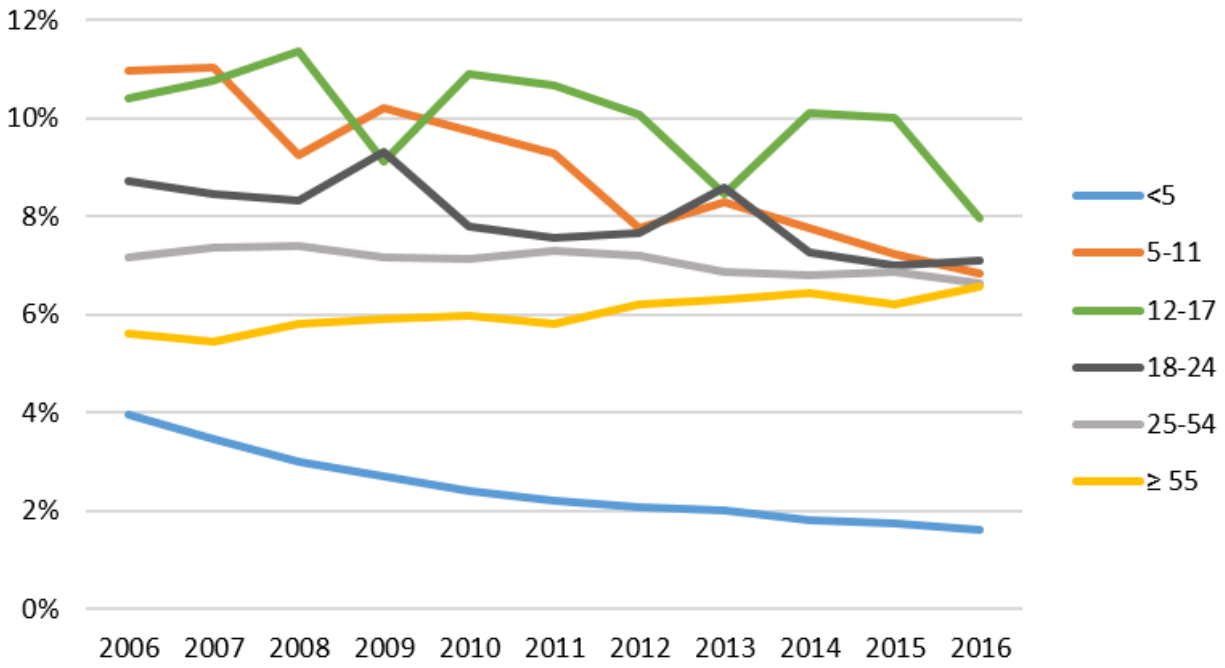
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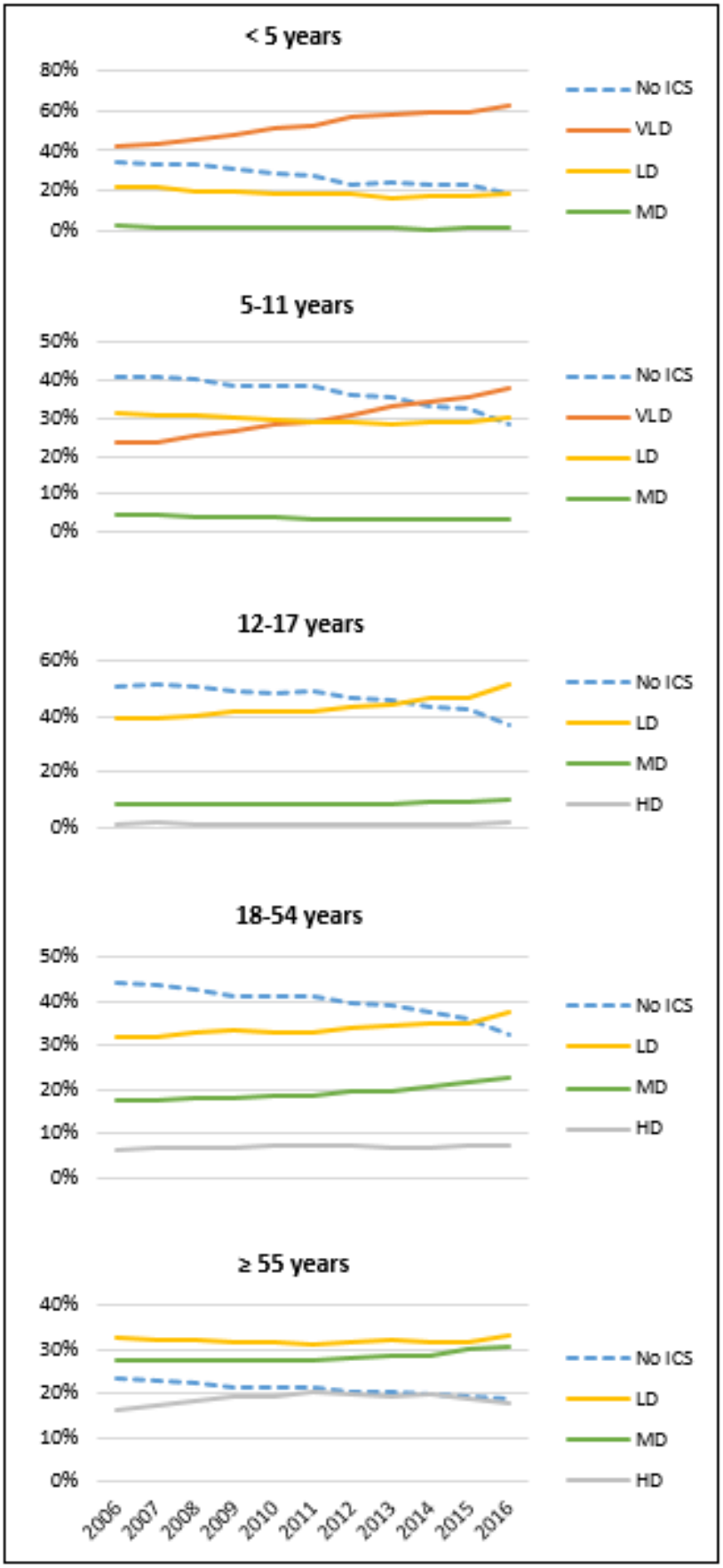
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No ICS
VLD
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No ICS
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18-54 years
50%
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No ICS
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≥ 55 years
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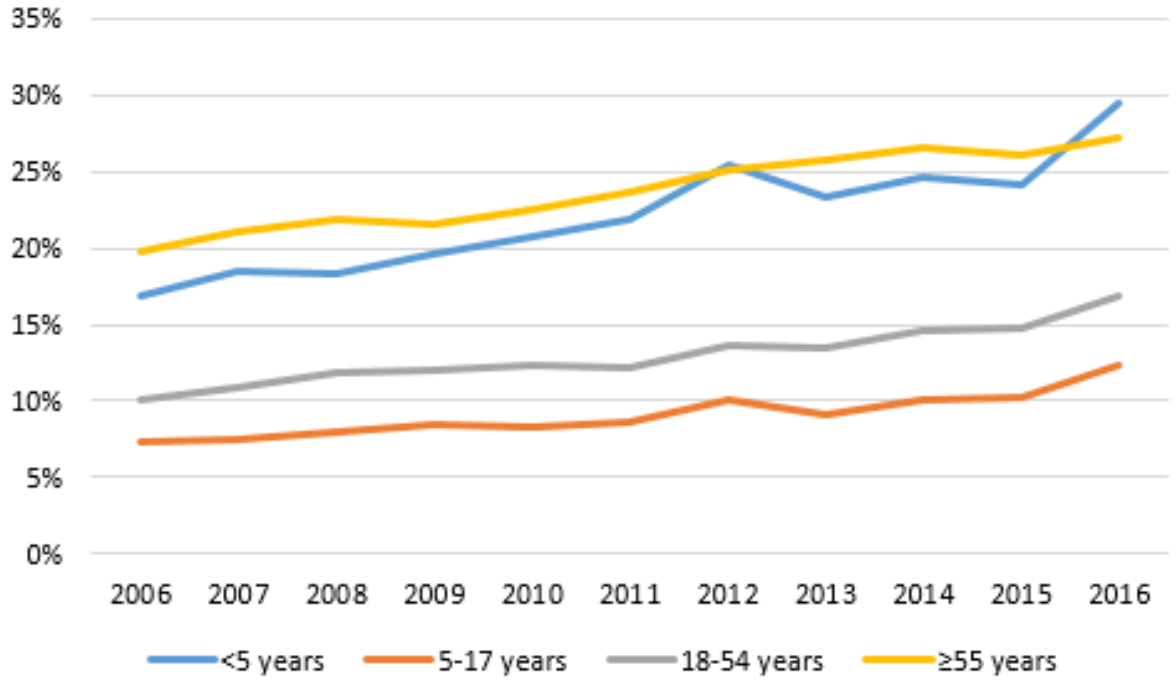
35%
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2011
2012
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2016
<5 years
5-17 years
18-54 years
≥55 years

Supplementary Table 1. Prevalence of total population and by gender and year

Year	Total Population, percent (95% CI)	Males, percent (95% CI)	Females, percent (95% CI)
All GP practices			
2006	7.22 (7.22-7.22)	6.56 (6.56-6.56)	7.88 (7.88-7.88)
2007	7.23 (7.23-7.23)	6.56 (6.56-6.56)	7.90 (7.90-7.90)
2008	7.20 (7.20-7.20)	6.52 (6.52-6.52)	7.87 (7.87-7.87)
2009	7.15 (7.15-7.15)	6.48 (6.48-6.48)	7.82 (7.82-7.82)
2010	7.07 (7.07-7.07)	6.40 (6.40-6.40)	7.74 (7.74-7.74)
2011	6.99 (6.99-6.99)	6.32 (6.32-6.32)	7.65 (7.65-7.65)
2012	6.91 (6.91-6.91)	6.22 (6.22-6.22)	7.58 (7.58-7.58)
2013	6.82 (6.82-6.82)	6.13 (6.13-6.13)	7.50 (7.50-7.50)
2014	6.77 (6.77-6.77)	6.06 (6.06-6.06)	7.47 (7.47-7.47)
2015	6.65 (6.65-6.65)	5.93 (5.93-5.93)	7.36 (7.36-7.36)
2016	6.52 (6.52-6.52)	5.79 (5.79-5.79)	7.23 (7.23-7.23)
Loyal GP practices only			
2006	7.12 (7.12-7.12)	6.51 (6.51-6.51)	7.73 (7.73-7.73)
2007	7.16 (7.16-7.16)	6.53 (6.52-6.53)	7.80 (7.79-7.80)
2008	7.15 (7.15-7.15)	6.50 (6.50-6.51)	7.79 (7.79-7.79)
2009	7.14 (7.14-7.14)	6.49 (6.49-6.49)	7.78 (7.78-7.78)
2010	7.11 (7.11-7.11)	6.45 (6.45-6.45)	7.76 (7.76-7.77)
2011	7.07 (7.07-7.07)	6.41 (6.41-6.41)	7.72 (7.72-7.72)
2012	7.01 (7.01-7.01)	6.34 (6.33-6.34)	7.68 (7.68-7.68)
2013	7.00 (7.00-7.00)	6.31 (6.31-6.31)	7.67 (7.66-7.67)
2014	6.97 (6.97-6.97)	6.26 (6.26-6.26)	7.67 (7.67-7.67)
2015	6.84 (6.84-6.84)	6.11 (6.11-6.11)	7.55 (7.55-7.55)
2016	6.53 (6.53-6.53)	5.80 (5.80-5.81)	7.24 (7.24-7.24)

Supplementary Table 2. Prevalence by age group and year

Year	<5 years, percent (95% CI)	5-11 years, percent (95% CI)	12-17 years, percent (95% CI)	18-24 years, percent (95% CI)	25-54 years, percent (95% CI)	≥55 years, percent (95% CI)
All GP practices in CPRD						
2006	3.96 (3.96-3.96)	10.98 (10.98-10.98)	10.4 (10.4-10.41)	8.73 (8.73-8.73)	7.17 (7.17-7.17)	5.62 (5.62-5.62)
2007	3.46 (3.46-3.46)	11.03 (11.03-11.03)	10.76 (10.76-10.76)	8.44 (8.44-8.44)	7.37 (7.37-7.37)	5.46 (5.46-5.46)
2008	2.99 (2.99-2.99)	9.26 (9.25-9.26)	11.37 (11.37-11.37)	8.34 (8.34-8.34)	7.41 (7.41-7.41)	5.83 (5.83-5.83)
2009	2.72 (2.72-2.72)	10.21 (10.21-10.21)	9.12 (9.12-9.12)	9.32 (9.31-9.32)	7.18 (7.18-7.18)	5.93 (5.93-5.93)
2010	2.42 (2.42-2.42)	9.74 (9.74-9.75)	10.90 (10.90-10.91)	7.81 (7.81-7.81)	7.13 (7.13-7.13)	5.99 (5.99-5.99)
2011	2.22 (2.22-2.22)	9.27 (9.27-9.28)	10.68 (10.68-10.69)	7.57 (7.57-7.57)	7.29 (7.29-7.29)	5.80 (5.80-5.80)
2012	2.09 (2.09-2.09)	7.78 (7.78-7.78)	10.08 (10.08-10.08)	7.66 (7.66-7.66)	7.20 (7.20-7.20)	6.20 (6.20-6.20)
2013	2.03 (2.03-2.03)	8.30 (8.30-8.30)	8.45 (8.45-8.46)	8.57 (8.57-8.57)	6.86 (6.86-6.86)	6.31 (6.31-6.31)
2014	1.82 (1.82-1.82)	7.76 (7.76-7.76)	10.10 (10.10-10.10)	7.27 (7.27-7.27)	6.81 (6.81-6.81)	6.45 (6.45-6.45)
2015	1.75 (1.75-1.75)	7.24 (7.24-7.24)	10.01 (10.01-10.01)	7.00 (7.00-7.00)	6.88 (6.88-6.88)	6.21 (6.21-6.21)
2016	1.60 (1.60-1.60)	6.83 (6.83-6.83)	7.96 (7.96-7.97)	7.09 (7.09-7.09)	6.65 (6.65-6.65)	6.57 (6.57-6.58)
Loyal GP practices only						
2006	4.32 (4.32-4.32)	10.68 (10.68-10.68)	10.38 (10.38-10.38)	8.79 (8.79-8.79)	7.05 (7.05-7.05)	5.50 (5.50-5.50)
2007	3.54 (3.54-3.54)	10.91 (10.91-10.92)	10.77 (10.77-10.77)	8.54 (8.54-8.54)	7.29 (7.29-7.29)	5.36 (5.36-5.36)
2008	2.96 (2.96-2.96)	9.19 (9.19-9.19)	11.46 (11.46-11.47)	8.50 (8.50-8.50)	7.37 (7.37-7.37)	5.72 (5.72-5.72)
2009	2.66 (2.65-2.66)	10.28 (10.28-10.28)	9.04 (9.04-9.04)	9.57 (9.57-9.57)	7.17 (7.17-7.17)	5.85 (5.85-5.85)
2010	2.40 (2.40-2.40)	9.83 (9.83-9.84)	10.96 (10.96-10.96)	8.10 (8.10-8.10)	7.18 (7.18-7.18)	5.95 (5.95-5.95)
2011	2.20 (2.20-2.20)	9.41 (9.41-9.41)	10.70 (10.70-10.70)	7.97 (7.97-7.97)	7.38 (7.38-7.38)	5.79 (5.79-5.79)
2012	2.07 (2.07-2.07)	7.59 (7.59-7.59)	10.62 (10.61-10.62)	8.05 (8.05-8.05)	7.36 (7.36-7.36)	6.21 (6.21-6.21)
2013	2.02 (2.02-2.02)	8.55 (8.55-8.55)	8.36 (8.36-8.36)	9.11 (9.1-9.11)	7.10 (7.10-7.10)	6.36 (6.36-6.36)
2014	1.87 (1.86-1.87)	7.99 (7.99-7.99)	10.13 (10.13-10.14)	7.71 (7.71-7.72)	7.06 (7.06-7.06)	6.56 (6.56-6.56)
2015	1.77 (1.77-1.77)	7.40 (7.40-7.40)	10.26 (10.26-10.26)	7.50 (7.50-7.50)	7.10 (7.10-7.10)	6.30 (6.30-6.30)
2016	1.59 (1.59-1.59)	6.85 (6.85-6.85)	8.05 (8.05-8.05)	7.15 (7.15-7.15)	6.65 (6.65-6.65)	6.59 (6.59-6.59)

Supplementary Table 3. Prevalence of total population and oldest age group, including patients with a COPD co-diagnosis

Year	Total Population N (95% CI)	≥ 55 years N (95% CI)
2006	8.30 (8.30-8.30)	8.56 (8.56-8.56)
2007	8.25 (8.25-8.25)	8.17 (8.17-8.17)
2008	8.17 (8.17-8.17)	8.46 (8.46-8.46)
2009	8.08 (8.08-8.08)	8.43 (8.43-8.43)
2010	7.94 (7.94-7.94)	8.35 (8.35-8.35)
2011	7.83 (7.83-7.83)	8.01 (8.01-8.01)
2012	7.70 (7.70-7.70)	8.34 (8.34-8.34)
2013	7.58 (7.57-7.58)	8.34 (8.34-8.35)
2014	7.50 (7.50-7.50)	8.40 (8.40-8.40)
2015	7.33 (7.33-7.33)	8.00 (8.00-8.00)
2016	7.14 (7.14-7.14)	8.26 (8.25-8.26)

Supplementary Table 4. Proportion of patients in each ICS dose category by age group and year

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
All GP practices											
<5 years (%)											
No ICS	34.3	33.7	32.8	31.1	29.0	27.3	23.5	24.4	22.7	23.2	18.0
VLD	42.2	43.8	45.6	47.9	51.4	52.9	56.8	57.9	59.7	58.9	62.4
LD	21.5	21.8	19.9	19.4	18.1	18.5	18.4	16.4	16.8	16.8	18.6
MD	2.1	1.7	1.7	1.6	1.4	1.3	1.3	1.4	0.9	1.1	1.1
5-11 years (%)											
No ICS	41.0	40.9	40.1	38.8	38.6	38.4	36.1	35.6	33.4	32.6	28.6
VLD	23.3	23.7	25.2	26.8	28.2	29.1	31.1	33.0	34.4	35.3	37.9
LD	31.1	31.0	30.5	30.4	29.5	28.8	29.2	28.1	28.9	28.9	30.4
MD	4.5	4.4	4.2	3.9	3.7	3.6	3.6	3.2	3.3	3.2	3.1
12-17 years (%)											
No ICS	51.2	51.2	50.5	49.0	48.7	49.0	46.8	46.1	43.8	42.6	37.0
LD	39.3	39.3	40.3	41.5	42.1	42.0	43.8	44.5	46.4	47.1	51.8
MD	8.3	8.1	8.0	8.3	8.1	7.9	8.3	8.3	8.6	9.2	9.9
HD	1.3	1.3	1.3	1.2	1.2	1.1	1.1	1.1	1.2	1.2	1.3
18-54 years (%)											
No ICS	44.3	43.6	42.5	41.3	41.1	41.0	39.4	39.2	37.4	36.2	32.6
LD	31.8	32.1	32.8	33.4	33.2	33.0	33.9	34.5	35.0	35.2	37.6
MD	17.4	17.6	18.0	18.3	18.6	18.8	19.6	19.6	20.6	21.5	22.5
HD	6.5	6.7	6.8	7.1	7.2	7.2	7.1	6.8	7.0	7.1	7.4
≥55 years (%)											
No ICS	23.4	22.8	22.2	21.6	21.4	21.2	20.5	20.3	19.9	19.4	18.6
LD	32.9	32.3	32.0	31.9	31.6	31.2	31.5	31.9	31.5	31.9	33.3
MD	27.7	27.7	27.6	27.5	27.6	27.5	28.0	28.4	28.6	30.1	30.7
HD	16.0	17.3	18.1	19.0	19.5	20.1	20.0	19.4	19.9	18.6	17.5
Loyal GP practices only											
< 5 years (%)											
No ICS	35.7	33.8	33.9	31.9	30.2	28.8	25.1	26.3	23.9	23.2	17.6
VLD	39.6	42.6	44.6	47.2	49.9	51.8	55.2	57.0	59.2	59.1	63.5
LD	22.3	21.7	19.6	19.4	18.4	18.0	18.4	15.4	16.1	16.7	17.7
MD	2.5	1.9	1.8	1.6	1.5	1.4	1.4	1.4	0.8	1.1	1.1
5-11 years (%)											
No ICS	41.8	41.8	41.2	39.9	39.8	39.5	37.2	37.3	34.6	32.6	28.9
VLD	22.7	23.5	25.1	26.5	27.8	28.5	30.9	32.7	34.1	35.4	37.9
LD	30.8	30.2	29.5	29.7	28.7	28.3	28.1	26.8	28.0	28.7	30.1
MD	4.6	4.5	4.2	3.8	3.7	3.6	3.7	3.2	3.2	3.1	3.0
12-17 years (%)											
No ICS	52.0	52.5	52.0	50.4	50.0	50.3	48.1	47.4	45.1	42.7	37.2
LD	37.8	37.6	38.5	40.0	40.5	40.5	42.4	43.0	45.2	47.1	51.6
MD	8.8	8.5	8.3	8.4	8.3	8.1	8.4	8.6	8.6	9.2	9.9
HD	1.4	1.5	1.3	1.2	1.2	1.2	1.1	1.0	1.1	1.1	1.3

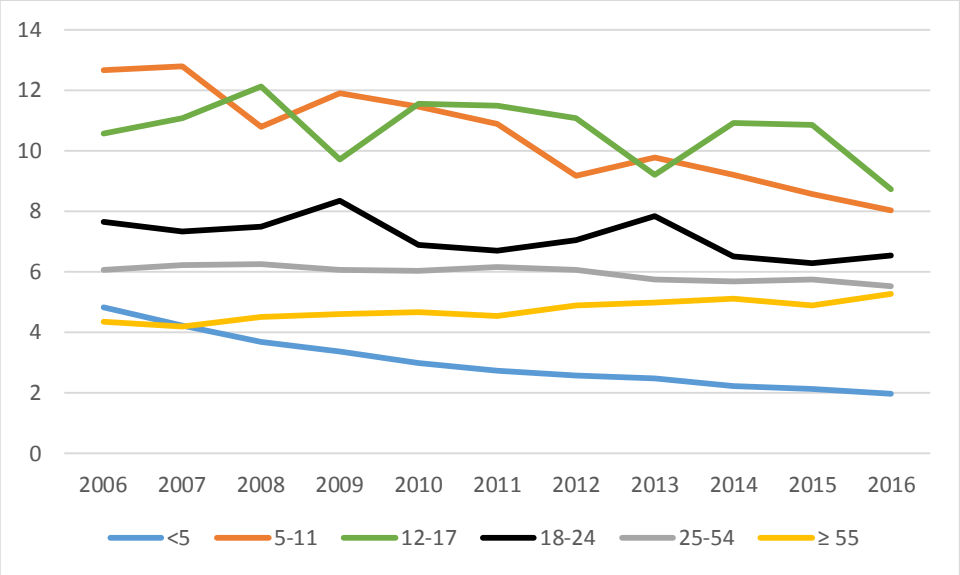
18-54 years (%)											
No ICS	45.3	44.5	43.4	42.2	41.7	41.5	40.3	40.0	38.0	36.4	32.6
LD	30.2	30.4	31.1	31.7	31.8	31.9	32.6	33.4	34.5	35.2	37.7
MD	18.0	18.3	18.6	19.0	19.3	19.3	20.0	19.8	20.6	21.4	22.4
HD	6.6	6.8	6.9	7.1	7.3	7.3	7.1	6.8	7.0	7.1	7.3
≥55 years (%)											
No ICS	24.2	23.4	22.8	22.2	21.8	21.6	21.1	20.9	20.3	19.5	18.5
LD	30.9	30.3	30.2	30.1	29.8	29.5	29.9	30.8	31.0	31.8	33.4
MD	28.6	28.8	28.6	28.5	28.5	28.6	28.9	29.0	29.2	30.0	30.6
HD	16.3	17.6	18.4	19.3	19.8	20.4	20.1	19.3	19.6	18.7	17.4

Supplementary Table 5. Proportion experienced an exacerbation treated within primary care, by age and year

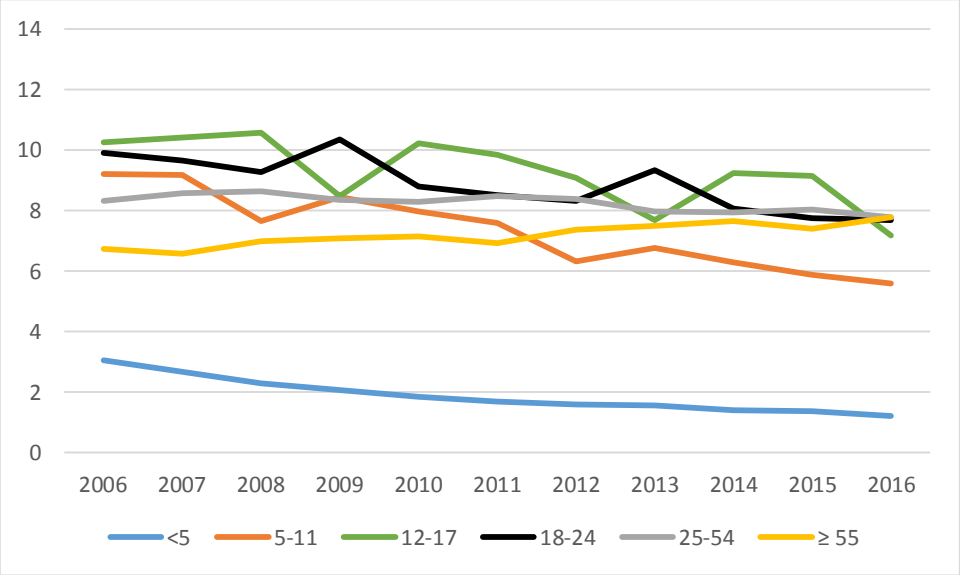
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
All GP practices											
< 5 years	16.9	18.5	18.3	19.6	20.8	21.9	25.5	23.4	24.7	24.1	29.5
5-17 years	7.8	7.6	8.1	8.4	8.3	8.7	10.1	9.1	10	10.3	12.3
18-54 years	10.1	10.9	11.9	11.9	12.3	12.1	13.7	13.4	14.6	14.8	16.8
≥ 55 years	19.8	21.1	21.9	21.6	22.6	23.7	25.2	25.8	26.5	26	27.3
Loyal GP practices only											
<5 years	16.1	17.8	16.4	18.5	19.9	20.9	24.1	22.8	23.4	23.9	28.8
5-17 years	7.1	7.4	7.8	8.2	8.1	8.5	9.8	8.7	9.8	10.1	12.1
18-54 years	9.8	10.6	11.4	11.5	12.0	11.9	13.3	13.0	14.1	14.6	16.6
≥55 years	20.0	20.9	21.6	21.5	22.4	23.3	24.9	25.3	25.9	26.8	28.1

Supplementary Figure 1. Asthma prevalence by gender (a) males (b) females, and age group

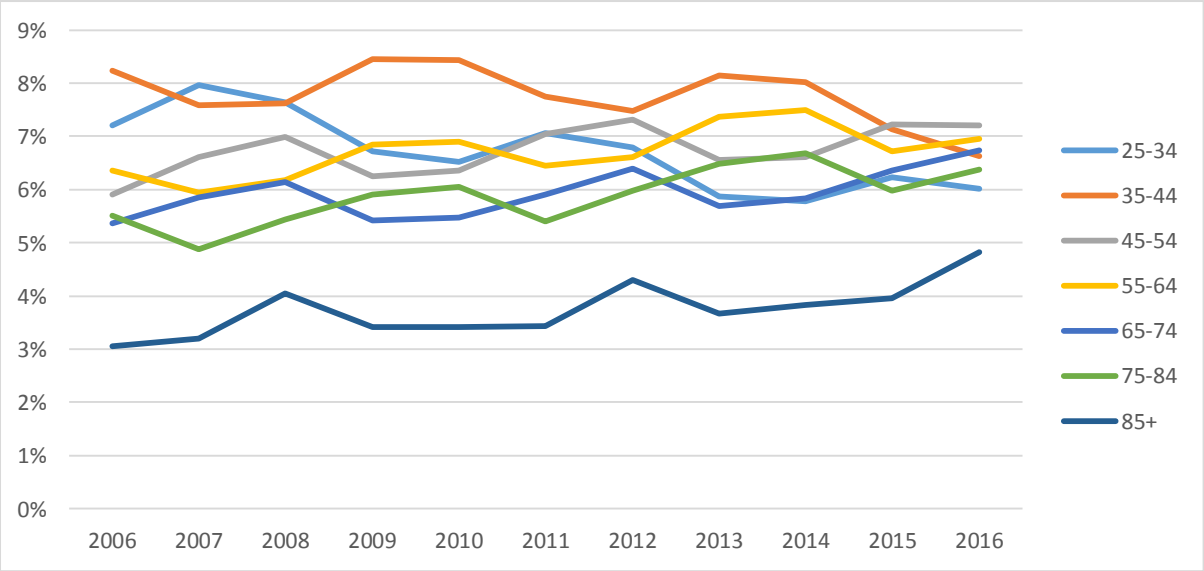
a) Male asthma patients



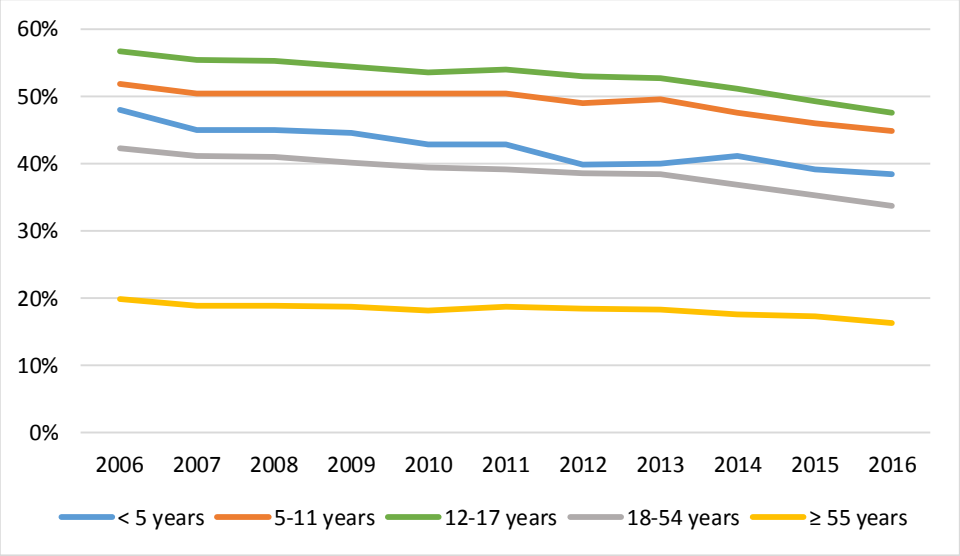
b) Female asthma patients



Supplementary Figure 2. Asthma prevalence by 10-year age groups from age 25 years

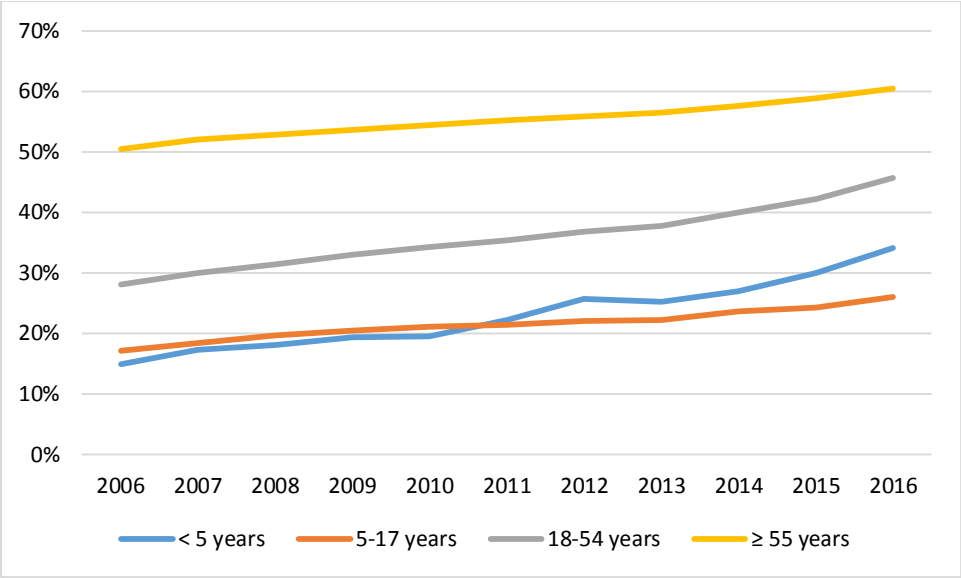


Supplementary Figure 3. Temporal changes in proportion of infrequent ICS users

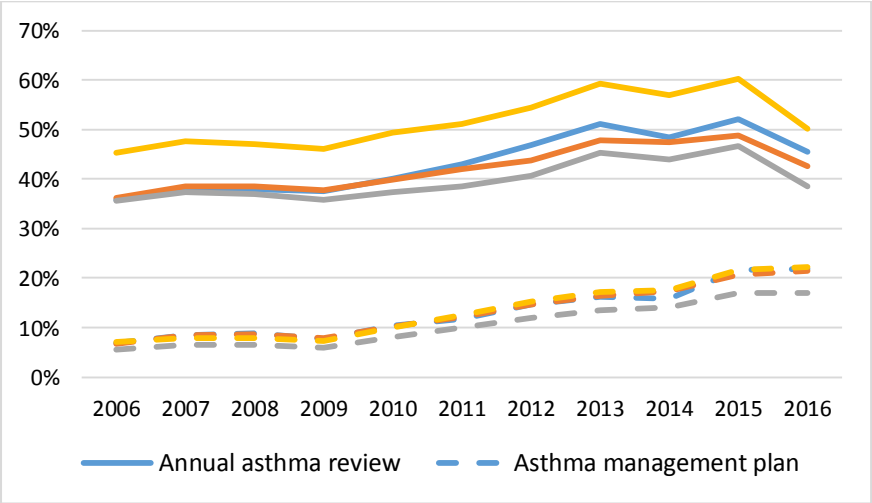


Infrequent ICS was defined as ≤2 prescriptions per year.

Supplementary Figure 4: Temporal changes in Add-On asthma medications

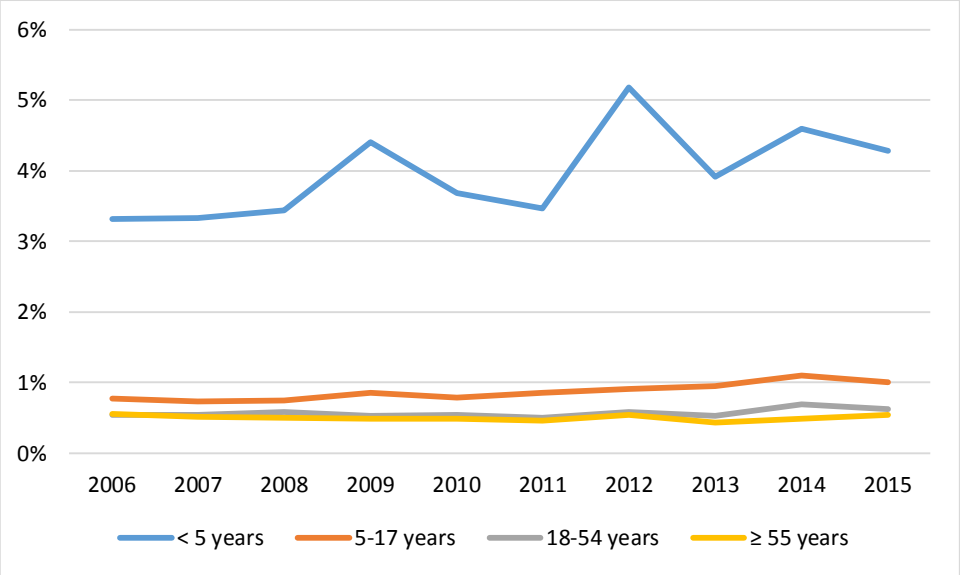


Supplementary Figure 5: Temporal changes in proportion of patients receiving annual asthma reviews and asthma management plans



By age group: <5 years=light blue lines, 5-17 years=dark orange lines, 18-54 years=grey lines, ≥55 years=yellow lines.

Supplementary Figure 6: Temporal changes of hospital exacerbations over time and by age



Proportion of patients with at least 1 exacerbation requiring admission to hospital in the year shown.