

ORIGINAL ARTICLE

Trends in asthma readmissions among children and adolescents over time by age, gender and season

Don Vicendese, BSc(Hons)¹, Michael J. Abramson, MBBS(Hons), BMedSc, PhD, FRACP, FAFPHM², Shyamali C. Dharmage, MBBS, MSc, MD, PhD³, Mimi L. Tang, MBBS, PhD, FRACP, FRCPA, FAAAAI⁴, Katrina J. Allen, MD, PhD, FAAAAI⁴, and Bircan Erbas, BSc(Hons), MSc, PhD¹

¹School of Public Health, La Trobe University, Bundoora, Australia, ²Department of Epidemiology & Preventive Medicine, Monash University, The Alfred Centre, Melbourne, Australia, ³School of Population Health, The University of Melbourne, Victoria, Australia, and ⁴Department of Allergy & Immunology, Royal Children's Hospital, Parkville, Australia

Abstract

Objectives: Little is known about asthma readmissions within 28 days over time by age or gender. We explored trends in childhood asthma hospital readmission rates over time by age, gender and season. **Methods:** Using a large database of 53 156 childhood admissions with a primary diagnosis of asthma from the Department of Health Victoria Australia for 1997–2009, we explored asthma hospital readmissions rates by seasonality, gender and age (2–18 years) using chi square tests, logistic regression models and graphical techniques. **Results:** Approximately 9459 (28%) of the children had two or more admissions over the whole study period, contributing to 55% (29 056/53 156) of all admissions. Approximately 5% of admissions were repeat admission within 28 days. Over time, despite a decline in asthma incidence, the rate of readmission within 28 days increased, particularly in the 2–12 year age groups. Girls were at greater risk of readmission within 28 days (odds ratio [OR] = 1.15; 95% CI: 1.004–1.32; $p = 0.04$) and 12 months (OR = 1.11; 95% CI: 1.05–1.19; $p = 0.001$). Grass pollen season was associated with readmissions within 28 days, but only in boys ($p = 0.01$). **Conclusion:** Over time, despite a fall in asthma incidence, readmission rates for childhood asthma significantly increased in younger age groups with girls at a higher risk of being readmitted than boys. Increased risk of repeat admission for boys was observed during the grass pollen season. These findings highlight high-risk groups, which has implications for both clinical services and patient care. More detailed monitoring of readmission rates amongst various risk groups over time is required.

Keywords

Admission, hospital, monitoring, pollen, time

History

Received 2 October 2013

Revised 3 June 2014

Accepted 15 June 2014

Published online 9 July 2014

Introduction

Australia and New Zealand have the highest prevalence of childhood asthma internationally [1,2]. In Australia, asthma is the most common chronic medical condition and is the most common reason for admission to hospital in children [3]. Children have higher rates of asthma hospitalization than adults and in 2006–2007, children between 0 and 14 years accounted for 58% of total asthma admissions [4]. Child asthma admissions are associated with a reduction in lung function [5] and are themselves a risk factor for readmissions [6]. Asthma readmissions within 28 days are a useful indicator of asthma severity and/or uncontrolled asthma and can also be influenced by a number of factors such as psychological co morbidity, effectiveness of hospital and community health services and developments in hospital admission criteria, diagnostic practice or emergency department management [7].

Seasonality may also be an important marker of total environmental risk [6,8,9]. The synergistic combination of environmental triggers, high allergen exposure and viral infection greatly increases the risk of sensitised children being hospitalised [10]. Trends of childhood asthma readmissions over time have been extensively studied in countries of varying geography, populations and climate [7,11–20]. In contrast, the seasonal trends of childhood asthma readmissions over time and how they vary by age and gender have been understudied [6,9,18,21]. To our knowledge, no study in the Australian context has focused on understanding the seasonal component of childhood asthma readmission within 28 days of the index admission.

Examining the association between seasonality and child asthma readmissions within 28 days may improve understanding of environmental triggers for severe or uncontrolled asthma with repeat admissions as a marker of severity. In this study, we explored trends in rates of childhood asthma readmission in Victoria between 1997 and 2009 by seasonality, age and gender, focusing on readmission occurring within 28 days of the index admission.

Correspondence: Associate Professor Bircan Erbas, School of Public Health, La Trobe University, Bundoora 3086, Victoria, Australia. Tel: +9479 5657. E-mail: b.eras@latrobe.edu.au

Table 1. Characteristics of all admissions, repeat admissions within 28 days and within 1 year.

Characteristics			
Variable	All admissions; N = 53 156	Repeat admissions within 28 days; N = 2 401	Repeat admissions within 1 year; N = 10 263†
Gender			
Male (%)	32 062 (60%)	1358 (57%)	5988 (58%)
Female (%)	21 094 (40%)	1043 (43%)	4275 (42%)
Age in years mean (SD)	6.39 (4.49)	6.83 (4.86)	6.36 (4.37)
Age in years (categories)			
2 to 5 (%)	30 020 (56%)	1305 (54%)	5974 (58%)
6 to 12 (%)	16 104 (30%)	695 (29%)	2946 (29%)
13 to 18 (%)	7032 (13%)	401 (17%)	1343 (13%)
Season			
Autumn (%)	15 618 (29%)	687 (29%)	3133 (31%)
Winter (%)	13 854 (26%)	733 (31%)	2598 (25%)
Spring (%)	12 688 (24%)	591 (25%)	2379 (23%)
Summer (%)	10 996 (21%)	390 (16%)	2153 (21%)
Grass pollen season (Oct–Jan) (%)	14 517 (27%)	649 (27%)	2697 (26%)

†Repeat admissions within 1 year do not include repeat admissions within 28 days.

Methods

Study design

This study was a retrospective analysis of the Victorian Admitted Episodes Data set (VAED) for all child asthma hospital admissions for financial years ending in 1997–2009. These data were collected using a probabilistic linkage algorithm that identified the child (supplied as de-identified code), sex, age in years, diagnostic codes, admission and separation dates. A child was defined as being between the ages of 2 and 18 years inclusive.

Approval was obtained from La Trobe University Human Research Ethics Committee and the Department of Health.

Description of data

The data set consisted of 78 974 admissions, which involved asthma as indicated by ICD-9 codes (493) up to 1998, and ICD-10 codes (J45 or J46) for the remainder of the data to 2009. The data was cleaned of duplicate admissions and ID that showed inconsistent sex and age entries over multiple admissions. This left a total of 76 527 admissions of which 53 156 (69.5%) had a principal diagnosis of asthma, 7413 (9.7%) a secondary diagnosis of asthma, 15 807 (20.7%) an associated diagnosis of asthma and 151 (0.2%) a complication diagnosis of asthma. Only admissions with a principal diagnosis of asthma were used for analyses. Readmissions were defined as a subsequent admission within 28 days of the previous discharge date. The definition of 28 days is based on four studies [22–25]. We defined age categories of 2–5 years, 6–12 years and 13–18 years that reflected developmental milestones and years at school. Grass pollen season was defined between October and January inclusive following Erbas et al. (2012) [26].

Statistical methods

Pearson's chi square tests by gender were used to compare seasonal variation among the age groups. Smooth plots were used to assess changes in seasonality over time and readmission rates by month and year were smoothed using kernel

smoothing techniques. We used logistic regression models adjusted for age group and repeated measures to assess difference in risk between boys and girls for admission and readmission. Yearly population figures for children between 2 and 18 years of age were obtained from the Australian Bureau of Statistics to compute yearly population incidence rates of new asthma admissions. All statistical analyses and tables were done using Stata 10.1 (Statacorp, College Station, TX). Unless otherwise stated, statistical analyses were done at a significance level of 0.05.

Results

There were a total of 53 156 admissions with a primary diagnosis of asthma, generated by 33 559 children who were admitted during the study period (Table 1). Of the total admissions, 40% (21 094/53 156) were girls. Girls were slightly older than boys with median ages of 5 versus 4 years with inter quartile ranges (3–11) and (3–8) respectively ($p < 0.001$). Approximately, 72% of the children had one admission only and 28% had two or more admissions. A logistic regression model showed that the odds ratio (OR) for girls compared to boys to have two or more admissions was 1.07, 95% CI: 1.01–1.13; $p = 0.02$.

All admissions

All admissions peaked in autumn (March to May; 29%) followed by winter (June to August; 26%), spring (September to November; 24%) and summer (December to February; 21%) (a comparison of all admissions between seasons, $p < 0.002$) (Table 1). For all admissions, the associations between season and age group were similar for boys and girls (Table 2). We stratified by each age group and compared the proportions of boys and girls admitted in each season. Significant differences between boys and girls for the 13–18 year age group were observed for all seasons (p values < 0.001) with boys over-represented in autumn (31%) and spring (25%) and under-represented in winter and summer (29% and 16%, respectively). The association between age group and pollen season (defined between October and January inclusive) was significant for boys but not for girls

Table 2. All admissions for the entire study period by gender, age and season.

Age group in years	All admissions							
	Males				Females			
	2–5	6–12	13–18	Season total	2–5	6–12	13–18	Season total
Season	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)
Autumn	5767 (29)	2774 (29)	929 (31) ^a	9470 (30)	3196 (30)	1839 (29)	1113 (28)	6148 (29)
Winter	4770 (25)	2457 (25)	862 (28)	8089 (25)	2775 (26) ^a	1712 (27) ^a	1278 (32) ^a	5765 (27)
Spring	4553 (24)	2480 (26)	750 (25) ^a	7783 (24)	2442 (23)	1564 (24)	899 (22)	4905 (23)
Summer	4242 (22)	2001 (20)	477 (16)	6720 (21)	2275 (21)	1277 (20)	724 (18) ^a	4276 (20)
Age group Total	19332	9712	3018	32062	10688	6392	4014	21094
Grass pollen season	5189 (59)	2854 (32)	822 (9)	8865 ^b	2811 (51)	1763 (30)	1078 (19)	5652

^aStatistically significant greater proportions than other sex for same age group and season.^bAge groups for boys have statistically significant different proportions than expected in grass pollen season.

Table 3. Repeat admissions within 28 days for the entire study period by gender, age and season.

Age group in years	Repeat admissions within 28 days							
	Males				Females			
	2 to 5	6 to 12	13 to 18	Season total	2 to 5	6 to 12	13 to 18	Season total
Season	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)
Autumn	250 (30)	78 (20)	53 (36) [†]	381 (28)*	153 (32)	88 (28) [†]	65 (26)	306 (29)
Winter	242 (29)	122 (32)	45 (30)	409 (30)	133 (28)	115 (37)	76 (30)	324 (31)**
Spring	200 (24)	115 (30) [†]	39 (26)	354 (26)	110 (23)	67 (21)	60 (24)	237 (23)
Summer	137 (17)	66 (17)	11 (7)	214 (16)*	80 (17)	44 (14)	52 (20) [†]	176 (17)
Age group Total	829	381	148	1358	476	314	253	1043
Grass pollen season	213	124	32	369	122	81	77	280

*associations between age group and seasonality among boys $p < 0.001$ autumn and $p = 0.01$ summer.**associations between age group and seasonality among girls for winter $p = 0.03$.[†]significant differences between boys and girls for each season stratified by age group.

($p < 0.001$ and $p = 0.19$, respectively). When we stratified by age group and compared boys and girls admitted during the pollen season, the boys tended to be a little over represented and girls a little under represented for the 6–12 year old group ($p = 0.01$). For 2–5 year olds, similar proportions occurred during the pollen season for boys and girls and for 13–18 year olds.

Readmissions within 28 days

Approximately 5% of children who were admitted (1689/33559) generated 2401 repeat admissions within 28 days. Of the repeat admissions within 28 days, 43.4% (1043/2401) were girls. A logistic regression model showed that the OR for girls compared to boys to experience a repeat admission within 28 days was 1.15, 95% CI: 1.004–1.32; $p = 0.04$ (borderline significance). In contrast to all admissions, readmissions within 28 days peaked in winter (31%), followed by autumn (29%), spring (25%) and summer (16%) (Table 1).

For readmission within 28 days, seasonality and age group were associated for autumn and summer among boys ($p < 0.001$ and $p = 0.01$) and winter among girls $p = 0.03$ (Table 3). When stratified by age group, differences between boys and girls for the 6–12 year age group were observed in autumn (20% of boys compared to 28% of girls, $p = 0.02$) and spring (30% of boys compared to 21% of girls, $p = 0.01$). For the 13–18 year age group, differences were observed in autumn (36% of boys compared to 26% of girls, $p = 0.03$) and summer (7% of boys compared to 20% of girls, $p < 0.001$). Grass pollen season and age group were

associated with repeat admissions within 28 days only in boys ($p = 0.01$).

The 28-day admission rates increased over time. This increase in the yearly readmission rates within 28 days were experienced by children in the 2–5 and 6–12 year age groups and predominately by the girls in the 6–12-year-old group. Post 2003, trends among boys and girls were similar in these two younger age groups (Figure 1).

Readmissions within 1 year

There were 10263 readmissions within one year (excluding readmissions within 28 days) and were generated by 5692 children. Of the repeat admissions in one year, 42% (4275/10263) were girls. Readmissions in one year peaked in autumn (31%), followed by winter (25%), spring (23%) and summer (21%) (Table 1). A logistic regression model showed that the OR for girls compared to boys to experience a repeat admission within one year was 1.11, 95% CI: 1.05–1.19; $p = 0.001$.

For readmission within 1 year, summer was associated with boys ($p = 0.04$) and winter and summer with girls ($p = 0.03$ and 0.004, respectively) (Table 4). Grass pollen season and age group were not associated with repeat admissions within one year for boys or girls ($p = 0.31$ and $p = 0.94$, respectively).

In Figure 2, we show yearly rates of readmissions within one year. Except for between 2001 and 2006, girls experienced highest rates of readmission within 1 year compared to boys in the 2–5 year age group.

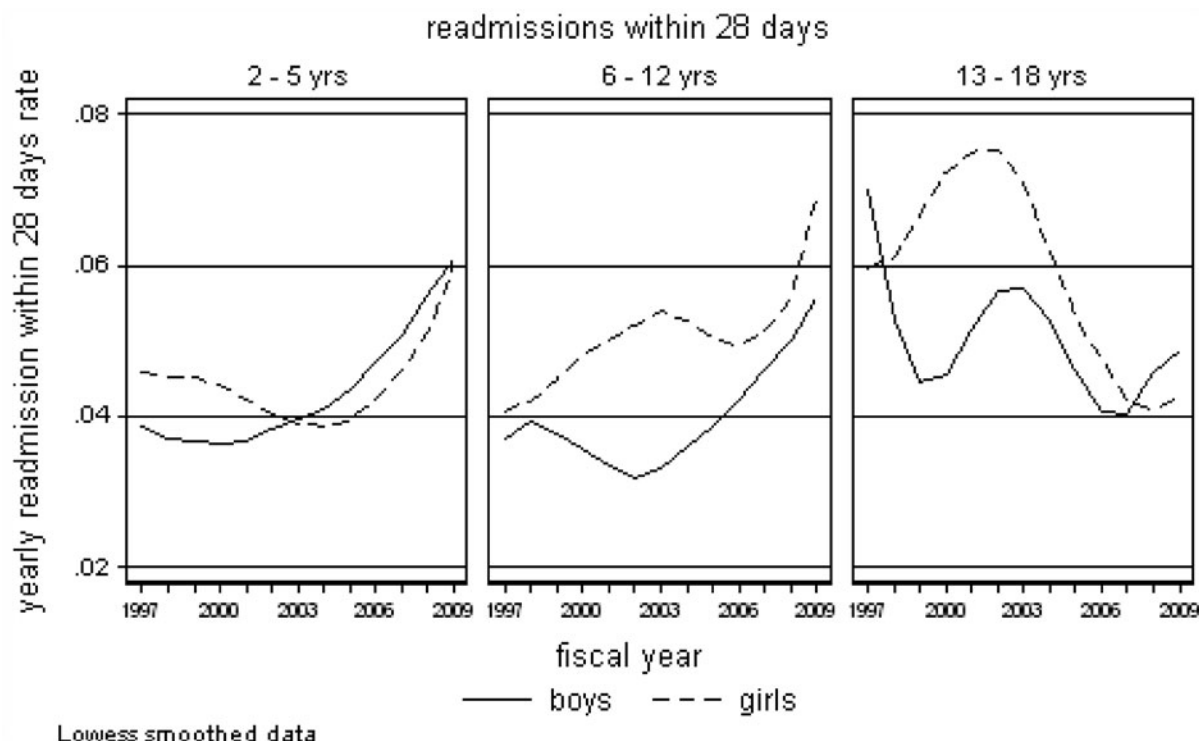


Figure 1. Smoothed yearly readmission rates within 28 days grouped by sex and age group. Within each age group, solid line represents males and dashed line females.

Table 4. Readmissions within 1 year for the entire study period by gender, age and season.

Age group in years	Repeat admissions within 1 year							
	Males				Females			
	2 to 5	6 to 12	13 to 18	Season total	2 to 5	6 to 12	13 to 18	Season total
Season	<i>N (%)</i>	<i>N (%)</i>	<i>N (%)</i>	<i>N (%)</i>	<i>N (%)</i>	<i>N (%)</i>	<i>N (%)</i>	<i>N (%)</i>
Autumn	1186 (31)	508 (30)	144 (29)	1838 (31)	655 (30)	384 (30)	256 (30)	1295 (30)
Winter	936 (25)	420 (25)	136 (28)	1492 (25)	529 (25)	328 (26)	249 (29)	1106 (26)**
Spring	842 (22)	399 (24)	125 (25)	1366 (23)	497 (23)	317 (25)	199 (23)	1013 (24)
Summer	852 (22)	354 (21)	86 (18)	1292 (22)*	477 (22)	236 (19)	148 (17)	861 (20)**
Age group Total	3816	1681	491	5988	2158	1265	852	4275
Grass pollen season	970	459	132	1561	575	332	229	1136

*Associations between summer (repeat admissions within 1 year in summer or not) and males $p=0.04$.

**Associations between readmission within one year in winter and girls ($p=0.03$) and summer and girls ($p=0.004$).

Discussion

Although the association between seasonality and childhood asthma readmissions has been examined previously [6,9,18,21], to our knowledge, this is the first study to focus on the seasonal trends in childhood asthma readmission within 28 days and how they vary by age and gender. Our exploratory analysis suggested an increase in repeat admissions in 28 days despite an overall decline in asthma new admissions. Both gender and younger age impacted on these trends for repeat admissions over time. Trends of repeat admissions over time were different for males and females and by age group. We found that girls were at a greater risk of readmission within 28 days and within a year. This modification effect by age in girls may be explained by hormonal changes that coincide with a reduction in the relative airway size to alveolar size that begins to take effect at 6–8 years of age and peaks at about 10–14 years of age [11], which may

be associated with a severe phenotype thereby resulting in a repeat admission within 28 days.

To the best of our knowledge, the association between pollen season and readmission has not been examined previously. We found that pollen season was not associated with readmissions within one year but it was associated with readmissions within 28 days but only for boys. It seems that boys may be more subject to an allergic reaction to pollen, which may have triggered a severe type of asthma that led to multiple admissions within 28 days.

Findings of the few studies that have examined the role of seasonality and how this varies by age and gender on overall childhood asthma readmission have been mixed.

Kao and colleagues [15] found that seasonality was associated with admissions, but did not assess any association between seasonality and readmission counts in Taiwan. However, they found that readmissions were associated with sex, but only for the girls in the older age group of 5–14 years.

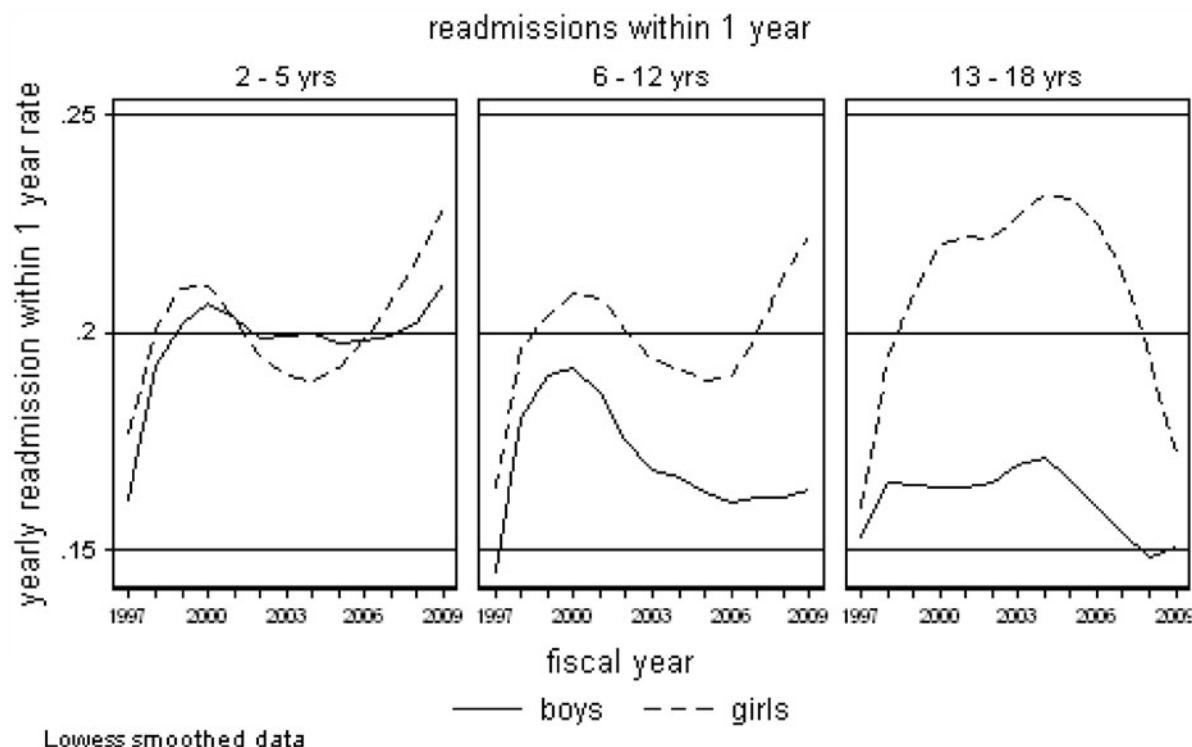


Figure 2. Smoothed yearly readmission rates within 1 year grouped by sex and age group. Within each age group, solid line represents males and dashed line females.

In this study, a readmission was defined as at least three admissions.

Bloomberg et al. [6] found no difference between month of admission and month of readmission in St. Louis, USA, where a readmission was defined as occurring anytime in the 10-year span of the study following index admission. Admissions peaked in the autumn and then winter months and were the lowest in summer. Although they found that the distribution of ages and proportion of sexes were similar for single and multiple admissions, they did not examine seasonality by age group or gender.

A study by Lin et al. [21] reported that June to August (summer) had lower admission rates and September to November (autumn) had higher admission rates in New York State, USA. This was similar to our study where we have reported highest numbers of admissions in autumn and lowest in summer. The authors did not assess seasonality and readmissions directly, but instead reported that the statistically significant seasonal pattern in admissions and the impact by age were not altered significantly when readmissions were removed from total admissions. In this study, readmissions were defined as occurring in the same year as the index admission. However, they reported that the season of index admission was a risk factor for readmission. In contrast to our study, they found that compared to girls, boys were at a greater risk of readmission, which may be a result of how the readmissions were defined.

Rottem et al. [18] found that in Israel, admissions peaked in autumn (40.0%) then winter (30.2%), spring (24.0%) and summer (16%). The seasonal distribution of readmissions was not reported, but a statistically significant seasonal difference between total, new and recurrent admissions was found. A readmission was defined as occurring anytime

within 1 year of index admission. Any differences by sex were not reported.

In Australia, only a few studies have been conducted on time trends of childhood asthma readmissions. McCaul et al. [7] examined trends over time for all age groups and readmission within 28 days and 1 year and found reductions in readmission trends by age and over time. In contrast to our study, the younger age group (1–6 years) sustained greater reductions than the older age group (7–14 years) for both readmissions within 28 days and one year. Direct comparisons are difficult due to the differences in the time frame in that study (1989–1996), and ages up to 49 years were included in their yearly rates. Correll et al. [12] examined asthma readmissions within 28 days between 2000 and 2003, and during this period, they found that children up to 4 years old were more likely to be readmitted than children aged between 5 and 14 years. We confirmed higher readmission rates for the younger age group compared to the older age group. None of these Australian studies considered seasonal influences on asthma readmission rates over time, and how these associations varied by age and gender.

Our study has a number of strengths. The VAED is a comprehensive and large data base that included all patients from Victorian public and private acute hospitals for financial years 1997–2009. The length of the study period and reasonable sample size provides sufficient power to detect meaningful differences between age and gender over time for childhood asthma readmissions.

In describing time trends of asthma readmission rates in children, we have not been able to adjust for other important individual variables such as atopy, family history of asthma, allergen exposure, respiratory infection and use of asthma medication. However, we may not expect to find a differential

effect of these and most are not easily modifiable. Allergen exposure and respiratory infection have been accounted for to a certain extent by the calendar and pollen season components of our analyses. We do not have data on the clinical characteristics (such as severity) or asthma care of the patients in these data sets. Without these data, we were unable to fully understand the contribution of such factors to increased risk of repeat admissions for asthma in children. Socio-economic indices and geographical differences are important factors, but were not the focus of this purely descriptive study.

Conclusions

Over time, despite a fall in asthma incidence, readmission rates for childhood asthma significantly increased in younger age groups, while declining in adolescents. Seasonality influenced readmissions within 28 days and readmissions within one year with this influence varying by age and gender. Association with seasonality was different for readmissions within 28 days and readmissions within one year. Boys aged between 6 and 12 years were more likely than girls to be readmitted within 28 days during the grass pollen season. These findings have implications for both clinical services and patient care. Due to the dynamic interplay between readmissions within 28 days by age, gender and seasonality, a single yearly readmission rate may not be suitable for capturing changes in paediatric asthma admissions.

Declaration of interest

Michael Abramson holds an investigator initiated research grant from Pfizer for unrelated research. All other authors declare that they have no conflicts of interest.

Role of each author in this study

Don Vicendese contributed to data analysis, drafting and revising the manuscript; Michael J. Abramson contributed to the design, interpretation of findings and revising the manuscript; Shyamali C. Dharmage, Mimi L. Tang and Katie J. Allen contributed to the design, interpretation of findings and revising the manuscript; and Bircan Erbas contributed to the conception and design, analysis and interpretation, drafting and revising of the manuscript.

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