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Differences in airway responsiveness between children and adults living in the same environment: an epidemiological study in two regions of New South Wales

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Differences in airway responsiveness between children and adults living in the same environment: an epidemiological study in two regions of New South Wales. J.K. Peat, E.J. Gray, C.M. Mellis, S.R. Leeder, A.J. Woolcock. ©ERS Journals Ltd 1994.

ABSTRACT: The aim of the present study was to compare the severity of asthma in children and adults living in the same home environments.

In winter 1991 and 1992, we studied two large random samples of children living in two different regions; and, three months later, we conducted a study of adults who lived with enrolled children. A total of 805 children and 814 adults attended in Lismore, and 850 children and 711 adults in Wagga Wagga. Questionnaires were used to measure symptom history, histamine inhalation challenge to measure airway hyperresponsiveness (AHR) and skin-prick tests to measure allergy.

There was a higher prevalence of asthma in children than in adults: recent wheeze was 1.5 times higher; asthma medication use was 1.5 times higher; diagnosed asthma was 1.6 times higher; and AHR was two times higher. Current asthma (AHR and recent wheeze) was 9.5–11.3% in children and 5.4–5.6% in adults. These differences were statistically significant. In both regions, airway responsiveness was more severe in children who were sensitized to common allergens than in similarly sensitized adults.

These results suggests that airways can develop protective mechanisms with age, or that recent environmental changes in factors such as allergen levels, diet or treatment practices have led to immunological changes and to incresed airway responsiveness in this generation of children.

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There is substantial evidence that the amount of morbidity caused by asthma is increasing in Australia, the USA, UK and Scandinavia [1–8], although there have been remarkably few epidemiological studies to investigate the factors which might be responsible. The increases in asthma have been recorded only in children and in young adults, and no major increase in adults has been reported in any country. The prevalence of recent wheeze (in the last 12 months) in Australian children doubled from approximately 12% in 1982 to 24% in 1992, and the prevalence of airway hyperresponsiveness (AHR) also doubled in this period but only in atopic children [9]. However, a similar comparison of adults in 1981 and 1990 showed that the prevalence of recent wheeze increased only in subjects less than 30 yrs of age and that the prevalence of AHR had not increased at all, even in atopic subjects [10].

So far, only two studies have used standardized tools to investigate the difference in prevalence between children and adults, but one was conducted more than a decade ago [11], and the other used questionnaires only [12]. Both studies found a similar prevalence of childhood and adult asthma, with a decrease during adolescence followed by an increase in older age groups. Because of the differences between children and adults in the recent changes in prevalence, it becomes increasingly important to document whether there are true differences in the prevalence of asthma between the two age groups and whether different aetiological factors are operative at different ages. This knowledge would lend insight into the present profile of asthma in the community and the factors associated with the present high prevalence of asthma in children.

We have studied two population samples of children and adults in order to assess the prevalence of respiratory symptoms and of AHR in these two different age groups. The study regions were Lismore, which is a humid, coastal region in northern New South Wales where house dust mite allergen levels are known to be high, and Wagga Wagga, which is a dry, inland region where Alternaria and ryegrass are the dominant allergens. In this study, we compare the prevalence of asthma and the allergic factors which have a significant influence on the distribution of asthma in the two age groups.

Methods

Population samples

The studies were conducted in Lismore, which is a town situated in a hot, humid region near the coast in northern New South Wales, and in Wagga Wagga which is an inland, rural town in southern New South Wales. We planned to study a sample both of adults and children which was large enough to satisfy power requirements for detecting a difference in the prevalence of AHR between Lismore, Wagga Wagga and other regions of New South Wales. It was estimated that at least 800 children were necessary in each sample in order to determine a difference of 4% in the prevalence of AHR between regions (significance 5%, power 80%).

The study methods have been described in detail previously [13]. Briefly, in the winter months of June, 1991 in Lismore and in July 1992 in Wagga Wagga, we studied a random sample of children aged 8–11 yrs. All public and Roman Catholic primary schools in Lismore were selected for study but one school was later omitted because of time constraints. In Wagga Wagga, one in two public and Roman Catholic schools were randomly selected from separate sampling frames to maintain the correct community distribution. In both regions, all children in school years 3, 4 and 5 at each selected school were invited to participate, and those for whom informed parental consent was obtained were studied. Children who did not have consent for study were asked if they had used any medication for asthma in the last month.

The adults living in the same homes as the children were invited for study in October (spring) 1991 in Lismore, and in October 1992 in Wagga Wagga. Initial contact was by letter to the home address. We asked all adults in the household to complete a questionnaire and then attend a location in the town centre for lung function and allergy tests. Follow-up phone calls were made to arrange appointments. A random selection of refusers and non-attenders was surveyed by telephone to collect information of recent asthma symptoms and medication use.

Respiratory symptoms and interviews

A parental self-administered questionnaire was obtained for each child and a self-administered questionnaire was completed by each adult. Most items in the children's questionnaire were identical to those used in our previous studies [14]. Questions asked whether the child had ever had wheeze, exercise wheeze or night cough, had ever used any medications for asthma or had asthma diagnosed by a doctor, and whether the symptoms had occurred in the 12 months prior to study. Additional measures of morbidity, including information of hospital and medical attendance, and effect of asthma on lifestyle, taken from the questionnaire of USHERWOOD *et al.* [15] were included. The repeatability of the children's questionnaire was tested during the course of the study and reaffirmed that the items used in this report have a high degree of repeatability.

The adult questionnaire was a shortened version of the International Union Against Tuberculosis (IUAT) questionnaire [16], and comprised questions of recent and past respiratory symptoms, including those associated with occupation, family history, diagnosed asthma and medication use, and hospital and doctor attendances. Subjects who were employed were divided into four broad categories of occupation: professional occupations (*e.g.* doctors, company directors, school principals); 'white collar' occupations that require tertiary qualifications (*e.g.* nurses, teachers, executives); 'blue collar' occupations that require a technical or trade certificate (*e.g.* receptionists, plumbers, carpenters), and unskilled occupations requiring no formal qualifications (*e.g.* drivers, shop attendants).

Lung function and airway responsiveness

A histamine bronchial challenge test was administered to all children and adults using the rapid method [17]. Lung function was recorded by Minjhardt dry rolling seal spirometers connected to IBM-PC computers running Scientific and Medical software for immediate data acquisition. Forced expiratory manoeuvres were repeated until two readings of forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) within 100 ml were obtained, of which the largest value was used in analyses. Subjects who had taken a beta-agonist within 6 h of presenting were asked to withhold medication before returning for later testing. Histamine diphosphate was administered by use of DeVilbiss No. 45 handheld nebulizers, in doses ranging 0.03–3.9 μmol histamine. The test was stopped if the FEV_1 fell by 20% or more, or if all histamine dose steps to 3.9 μmol had been administered. Salbutamol aerosol was given to aid recovery when necessary.

For subjects who had a fall in FEV_1 of 20% or more, the provocative dose of histamine that caused a 20% fall in FEV_1 ($PD_{20}FEV_1$) was calculated. Subjects with a $PD_{20}FEV_1$ were classified as having AHR and the remainder were classified as having normal responsiveness. Dose-response ratio (DRR) was calculated for all subjects as the percentage fall in FEV_1 at the last dose, divided by total dose administered [18]. Because many subjects had an FEV_1 which remained stable or improved slightly during bronchial challenge, and thus gave a zero or negative DRR value, a constant of 3 was added to all DRR values to obtain a positive value for logarithmic conversion [19], so that they are indicated by units % fall FEV_1/μmol+3.

Subjects who presented with an FEV_1 less than 60% of predicted did not undergo histamine challenge but were given a bronchodilator challenge. After measurement of baseline lung function, 200 μg of salbutamol was administered and lung function measured again after 10 min. Subjects with an increase in FEV_1 of 15% or more were considered to have a positive bronchodilator challenge.

Allergic sensitization

Sensitization to common allergens was measured by skin-prick test reactions to the forearm [20]. The eight allergens tested were: house dust; house-dust mites (*Dermatophagoides pteronyssinus* and *D. farinae*); cat dander; ryegrass; plantain; *Alternaria tenuis*; and cockroach. Histamine and glycerol were used as positive and negative controls. Subjects with a negative histamine or a positive glycerol test were retested, and the few subjects in whom the result was repeated were excluded from analyses. After 15 min, wheal size was recorded as the long axis and its perpendicular; mean wheal size was used in analyses. A skin prick reaction was regarded as positive if the wheal size was ≥3 mm for children and ≥4 mm for adults. Subjects were considered to be sensitized to house-dust mites if they had a positive wheal to either of the Dermatophagoides allergens, and were considered atopic if they had a positive reaction to any of the allergens in the testing panel.

Statistical methods

Data were analysed using the statistical package SAS (SAS Institute Inc., Cary, NC, USA). Geometric mean values are reported for DRR values which were converted to base 10 logarithms prior to analyses. Prevalence rates and mean values are given with the 95% confidence interval (CI). Chi-squared tests were used to determine the significance of differences in categorical variables between groups, and unpaired t-tests were used to determine the significance of differences between continuous variables. For multiple comparisons, analysis of variance using Duncan's post-hoc test was used to assess differences in DRR values between groups. Logistic regression was used to compute odds ratios for the risk of asthma in sensitized subjects, adjusted for sensitization to each allergen group.

Definitions

Symptoms which occurred in the previous year were classified as being "recent". Subjects who reported recent wheeze or recent wheeze following exercise were classified as having "recent wheeze". Adults who reported recent chest tightness on waking or recent shortness of breath coming on at rest were also included as "recent wheeze". Subjects with both recent wheeze and AHR (or who had poor resting lung function and a positive bronchodilator response) were classified as "current asthma". Subjects with "recent wheeze" but no AHR were classified as "episodic symptoms" if they had used any asthma medicine in the previous year, and as "trivial symptoms" if they had not used asthma medication in the previous year. Subjects with a previous diagnosis of asthma who did not have "recent wheeze" were classified as having "past asthma". Subjects who answered yes to any of the three questions of recent asthma morbidity (hospitalization, emergency room visit or urgent doctor visit for asthma) were classified as having "an urgent doctor visit".

Results

The characteristics of the two groups of children are shown in table 1. Neither sample was biased in terms of children who used an asthma medicine preferentially attending or declining to attend (p=0.9 for both regions). The demographic characteristics of the adult samples are shown in table 2. In Lismore, 57% of the adult sample was female and the age range was 25–72 yrs (mean 39 yrs; SD 5 yrs). In Wagga Wagga, 57% of the adult sample was female and the age range was 18–73 yrs (mean 38 yrs; SD 6 yrs). Only 10 adults in Lismore and seven in Wagga Wagga were of non-Caucasian ethnicity. In both regions, more females than males attended (p<0.001), and females were different to the males in terms of age distribution (p<0.001) and occupation (p<0.001), but not in terms of smoking history.

It was estimated that the 814 adult attenders in Lismore comprised at least 60% of the sample base. A telephone survey of 158 nonattenders showed that 13.2% had recent wheeze and 5.1% had taken an asthma medicine in the last month, compared to 18.8% and 6.6% of attenders, respectively, (p=0.25 and p=0.75). In Wagga Wagga, the 711 adult attenders comprised 62% of the sample base, and a survey of 305 nonattenders showed that 3.3% had taken an asthma medicine in the last month,

Table 1. – Demographic and sample characteristics of the two groups of children

	Lismore	Wagga Wagga
Total n	805	850
Age yrs	8–11	8–11
Male %	53	46
Born in Australia %	97	97
Response rate %	77	83
Asthma medication use:		
Responders %	11.2	12.0
Nonresponders %	10.4	11.1

Table 2. – Demographic characteristics of the two study samples of adults

	Lismore		Wagga Wagga	
	Males	Females	Males	Females
Total n	339	475	306	405
Age group				
<30 yrs	4.1	3.0	6.6	5.9
30–39 yrs	69.1	53.7	64.0	47.1
40–49 yrs	26.1	39.2	26.7	40.2
≥50 yrs	0.9	4.2	2.7	6.8
Occupation				
Professional	5.9	0.8	19.1	2.5
White collar	23.6	24.4	23.2	20.8
Blue collar	36.6	11.4	28.7	6.3
Unskilled	27.4	27.6	22.9	26.3
Unemployed	6.4	35.8	6.1	44.0
Smoking history				
Ex-smoker	32.2	28.8	31.1	24.0
Current smoker	20.7	19.0	20.3	18.3

Data are presented as percentage of each gender group.

Table 3. – Positive responses to questionnaire items

	Lismore			Wagga Wagga		
	Children	Adults	p-value	Children	Adults	p-value
Total n	805	814		850	711	
Wheeze or tightness						
Wheeze ever	39.5 (36.1–42.9)	32.1 (28.9–35.3)	<0.01	36.9 (33.7–40.1)	32.7 (29.3–36.2)	NS
Recent wheeze	25.8 (2.3–28.8)	18.8 (16.1–21.5)	<0.001	22.1 (19.3–24.9)	18.6 (15.7–21.5)	NS
Recent exercise wheeze	18.4 (15.7–21.1)	6.0 (4.4–7.6)	<0.001	15.8 (13.4–18.3)	10.4 (8.2–12.6)	<0.001
Asthma						
Diagnosed asthma	30.9 (27.7–34.1)	17.9 (15.3–20.5)	<0.001	29.3 (26.2–32.4)	18.9 (16.0–21.8)	<0.001
Recent asthma medicine	22.1 (19.2–25.0)	14.0 (11.6–16.4)	<0.001	24.4 (21.5–27.3)	15.7 (13.0–18.4)	<0.001
Urgent medical visit	5.2 (3.7–6.7)	5.2 (3.7–6.7)	NS	6.6 (4.9–8.3)	4.2 (2.7–5.7)	NS
Hay fever	40.2 (36.8–43.6)	41.8 (38.4–45.2)	NS	43.4 (40.1–46.7)	53.0 (48.8–56.2)	<0.001
Cough						
Cough for 3 months of year	-	9.6 (7.6–11.6)		-	13.4 (10.9–15.9)	
Woken by cough	-	19.4 (16.7–22.1)		-	23.7 (20.6–26.8)	
Recent night cough	22.9 (20.0–25.8)	-		19.6 (40.1–46.7)	-	
Airway hyperresponsiveness	19.0 (16.3–21.7)	7.4 (5.6–9.2)	<0.001	18.1 (15.5–20.7)	8.6 (6.5–10.7)	<0.001
Current asthma	11.3 (9.1–13.5)	5.4 (3.9–7.0)	<0.001	9.5 (7.5–11.5)	5.6 (3.9–7.3)	<0.01
Sensitization to any allergen	34.9 (31.6–38.2)	44.0 (40.6–47.4)	<0.001	39.9 (36.6–43.2)	44.3 (40.7–48.0)	<0.001
House-dust mites	29.3 (26.2–32.4)	33.3 (30.1–36.5)	NS	20.7 (18.0–23.4)	28.3 (25.0–31.6)	<0.001
Alternaria	4.0 (2.7–5.4)	3.4 (2.2–4.7)	NS	15.4 (13.0–17.8)	8.3 (6.3–10.3)	<0.001
Ryegrass	6.9 (5.2–8.7)	18.8 (16.1–21.6)	<0.001	22.8 (20.0–25.6)	29.8 (26.4–33.2)	<0.01
Cat dander	5.1 (3.6–6.6)	4.5 (3.1–5.9)	NS	4.3 (2.9–5.7)	4.5 (3.0–6.0)	NS

Data are presented as percentage prevalence and 95% confidence interval in parenthesis. NS: nonsignificant.

Fig. 1. – Distribution of different severities of asthma in each sample. AHR: airway hyperresponsiveness. ▭ : current asthma; ▨ : asymptomatic AHR; ▩ : episodic symptoms; ⁘ : trivial symptoms; ■ : past asthma; □ : normal.

compared to 7.7% of attenders (p<0.05). These differences suggest that adults with recent asthma were more likely to attend.

Subjects who were not challenged because of poor resting lung function but who had a positive bronchodilator response and a report of recent wheeze were considered to have current asthma. There was one child and seven adults in Lismore, and four adults in Wagga Wagga who met these criteria. Children had a higher prevalence of most measures of asthma symptoms, especially recent conditions (table 3). The measures which showed the largest differences between children and adults were: diagnosed asthma (over 1.6 times higher in children); use of asthma medicine ever (over 1.4 times higher in children); recent use of asthma medicine (1.5 times higher in children); and recent exercise wheeze (over

1.5 times higher in children). However, the same proportion both of children and adults had attended a hospital, an emergency room, or had an urgent visit to their doctor because of their asthma.

Adults in Wagga Wagga had slightly more hay fever than children. In both regions, children had significantly more AHR and current asthma than adults by a factor of approximately two fold. More children and adults were sensitized to house-dust mites in Lismore and to Alternaria and ryegrass in Wagga Wagga. Adults also had a higher prevalence of atopy, largely because more adults than children were sensitized to ryegrass in Lismore and to house-dust mites and ryegrass in Wagga Wagga. In Wagga Wagga, more children than adults were sensitized to Alternaria.

To reflect the spectrum of severity of asthma, defined according to AHR, recent wheeze, current medication use and diagnosed asthma, each sample was divided into mutually exclusive groups (fig. 1). Children had more current asthma and asymptomatic AHR but both age groups had the same amount of episodic symptoms, that is wheeze without AHR but which required the use of medication. Adults had a significantly higher prevalence of trivial symptoms, that is symptoms which did not require the use of an asthma medication ($p<0.001$).

Children who were sensitized to the dominant allergens in their regions (house-dust mites in Lismore and ryegrass and/or Alternaria in Wagga Wagga) had more severe airway responsiveness than adults who were sensitized to the same allergens. Figures 2 and 3 show the cumulative frequency distribution of DRR values in groups categorized according to their allergic sensitization. The distributions of DRR values in sensitized children were clearly shifted towards the severe range for DRR compared to the distribution for nonsensitized subjects. The curves for sensitized subjects has a skewed rather than a parallel shift in the distribution when compared to adults, which suggests that more than half of the sensitized children had increased airway responsiveness, compared both to the sensitized adults and to nonsensitized children. The mean DRR ratio in each group is shown in table 4.

Table 5 shows the association between sensitization to common allergens and different severities of asthma in each age group expressed as odds ratios adjusted for sensitization to the other allergens. In Lismore, sensitization to house-dust mites was a significant risk factor for current asthma and was a less important, but nevertheless significant, risk factor for asymptomatic AHR, episodic symptoms and hay fever in both age groups, and for trivial symptoms in adults. Sensitization to Alternaria was a significant risk factor for hay fever in adults, and sensitization to ryegrass was a significant risk factor for hay fever in both age groups. Sensitization to cat dander was a significant risk factor for current asthma and hay fever in children.

In Wagga Wagga, sensitization to house-dust mites was an important risk factor for current asthma, asymptomatic AHR and episodic symptoms in both age groups, and had a small association with hay fever in adults. In addition, sensitization to Alternaria was strongly associated with current asthma in both age groups, and to a lesser extent with asymptomatic AHR, episodic symptoms and hay fever in children only. Sensitization to ryegrass was also a significant risk factor for current asthma and for hay fever in both age groups, and for asymptomatic AHR and episodic symptoms in adults only. Sensitization to cat dander was a significant risk factor for current asthma in children.

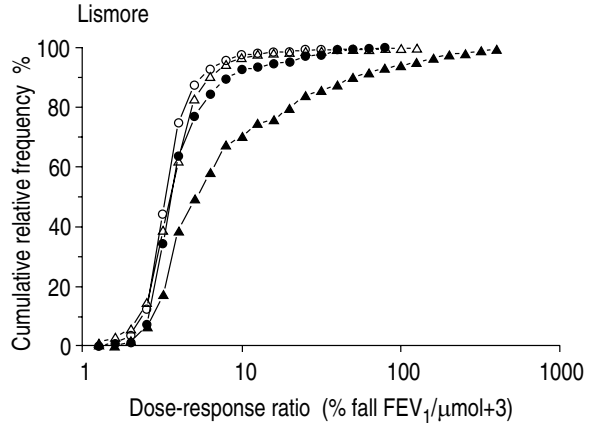

Fig. 2. – Cumulative relative frequency of the dose-response ratio in Lismore adults and children who were not sensitized to allergens and in those who were sensitized to house-dust mites. –○–: nonsensitized adults; –△–: nonsensitized children; –●–: sensitized adults; –▲–: sensitized children. FEV_1: forced expiratory volume in one second.

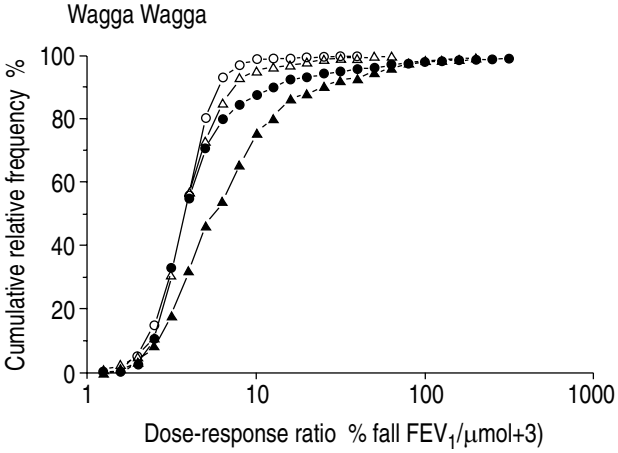

Fig. 3. – Cumulative relative frequency of the dose-response ratio in Wagga Wagga children and adults who were not sensitized to allergens and in those who were sensitized to Alternaria and/or ryegrass. –○–: nonsensitized adults; –△–: nonsensitized children; –●–: sensitized adults; –▲–: sensitized children. FEV_1: forced expiratory volume in one second.

Discussion

In both regions, children had a higher prevalence of recent symptoms, AHR and current asthma than adults, and children who were sensitized to the dominant allergens in each region (house-dust mites in Lismore and Alternaria or ryegrass in Wagga Wagga) had more severe airway responsiveness than adults who were similarly

Table 4. – Dose-response ratio (% fall FEV_1/μmol) in nonsensitized subjects and in subjects sensitized to the dominant allergens in their region (house-dust mites in Lismore and ryegrass or Alternaria in Wagga Wagga), or to other tested allergens

	Lismore		p-value	Wagga Wagga		p-value
	Children	Adults		Children	Adults	
Total n	805	814		850	711	
Nonsensitized	4.11 (3.93–4.31)	3.94 (3.77–4.11)	NS	4.27 (4.07–4.47)	4.02 (3.85–4.19)	NS
Sensitized to common allergens	10.40 (8.84–12.23)	4.75 (4.39–5.15)	<0.001	7.55 (6.70–8.51)	5.97 (5.32–6.70)	<0.01
Sensitized to other allergens	4.89 (4.20–5.69)	4.03 (3.66–4.43)	<0.05	6.46 (5.34–7.81)	4.97 (4.30–5.74)	<0.05

Data are presented as mean, with 95% confidence interval in parenthesis. FEV_1: forced expiratory volume in one second; NS: nonsignificant.

Table 5. – Adjusted odds ratios, with 95% confidence interval in parentheses for different severities of asthma and for hay fever in the presence of sensitization to specific allergens

		n	House-dust mites	Alternaria	Ryegrass	Cat dander
Lismore						
Current asthma	Children	92	31.5 (14.7–67.7)#	1.9 (0.6–5.8)	1.1 (0.5–2.8)	4.4 (1.7–11.5)**
	Adults	37	3.1 (1.4–6.8)**	2.1 (0.5–9.1)	1.1 (0.5–2.7)	2.2 (0.9–5.3)
Asymptomatic AHR and episodic symptoms	Children	149	2.8 (1.7–4.7)#	1.9 (0.6–5.7)	0.5 (0.2–1.3)	1.5 (0.4–5.1)
	Adults	98	2.4 (1.4–4.1)**	1.1 (0.6–2.0)	1.8 (0.5–6.0)	1.1 (0.6–2.3)
Trivial symptoms	Adults	110	1.7 (1.1–2.8)*	1.7 (0.5–5.7)	1.9 (1.0–3.3)*	0.8 (0.4–1.4)
Hay fever	Children	324	4.1 (2.7–6.0)#	1.9 (0.8–4.4)	2.6 (1.3–4.9)**	3.2 (1.3–7.9)*
	Adults	340	1.5 (1.0–2.2)*	14.2 (1.8–108.8)**	2.6 (1.6–4.3)#	1.1 (0.6–1.9)
Wagga Wagga						
Current asthma	Children	82	4.1 (2.2–7.4)#	3.0 (1.5–6.0)**	4.1 (2.1–7.8)#	7.3 (2.4–21.9)#
	Adults	40	3.4 (1.6–7.1)**	4.9 (2.0–11.8)#	3.9 (1.8–8.1)**	0.8 (0.2–3.6)
Asymptomatic AHR and episodic symptoms	Children	157	2.2 (1.3–3.6)**	2.3 (1.3–4.1)**	1.6 (0.9–2.8)	2.4 (0.8–7.3)
	Adults	93	2.1 (1.2–3.6)**	1.0 (0.4–2.4)	3.3 (2.0–5.5)#	3.0 (1.2–7.9)*
Trivial symtoms	Adults	80	1.3 (0.7–2.3)	1.9 (0.8–4.6)	1.4 (0.8–2.6)	1.4 (0.3–5.6)
Hay fever	Children	348	1.2 (0.8–1.8)	5.2 (3.1–8.7)#	3.6 (2.4–5.4)#	1.5 (0.6–3.9)
	Adults	377	1.7 (1.2–2.5)*	1.1 (0.5–2.1)	4.7 (2.8–6.4)#	3.6 (1.0–12.9)*

AHR: airway hyperresponsiveness. *: $p<0.01$; #: $p<0.001$ for the significance of the odds ratio.

sensitized. The prevalence of allergic sensitization was higher in adults, although both age groups were presumably exposed to much the same allergen levels in their home environments. The reasons for these age-related differences in airway abnormality are not known. We hypothesize that adult airways have developed a mechanism to enable them to tolerate common allergens, or that such a mechanism in the airways of sensitized children has been altered by recent environmental or lifestyle changes. Alternatively, increases in local allergen levels in recent years [21] may have resulted in children being exposed to higher allergen levels at an early stage in the development of their immune system than the adults were, or continuing higher exposure to allergens may have caused more severe airway responsiveness in the children.

For these studies, we chose reliable epidemiological methods. Because we attained a high consent rate for children and we found no bias in terms of current asthmatics preferentially attending or refusing study, the children studied were likely to be representative of the populations living in those regions. Although the response rates for the adult samples were lower and were just adequate for estimates of prevalence, comparisons of severity of airway responsiveness between groups and estimates of adjusted odds ratios between subgroups are likely to be reliable. We found only a slightly higher rate of adult attenders with recent wheeze, which would tend to reduce differences in symptom prevalence between children and adults and not overestimate them. In Lismore, we omitted to collect information on the number of parents or guardians in each household, so that we have probably underestimated the true response rate for the adult study. We measured airway responsiveness and sensitization to common aeroallergens using standard, validated epidemiological tools [19, 22], and based our definitions of asthma severity on measurements which accurately discriminate asthma symptoms and identify the group with the most severe impairment [23, 24].

It is unlikely that the higher prevalence of AHR in children than in adults is due solely to differences in lung size. LE SEOUF [25] has suggested that subjects with a small lung size may receive a higher dose of agonist

than those with a larger lung size, so that an age-related decline in airway responsiveness would be expected. In the current studies, we have measured the response to histamine inhalation as a percentage fall in FEV_1 rather than an absolute fall, so that the magnitude of the change is inherently adjusted for lung size. Furthermore, multiple regression analyses showed that atopy, gender, past and recent symptoms of asthma, and FEV_1/FVC contribute significantly to the variability of DRR in adults, but that lung size, as estimated by FVC, does not explain any further variation (P=0.66) or improve the adjusted r^2 value for the model. Moreover, we found an almost identical cumulative frequency distribution of DRR values in adults and children who were not sensitized to allergens (figs. 1 and 2). Although lung size may contribute a small source of variability, a parallel shift in the children's curves compared to the adults' curves was not seen for either the nonsensitized or sensitized groups; and, therefore, this factor is not likely to be a major component of the differences in DRR values between adults and children.

Asthma is sometimes described as a disease of childhood, although no previous studies have used identical and objective protocols to measure AHR and allergy in children and adults living in the same conditions. Although the prevalence of wheeze and asthma medication use was high in the children studied, it was similar to rates measured recently in other regions of New South Wales using the same methods [13]. It was of interest that the prevalence of recent symptoms and AHR were higher in children than adults, but that the rate of urgent medical visits for asthma was similar in both age groups. The subjects in this category who use hospital and emergency medical services for their care may have different attitudes to health care services than subjects who use the normal avenues of medical care. Alternatively, the natural profile of asthma may be such that there is a fixed proportion of the population who have severe exacerbations of symptoms which require urgent medical attention, but that children have more current asthma and more asymptomatic AHR than adults, and that adults are more likely to have trivial symptoms than children. It is likely that symptoms and AHR are independent mechanisms [26, 27], and the finding of a different spectrum of severity of asthma at different ages may reflect the natural history of this illness, or may be an indication of a cohort effect in increasing prevalence.

The rates of symptoms in adults were similar to those found in a study of adults in Busselton, Western Australia using an identical protocol [10]. Because few of the adults studied were older than 50 yrs, misclassification due to the presence of chronic airflow limitation was unlikely. A multicentre questionnaire study of symptom prevalence in adults living in three states [28] reported that the prevalence of recent wheeze was 19%, which is similar to the current studies (18.8% in Lismore and 18.6% in Wagga Wagga), but that the prevalence of morning chest tightness was 16%, which is higher than in the current studies (9.2% and 8.6%), and the prevalence of diagnosed asthma was 7% which is lower than the current studies (17.9% and 18.9%). A study of Victorian adults found a similar prevalence of recent wheeze (22%) and night cough (21% *vs* 19.4% in Lismore and 23.7% in Wagga Wagga) but less diagnosed asthma (13%) and a lower rate of recent asthma medication use (6% *vs* 14.0% and 15.7%, respectively) [29]. Our study samples of adults were largely Caucasian with few migrants, unlike the other studies undertaken in cosmopolitan cities. A higher prevalence of asthma in Australian born subjects, which may be a consequence of early exposure to environmental factors in this country, has been reported in other studies [12, 29], and could explain some of the differences between studies conducted in rural regions and in major cities.

The prevalence of asthma in adults living in other countries where studies have been conducted in the last decade appears to be lower than in Australia. A recent European study found that the prevalence of recent wheeze was 6.4% in males and 3.5% in females, and was higher in adults than in children [30]. Recent studies in Europe have found that 3% of adults have diagnosed asthma [11], and in Latin America that 5% of adults have diagnosed asthma [31], which is much lower than the 18–19% found in the current studies. The prevalence of AHR in the current studies in which a maximum dose of 3.9 μmol of histamine was given was 7–9%, which is lower than 14% found in a study in the UK which used a maximum dose of 8 μmol of histamine [32]. Given the different doses used, this does not suggest that there is more AHR in Australia than in the UK. A study in The Netherlands found that the prevalence of AHR was 22–28% in adults, but used a higher dose of histamine and a lower threshold to define AHR [33].

Because we studied children and their parents, domestic allergen exposure was presumably similar in both age groups. Dust collected from the homes of children showed that levels of house-dust mite allergens were exceptionally high in Lismore, compared to inland regions [12] and to other humid regions overseas [34, 35]. In Lismore, the odds ratio for current asthma associated with house-dust mite sensitization was much higher in children than in adults, which suggests that adult airways are protected from developing AHR in response to high exposures. Similarly, in Wagga Wagga, adults who were sensitised to common allergens had less AHR than children. Although allergen exposure is obviously associated with increased AHR, other factors must also be involved.

In Lismore, the prevalence of sensitization to house-dust mites or Alternaria was not different between children and adults, but more adults were sensitized to ryegrass. In Wagga Wagga, more adults were sensitized to house-dust mites and ryegrass, which is presumably a result of different lifetime exposures. Ryegrass may not be as potent as other allergens, and repeated seasonal exposures are thought necessary to increase sensitization [36]. This may explain why there was less difference in the severity of airway responsiveness between sensitized children and adults in Wagga Wagga compared to Lismore (table 4). Intact grass pollens are too large to be respirable, and it is thought that they generally deposit in the nose, which would explain their close association with hay fever.

It is not known whether the study children who were sensitized to dominant allergens and who had AHR will have more severe asthma when they become adults than their parents have now. However, evidence from longitudinal studies suggests that children who have the most severe symptoms or the most severe airway responsiveness tend to maintain their asthma status as they become older [37, 38]. It is clear that the airways of this generation of sensitized children are not protected from allergens in the same way as the airways of adults. We hypothesize that environmental factors, such as increased allergen levels, different dietary habits, or increased beta-agonist use in children, have either increased the permeability of the airways to allergens or have led to changes in the immunological mechanisms which protect the airways. The higher rate of use of asthma medications in children may be an important factor, because it has recently been reported that regular use of salbutamol increases airway responsiveness to allergens, which suggests that beta-agonists may be "proinflammatory" [39]. There is now an urgent need for interventions to help protect future generations of sensitized children from the development of AHR. Because there is growing evidence that allergens encountered at an early age can increase sensitization and AHR [40], and because the sensitized adults in the current studies had less severe AHR, it seems likely that such interventions could be especially effective if instigated in early life, prior to critical stages in the development of the immune system.

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