Pediatr Allergy Immunol 1999: 10: 199–208
Printed in UK. All rights reserved

PEDIATRIC ALLERGY AND IMMUNOLOGY
ISSN 0905-6157

Indoor environment, atopy and the risk of asthma in children in New Zealand

Wickens K, Pearce N, Siebers R, Ellis I, Patchett K, Sawyer G, Stone L, Tohill S, Kennedy J, Slater T, Lewis S, Fitzharris P, Crane J. Indoor environment, atopy and the risk of asthma in children in New Zealand. Pediatr Allergy Immunol 1999: 10: 199–208. © Munksgaard, 1999

The objective of this study was to examine the relationship between the indoor environment, atopy and asthma in 7–9-year-old children. Cases and controls were randomly selected from children who participated in the International Study of Asthma and Allergies in Childhood (ISAAC) in Wellington, New Zealand. Cases were children with a previous diagnosis of asthma and current medication use (n = 233) and controls were children with no history of wheezing and no diagnosis of asthma (n = 241). Information was recorded about the indoor environment during the first year of life and currently. Dust was sampled from floors and beds and Der p 1 and Fel d 1 measured using enzyme-linked immunosorbent assays. Skin-prick tests were performed with eight common allergens. Sensitization to *Dermatophagoides farinae* (OR = 3.19; 95% CI 1.74–5.84), *Dermatophagoides pteronyssinus* (OR = 2.06; 95% CI 1.16–3.65) and cat (OR = 3.89; 95% CI 1.06–14.30) were independently associated with current asthma. The use of a sheepskin in the first year of life (OR = 1.91; 95% CI 1.11–3.33) was also independently associated with current asthma but current Der p 1 levels showed no association with current asthma. Exposures in early life may be more important than current exposures in determining asthma at age 7–9 years. Prospective studies are needed in New Zealand to determine the relative importance of early life exposures to Der p 1 and other risk factors for asthma.

Kristin Wickens, Neil Pearce, Robert Siebers, Ian Ellis, Kathryn Patchett, Gillian Sawyer, Louise Stone, Sarah Tohill, Jo Kennedy, Tania Slater, Simon Lewis, Penny Fitzharris and Julian Crane

Wellington Asthma Research Group, Wellington School of Medicine, PO Box 7343, Wellington South, New Zealand

Key words: atopy; bedding; carpet; case–control; damp; Der p 1; Fel d 1; indoor environment; pets

Kristin Wickens, Wellington Asthma Research Group, Wellington School of Medicine, PO Box 7343, Wellington South, New Zealand
Tel: +64 4385-5999 ext 6780
Fax: +64 4389-5427
E-mail: kwickens@wnmeds.ac.nz

Accepted 28 April 1999

Recent international prevalence studies have confirmed the previously suspected high prevalence of asthma in children in New Zealand and other English-speaking countries, with 25% of New Zealand 6–7-year-olds reporting wheezing in the last 12 months (1,2). Furthermore, 12.5% of children currently use asthma medication (3). Although national time series data are not available, there is evidence from two local studies, using the same methodology in the same population, of an increase in asthma prevalence between 1969 and 1982 (4) and between 1975 and 1989 (5).

The reasons for the high prevalence of asthma in English-speaking countries are unclear but a number of hypotheses have been based around housing and lifestyle factors that may have changed over time and contributed to the current high asthma prevalence. In particular, it has been suggested that changes in domestic heating, washing and home ventilation may have resulted in increased indoor humidity. This, together with the widespread use of fitted carpets, is likely to have created environments conducive to the growth and persistence in the environment of indoor allergens, such as dust mites, cat and moulds. An atopic response to these allergens is closely associated with asthma (6,7). It has also been proposed that increasing amounts of time are spent indoors as television viewing has increased among children (8), so even if indoor allergen levels have remained constant, exposure to these or other indoor factors may have increased.

This study investigates the relationship between the indoor environment, atopy and current asthma in 7–9-year-old children in Wellington, New Zealand.

Methods

This case–control study is based on the Wellington, New Zealand arm of the International Study of Asthma and Allergies in Children (ISAAC) (9) which was a population-based cross-sectional prevalence study of all children aged 6–7 and 13–14 attending randomly selected schools. The ISAAC study did not include the collection of risk factor information.

Study size

It was estimated that with an achieved sample of 240 cases and 240 controls, and if 30% of the controls were exposed to a particular factor, the study would have 95% power to detect a relative risk of 2.0.

Recruitment of study subjects

Potential cases and potential controls were selected from the 3318 ISAAC Wellington participants in the younger age group, by then aged 7–9 years (mean 8.29). The 781 ISAAC children who reported wheezing or whistling in the chest in the last 12 months and reported ever having had asthma constituted the sampling frame from which 399 potential cases were selected at random. In order to limit the cases to children with current asthma, screening questions to the parents further restricted the cases to children with diagnosed asthma who had used medication in the last 12 months.

The 2113 ISAAC children whose parents had reported that their child had never had wheezing or whistling in the chest and never had asthma constituted the sampling frame from which the 398 potential controls were selected. Further screening questions to the parents ensured that these children had never had wheezing or whistling in the chest and never had a doctor's diagnosis of asthma.

Collection of exposure information

Questionnaires. Questionnaires recorded information about condensation, dampness or mould in the home, type and age of floor coverings and mattress, type and cleaning of bedding, and the presence of pets. This information was recorded for the present, and, retrospectively, for the first year of the child's life. Detailed information on sheepskin use was collected for the first year of life only.

Dust sampling. Reservoir dust was sampled from the living room floor, the child's bedroom floor and the bedding of each child according to a standard protocol described in a previous paper (10).

Petri dishes. The lid and base of 140 mm diameter Petri dishes, which had been coated in fish gel, were used for the collection of settle dust in the child's bedroom. They were placed on a high surface with no overhanging shelves and away from any opening window, then collected after 4 weeks and frozen until analysis of Der p 1 levels.

Der p 1 and Fel d 1 measurement. Der p 1 was assayed in all reservoir dust samples and Fel d 1 in samples from a random selection of 51 case and 47 control subjects. Extractions were at room temperature with phosphate-buffered saline and levels were estimated using standard monoclonal antibody enzyme-linked immunosorbent assays (ELISAs) for Der p 1 (11) and Fel d 1 (12). The between-batch coefficient of variation was 10.2% for Der p 1 and 7.1% for Fel d 1.

Skin-prick tests. Skin-prick tests were performed on the forearm using Bayer prick lancets with eight common allergens (cockroach, four-mould mix, *Dermatophagoides pteronyssinus, Dermatophagoides farinae*, rye grass, timothy grass, dog and cat; Dome/Hollister Stier supplied by Ebos Group Ltd, Auckland, New Zealand) and a negative and positive (histamine) control. The sampled child and, where possible, both biological parents were tested.

Weal size was recorded at 15 min with a mean weal diameter of ≥ 3 mm being considered positive and indicative of atopy.

Statistical analysis

Data analysis was conducted using SAS version 6.12. Odds ratios (and 95% confidence intervals) were estimated using the Mantel–Haenszel method (13) for the basic analysis and logistic regression (14) to adjust for potential confounders in some analyses.

Der p 1 and Fel d 1 data were approximately log-normally distributed so geometric means (and 95% confidence intervals) were used for analyses involving differences in levels between subgroups. For the categorical analysis of Der p 1, less than 10 μg/g of Der p 1 was chosen as the reference category as 10 μg/g has been proposed as the level at which symptoms occur (15). Der p 1 levels above 10 μg/g were then grouped so that each exposure category represented a doubling of Der p 1 levels, as this pattern of Der p 1

exposure has been shown to be associated with asthma among dust mite-sensitized children (16). To reduce variation in odds ratios due to small numbers at some exposure levels, these categories were collapsed so that the final analysis used the exposure categories 10 to < 40 μg/g and ≥ 40 μg/g for the floor sites, and 10 to < 40 μg/g, 40 to < 160 μg/g and ≥ 160 μg/g for the bed site.

A dampness score was estimated separately for the child's bedroom, the living room and the bathroom based on the number of dampness indicators (condensation, dampness, mould) reported. Each indicator was scored as 0 if absent or 1 if present, giving possible scores of between 0 and 3 for each room. The sum of these scores gave a dampness score for the whole house.

The study was approved by the Central Regional Health Authority Ethics Committee.

Results

Ninety-seven of the 399 potential cases selected from the ISAAC survey were ineligible because they had no doctor's diagnosis of asthma (n = 8), no medication use in the last 12 months (n = 59), had moved from Wellington (n = 24), their whereabouts was unknown (n = 4); two were ineligible for miscellaneous reasons. Of the 398 potential controls, 50 were ineligible because they reported past wheezing or whistling in the chest (n = 14), had had a doctor's diagnosis of asthma (n = 5), had moved away from Wellington (n = 29) or their whereabouts was unknown (n = 2). Of the eligible sample, 44 cases and 69 controls refused, and there were 25 cases and 38 controls from whom we did not get a response. The remaining 233 cases and 241 controls participated in the survey giving a response rate of 77% for cases and 69% for controls.

Der p 1

Vacuum dust. Geometric mean levels (95% confidence intervals, CI) of living room floor Der p 1 were similar for cases (25.8 μg/g; 95% CI 22.0–30.2) and controls (25.2 μg/g; 95% CI 21.5–29.6). Bedroom floor levels were also similar for cases (27.2 μg/g; 95% CI 23.8–31.2) and controls (25.5 μg/g; 95% CI 21.8–29.9) but bed levels were significantly lower ($p = 0.014$) for cases (41.3 μg/g; 95% CI 36.0–47.4) than controls (52.5 μg/g; 95% CI 46.0–59.8). Table 1 shows that the relative risk of asthma tended to be > 1 for floor levels of Der p 1 above 10 μg/g. For dust mite-sensitive children, there was a significantly ($p = 0.026$) higher risk of asthma if the living room level was 10 to < 40 μg/g, compared to levels below 10 μg/g. In contrast, higher concentrations of Der p 1 in the bed were associated with a lower prevalence of asthma.

There were no significant differences in Der p 1 levels according to measures that were indicative of asthma severity. For example, there were no significant differences in floor Der p 1 levels among asthmatics with or without a history of asthma hospitalization or among asthmatics taking or not taking preventive medication (oral or inhaled steroids). There were no significant differences in bed Der p 1 depending on whether the child had been hospitalized or was taking preventive medication, although the latter showed differences which approached significance ($p = 0.065$): using preventive medication 40.9 μg/g (95% CI 34.6–48.5), not using preventive medication 49.7 μg/g (95% CI 44.2–55.8).

For dust mite-sensitive children, living room Der p 1 levels were significantly ($p = 0.042$) higher (29.3 μg/g; 95% CI 24.1–35.6) than in non-sensitized children (23.1 μg/g; 95% CI 20.1–26.5), although the difference was not large. There was no dose–response relationship between increasing weal size to dust mites and floor or bed Der p 1 levels.

Settle dust. Der p 1 collected in Petri dishes was significantly ($p = 0.008$) higher in the bedrooms of controls (106.5 ng/day/m^2; 95% CI 92.6–122.6) compared with the bedrooms of cases (80.8 ng/day/m^2; 95% CI, 69.5–94.0) ($p = 0.008$). There was no difference in levels of Petri dish Der p 1 between dust mite-sensitized children and non-sensitized children. Increasing weal diameter reactivity to dust mites also showed no association with Petri dish Der p 1 levels.

Fel d 1

In the total study population, there were no significant differences for geometric mean concentrations of Fel d 1 for either living room (cases 13.5 μg/g, 95% CI 7.8–23.5; controls 14.4 μg/g, 95% CI 6.7–31.0) or bedroom floor (cases 8.5 μg/g, 95% CI 5.3–13.6; controls 12.1 μg/g, 95% CI 6.5–22.7). Bed levels were higher for controls (20.2 μg/g; 95% CI 11.1–36.6) than cases (10.9 μg/g; 95% CI 6.0–19.7), but this difference was not significant. There were no consistent or statistically significant associations between increasing quartiles of floor Fel d 1 and the risk of asthma, although the risk of asthma

Table 1. Odds ratios and 95% confidence intervals for the association between asthma in New Zealand children and exposure to current Der p 1 (μg/g)

	Cases	Controls	OR	95%CI	p value
All respondents	n = 233	n = 241			
Living room floor (μg/g)					
< 10	41	50	1.00†		
10 – < 40	97	98	1.21	0.73–1.99	0.461
≥ 40	94	90	1.27	0.77–2.11	0.347
Bedroom floor (μg/g)					
< 10	36	42	1.00†		
10 – < 40	113	102	1.29	0.77–2.17	0.333
≥ 40	82	93	1.03	0.60–1.76	0.918
Bedding (μg/g)					
< 10	23	13	1.00†		
10 –< 40	86	73	0.67	0.32–1.41	0.286
40 – < 160	100	121	0.47	0.23–0.96	0.038
≥ 160	21	30	0.40	0.17–0.95	0.038
Among dust mite atopics	n = 141	n = 49			
Living room floor (μg/g)					
< 10	19	13	1.00†		
10 –< 40	54	13	2.84	1.14–7.11	0.026
≥ 40	68	21	2.22	0.95–5.19	0.067
Bedroom floor (μg/g)					
< 10	24	10	1.00†		
10 – < 40	63	19	1.38	0.56–3.40	0.482
≥ 40	54	18	1.25	0.50–3.12	0.632
Bedding (μg/g)					
< 10	11	2	1.00†		
10 – <40	54	16	0.61	0.12–3.05	0.551
40 – < 160	59	24	0.45	0.09–2.12	0.310
≥ 160	15	5	0.55	0.09–3.39	0.516

†Reference category.

was lower (OR = 0.50; 95% CI 0.20–1.28) when concentrations of bed Fel d 1 exceeded 2.5 μg/g (the lowest quartile).

Atopy

Table 2 shows the positive relationship between skin-prick test sensitivity to individual allergens and asthma, and a dose–response relationship, with increasing numbers of positive responses and increasing mean weal diameters across all allergens related to increasing risks of asthma.

Damp

For the home during the first year of life, reported condensation or dampness in bathrooms, living rooms, the child's bedroom or any room in the home was not related to current asthma. Reported mould in each room was also unrelated to current asthma but the reporting of any mould in the house showed a significant (p = 0.042) negative association (OR = 0.63; 95% CI 0.40–0.98). In general, the dampness score, calculated for the home during the first year of life, in each of these rooms or in the whole house was also not associated with current asthma although a high dampness score in the child's bedroom was negatively associated with current asthma (OR = 0.43; 95% CI 0.19–0.99) (p = 0.047).

For the current home, any reported condensation, dampness or mould in bathrooms, living rooms, the child's bedroom or any room in the home was also not significantly related to current asthma, although there was a tendency for the odds ratio for asthma to be less than 1 for children in homes with a house dampness score greater than 0.

Floor covering

Table 3 shows that, although having carpets currently was not associated with asthma, there were non-significant positive associations between having a carpeted bedroom in the first year of life and the development of asthma.

Bedding

Table 4 shows that any sheepskin use in the first year of life was significantly (p = 0.003) associated with an increased risk of asthma and that this increased risk persisted for sheepskins used in different sites and for any period of use. This risk was greater for children with any atopy and for children who were atopic to dust mites than among the total study population. Washing,

Table 2. Odds ratios and 95% confidence intervals for the association between asthma in New Zealand children and atopy

	Cases (n = 230)		Controls (n = 237)				
	Yes	No	Yes	No	OR	95%CI	p value
Any atopy	156	74	59	178	6.36	4.31–9.39	< 0.001
Cockroach	20	210	5	232	4.42	1.76–11.11	0.002
Mould	12	218	1	236	12.99	2.63–64.19	0.002
D. farinae	119	111	31	206	7.12	4.63–10.96	< 0.001
D. pteronyssinus	125	105	41	196	5.69	3.78–8.56	< 0.001
Any dust mite	141	89	49	188	6.08	4.09–9.03	< 0.001
Cat	34	196	3	234	13.53	5.26–34.82	< 0.001
Dog	3	227	1	236	3.12	0.36–26.97	0.301
Rye grass	80	150	32	205	3.42	2.18–5.35	< 0.001
Timothy grass	72	158	34	203	2.72	1.74–4.26	< 0.001
Number of positive responses							
None	74		178		1.00†		
1	23		11		5.03	2.46–10.30	< 0.001
2	43		21		4.93	2.82–8.62	< 0.001
3	36		17		5.09	2.79–9.30	< 0.001
4	30		7		10.31	4.88–21.79	0.001
5+	24		3		19.24	7.50–49.41	< 0.001
Mean diameter (mm) all allergens							
0	59		151		1.00†		
0.1– < 1	32		37		2.21	1.27–3.86	0.005
1–1.99	52		23		5.79	3.34–10.01	< 0.001
2–2.99	42		16		6.72	3.66–12.32	< 0.001
3+	45		10		11.52	5.95–22.30	< 0.001

†Reference category.

drycleaning or covering the sheepskin was not found to affect the risk of asthma.

The use of a secondhand mattress during the first year of life showed a non-significant negative association with current asthma (OR = 0.68; 95% CI 0.45–1.02). However, covering the mattress, sleeping in the parents' bed, a bassinet or a cot did not affect the risk of current asthma.

Table 5 shows the association between current bedding characteristics and current asthma. The use of a wool underlay (p = 0.048) or a plastic sheet (p = 0.045) was associated with significantly increased risks of asthma, while the use of an electric blanket or a mattress > 1 year old was marginally associated with increased risks of asthma.

There were no significant associations between washing underblankets, top blankets, bedspreads or any bedding and asthma. However, washing the duvet 3–6 times a year (OR = 2.32; 95% CI 1.29–4.16) (p = 0.005) or more than 6 times a year (OR = 2.75; 95% CI 1.39–5.44) (p = 0.004) was positively associated with asthma. In contrast, drycleaning the duvet (OR = 0.20; 95% CI 0.05–0.80) (p = 0.023) or drycleaning any bedding (OR = 0.43; 95% CI 0.17–1.11) (p = 0.080) was negatively associated with asthma. Airing the mattress was not associated with asthma, but airing the underblanket 3–6 times (OR = 2.17; 95% CI 1.00–4.72) (p = 0.051) or more than 6 times in the last year (OR = 1.83; 95% CI 0.93–3.57) was positively associated with asthma compared with not airing underblankets in the last 12 months. Airing the duvet up to 3 times (OR = 1.44; 95% CI 0.95–2.18) or 3 or more times (OR = 1.60; 95% CI 0.78–3.29) compared to not airing the duvet in the last 12 months was also positively associated with asthma.

Pets

Fifty-four per cent of cases and 49% of controls had cats in their current home, and, for the first year of life, 48% of cases and 41% of controls had cats in the home. While the presence of cats, dogs or birds inside or in the bedroom during the first year of life, or currently, was not significantly related to current asthma, the presence of cats both during the first year of life and currently was marginally significantly associated with current asthma (OR = 1.42; 95% CI 0.97–2.08) compared to when no cats had been present or cats were present at just one of these times.

Multi-variate analysis

As atopy is likely to be an intermediate variable between allergen exposures and asthma, variables measuring atopy were considered separately from the variables that were indicative of allergen exposure. Thus a model which included all atopy variables, found that sensitivity to *D. farinae* (OR = 3.19; 95% CI 1.74–5.84) (p < 0.001),

Table 3. Odds ratios and 95% confidence intervals for the association between asthma in New Zealand children and floor covering in the first year of life and currently

	Cases (n = 233)	Controls (n = 241)	OR	95%CI	p value
Floor covering currently					
Living room floor					
No carpet/rugs only	20	14	1.00†		
Carpet $\leq$ 1 year	9	7	0.90	0.27–3.03	0.865
Carpet $>$ 1 year	202	218	0.65	0.32–1.31	0.229
Bedroom floor					
No carpet/rugs only	15	12	1.00†		
Carpet $\leq$ 1 year	7	7	0.80	0.22–2.96	0.738
Carpet $>$ 1 year	210	221	0.76	0.35–1.66	0.491
Floor covering during the first year of life					
1st bedroom					
No carpet/rugs only	17	25	1.00†		
Carpet	213	212	1.48	0.78–2.81	0.234
2nd bedroom	n = 95	n = 103			
No carpet/rugs only	9	15	1.00†		
Carpet	86	88	1.63	0.68–3.91	0.274

†Reference category.

D. pteronyssinus (OR = 2.06; 95% CI 1.16–3.65) (p = 0.014) and cat (OR = 3.89; 95% CI 1.06–14.30) (p = 0.041) remained significantly associated with current asthma, and mould sensitivity (OR = 3.60; 95% CI 0.39–33.61) remained strongly but non-significantly associated with asthma. A separate multi-variate analysis (Table 6) controlled for all other variables that were strongly or significantly related to asthma in the univariate analysis, including exposures not reported in this paper. These variables included sheepskin use in the first year of life, current use of a waterbed or a plastic sheet, age of current mattress, gender, maternal and paternal asthma, eczema and hayfever, social class (categories 1–6, unemployed), family size, measles and whooping cough infection, polio, hepatitis B and measles, mumps, rubella (MMR) vaccination, childcare use in the first year of life and passive smoking exposure. After adjusting for these variables, sleeping on a sheepskin during the first year of life remained a significant (p = 0.021) risk factor associated with asthma. Current use of a waterbed or an older mattress were also associated with non-significant but increased risks of asthma but the effect estimate for the current use of a plastic sheet decreased and became non-significant. Because of problems with multi-collinearity, the current use of a wool underlay or an electric blanket could not be included in this model but when each of these replaced the variable for plastic sheet use, the effect of each also reduced (electric blanket: OR = 1.62, 95% CI 0.74–3.55; wool underlay: OR = 1.16, 95% CI 0.52–2.60).

An additional model was run to determine the independent effects of a waterbed or plastic sheet on the mattress, washing or airing the duvet, or

Table 4. Odds ratios and 95% confidence intervals for the association between asthma in New Zealand children and use of a sheepskin in first year of life

	Total population			Atopics			Dust mite atopics		
	OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value
Place used									
Not used	1.00†			1.00†			1.00†		
Any use	1.91	1.24–2.93	0.003	2.44	1.27–4.69	0.007	2.86	1.43–5.72	0.003
Bed	1.96	1.25–3.05	0.003	2.65	1.33–5.27	0.006	2.96	1.42–6.16	0.004
Floor	2.11	1.32–3.37	0.002	2.69	1.29–5.61	0.008	3.37	1.52–7.47	0.003
Carseat	1.87	1.14–3.08	0.014	2.09	0.96–4.52	0.062	2.14	0.95–4.85	0.067
Pram or carry cot	1.93	1.21–3.07	0.006	2.72	1.29–5.73	0.008	3.16	1.42–7.05	0.005
Pushchair	2.23	1.41–3.52	$<$ 0.001	3.23	1.55–6.73	0.002	3.43	1.57–7.49	0.002
Bouncinette	2.71	1.59–4.58	$<$ 0.001	4.35	1.78–10.64	0.001	5.12	1.91–13.69	0.001
Time used (months)									
$<$ 3	1.81	0.76–4.32	0.178	1.42	0.38–5.34	0.604	1.67	0.38–7.26	0.496
3–6	3.35	1.62–6.94	0.001	4.26	1.18–15.34	0.027	4.29	1.18–15.64	0.028
$>$ 6–9	2.09	0.99–4.44	0.055	3.31	0.88–12.44	0.076	2.86	0.73–11.17	0.131
$>$ 9–12	1.72	1.09–2.69	0.019	2.27	1.13–4.55	0.021	2.78	1.31–5.91	0.008

†Reference category.

Table 5. Odds ratios and 95% confidence intervals for the association between asthma in New Zealand children and current bedding characteristics

	Cases (n = 233)	Controls (n = 241)	OR	95%CI	p value
Current mattress type					
Foam	60	56	1.00†		
Kapok	3	8	0.35	0.09–1.33	0.123
Inner sprung	157	168	0.87	0.57–1.33	0.528
Cotton	2	2	0.93	0.13–6.91	0.946
Waterbed	10	3	3.11	0.86–11.32	0.085
Age of current mattress (years)					
≤ 1	11	22	1.00†		
> 1	217	212	2.05	0.98–4.27	0.056
Current underbedding					
None	26	40	1.00†		
Foam squab	14	14	1.54	0.63–3.76	0.344
Sheepskin	7	10	1.08	0.36–3.21	0.894
Wool underlay	52	42	1.91	1.01–3.61	0.048
Underblanket	149	151	1.52	0.88–2.61	0.131
Plastic sheet	27	19	2.19	1.02–4.70	0.045
Electric blanket	58	49	1.82	0.98–3.39	0.059

†Reference category.

airing the underblanket and bed Der p 1 levels. This analysis showed that all levels of Der p 1 exposure were still negatively associated with asthma but these became non-significant (10 to < 40 μg/g: OR = 0.79, 95% CI 0.36–1.74; 40 to < 160 μg/g: OR = 0.57, 95% CI 0.26–1.23; ≥ 160 μg/g: OR = 0.52, 95% CI 0.20–1.32).

Discussion

This study confirms the findings of several previous studies (17–20) that showed that sensitization to common indoor allergens, including house dust mite, cat and mould allergens, confers a substantially increased risk of the development of asthma. The risk of asthma increased with the extent of allergic sensitization whether measured by number of positive responses or by mean weal diameter (Table 2).

There is now clear evidence for two common indoor allergens, Der p 1 and Fel d 1, that exposure to higher concentrations of these environmental allergens results in a higher prevalence of sensitization (21,22), with prevalence also being increased by positive family history of atopy (21).

An increasing body of evidence also suggests that exposures during the early months, or perhaps years, of life have particularly important effects on the development of allergic sensitization and asthma. Increased specific sensitization to house dust mite by the age of five years has been associated with Der p 1 exposures ≥ 2 μg/g (23), while a fivefold increase in asthma by the age of 11 was found by Sporik et al. (18) to be associated with Der p 1 exposures in infancy ≥ 10 μg/g.

Domestic Der p 1 levels in Wellington are amongst the highest reported worldwide. Over

Table 6. Adjusted§ odds ratios and 95% confidence intervals for the association of asthma in New Zealand children and bedding characteristics

	Cases (n = 233)	Controls (n = 241)	OR	95%CI	p value
Sheepskin use in first year of life					
Yes	189	166	1.91	1.11–3.33	0.021
No	43	72	1.00†		
Waterbed currently					
Yes	10	3	3.01	0.58–15.56	0.188
No	222	237	1.00†		
Age of current mattress (years)					
> 1	217	212	2.37	0.96–5.88	0.062
≤ 1	11	22	1.00†		
Use of plastic sheet currently					
Yes	27	19	1.63	0.65–4.08	0.293
No	206	222	1.00†		

†Reference category. §All variables in the table are adjusted for each other plus gender, maternal and paternal asthma, eczema and hayfever, social class (categories 1–6, unemployed), family size, measles and whooping cough infection, polio, hepatitis B and MMR vaccination, childcare use in the first year of life, and passive smoking exposure.

99% of the homes in this study had a floor or bed Der p 1 concentration > 10 μg/g (10), the suggested threshold for the provocation of asthma symptoms (15).

We have shown here an increased risk of asthma associated with the recalled use of sheepskin bedding in infancy. While increased allergen exposure from sheepskins is not the only possible mechanism for this effect, we have found from a study of the bedding of 154 infants at ages 11 weeks and 15 months that bedding which included sheepskin contained higher concentrations of Der p 1. For example, at the 15-month sampling, the geometric mean (95% CI) Der p 1 in non-sheepskin bedding was 33.6 μg/g (25.5–44.2), while for sheepskin bedding it was 67.8 μg/g (46.0–99.8), this difference being significant (24). Other possible explanations for the association of sheepskin use in infancy with asthma at age 7–9 years would include differential selection of warm bedding for wheezy infants, differential recall bias or exposure to an unidentified asthma-provoking agent associated with sheepskin use. The presence of carpets in the first year of life, which have also been shown to be associated with high Der p 1 levels (10,25), was also associated with a non-significant increased risk of asthma. Unfortunately, the high prevalence of carpets made it difficult to determine the true association between the presence of carpets and the development of asthma.

In this study, we found that current concentrations of Der p 1 and Fel d 1 were lower in the beds of asthmatics than those of control subjects, suggesting that parents of asthmatic children are selectively adopting measures that reduce Der p 1 and Fel d 1 exposure. Indeed the difference appeared partly, but not wholly, due to the increased use of waterbeds and plastic sheets, and the more frequent washing and airing of bedding by asthmatics. Unfortunately, we did not record whether these bedding choices were made because of the child's asthma. Alternatively, this inverse association could arise if high dust mite exposure were a marker for high microbial exposure in homes with lower standards of hygiene. This explanation is consistent with the hypothesis that infections, through promoting a predominantly TH1 immunologic response, protect against the development of allergic disease (26,27).

While high allergen exposure has been clearly associated with increased specific IgE sensitization, it is less clear whether continuing high allergen exposure influences subsequent or concurrent development of asthma in the sensitized individual. Our findings for living room Der p 1 and asthma among dust mite-sensitized children confirm those of Peat et al. (16) who found that the risk of dust mite-sensitized children having current asthma doubled with each doubling of Der p 1 level. However, we did not find any positive association between the current levels of Der p 1 and the presence of asthma at age 7–9 years in the total sample. This is similar to the findings of Marks et al. (28) in 8–10-year-old children in Australia, and may suggest that, in the presence of almost universally high exposure to Der p 1, the development of asthma is limited by other factors, such as genetic background. A recent study in the UK has suggested that several parameters of current asthma severity in mite-sensitive patients correlate with house dust mite allergen levels in the bed (29). Our study did not examine the clinical severity of asthma symptoms other than recording past hospitalization and use of preventive medicines. No definite association was found between these measures and Der p 1 levels.

While Der p 1 exposure in New Zealand is almost universal both in infancy and later childhood, the level of domestic Fel d 1 exposure is determined by the presence or absence of a cat in the household (24). It is interesting in this regard that we have identified a modest association of asthma risk with the presence of a cat in the house both in early life and currently, compared to owning a cat at just one of these times or not owning a cat at all, although there were no significant differences in Fel d 1 concentrations between asthmatics and controls.

Although in some countries dampness may be indicative of deprived social conditions, most New Zealand homes are damp regardless of social position, reflecting poor heating and insulation and high outdoor humidity. These characteristics may explain why, in contrast to other studies (30–34), we did not find a relationship between dampness and current asthma. Alternatively the lack of an association for the presence of dampness in the first year of life and the development of asthma may reflect a non-differential recall bias due to our retrospective collection of data using questionnaires.

Finally, it must be noted that since we examined many factors it is possible that some may be significant by chance alone.

In conclusion, we confirmed the strong association of atopy, particularly to house dust mite and cat, with the presence of asthma. Current levels of Der p 1 were high in the homes of both cases and controls, and we did not find a positive association between current levels and risk of current asthma. The lower allergen levels in the beds of asthmatics suggest that the parents of

these children are intervening to reduce their child's exposure to allergens. This makes it difficult to assess the true relationship between current allergen levels and current asthma. However, it is likely that allergen levels in the infant environment are more important than current levels in determining asthma at age 7–9 years. In support of this, we found that sheepskin use and carpets in infancy were positively associated with current asthma prevalence. Alternatively, the lack of association between current floor levels and current asthma may be due to the influence of other genetic and/or environmental factors on the development of asthma. Prospective studies are needed in New Zealand to determine the relative importance of early life exposures to Der p 1 and other risk factors for asthma.

Acknowledgments

The Wellington Asthma Research Group is funded by a Program Grant from the Health Research Council of New Zealand. Funding for this study was from a Health Research Council Project Grant.

References

1. The International Study of Asthma and Allergies in Childhood (ISAAC). Worldwide variations in the prevalence of asthma symptoms: the International Study of Asthma and Allergies in Childhood (ISAAC). Eur Respir J 1998: 12: 315–35.
2. The International Study of Asthma and Allergies in Childhood (ISAAC). Worldwide variation in the prevalence of symptoms of asthma, allergic rhinoconjunctivitis and atopic eczema: ISAAC. Lancet 1998: 351: 1225–32.
3. Burr M, Limb E, Andrae S, Barry D, Nagel F. Childhood asthma in four countries: a comparative survey. Int J Epidemiol 1994: 23: 341–7.
4. Mitchell E. Increasing prevalence of asthma in children. NZ Med J 1983: 96: 463–4.
5. Shaw R, Crane J, O'Donnell T, Porteous L, Coleman E. Increasing asthma prevalence in a rural New Zealand adolescent population: 1975–89. Arch Dis Child 1990: 65: 1319–23.
6. Burrows B, Sears M, Flannery E, Herbison P, Holdaway M. Respiratory pathophysiologic responses. Relations of bronchial responsiveness to allergy skin test reactivity, lung function, respiratory symptoms, and diagnosis in thirteen-year-old New Zealand children. J Allergy Clin Immunol 1995: 95: 548–56.
7. Sears M, Burrows B, Flannery E, Herbison G, Holdaway M. Atopy in childhood. I Gender and allergen related risks for development of hayfever and asthma. Clin Exp Allergy 1993: 23: 941–8.
8. Gortmaker S, Must A, Sobol A, Peterson K, Colditz G, Dietz W. Television viewing as a cause of increasing obesity among children in the United States: 1986–90. Arch Pediatr Adolesc Med 1996: 150: 356–62.
9. Asher M, Keil U, Andersen H, et al. International study of asthma and allergies in childhood (ISAAC): rationale and methods. Eur Respir J 1995: 8: 483–91.
10. Wickens K, Siebers R, Ellis I, et al. Determinants of house dust mite allergen in Wellington, New Zealand. Clin Exp Allergy 1997: 27: 1077–85.
11. Luczynska C, Arruda L, Platts-Mills T, Miller J, Lopez M, Chapman M. A two-site monoclonal antibody ELISA for the quantification of the major *Dermatophagoides* spp allergens Der p 1 and Der f 1. J Immunol Methods 1989: 118: 227–35.
12. Chapman M, Aalberse R, Brown M, Platts-Mills T. Monoclonal antibodies to the major feline allergen Fel d 1 II. Single step affinity purification of Fel d 1, N-terminal sequence analysis, and development of a sensitive two-site immunoassay to assess Fel d 1 exposure. J Immunol 1988: 140: 812–8.
13. Mantel N, Haenszel W. Statistical aspects of the analysis of data from retrospective studies of disease. J Natl Cancer Inst 1959: 22: 719–48.
14. Harrell F. The Logist Procedure. SAS Supplemental Library User's Guide. Cary, North Carolina: SAS Institute, 1983.
15. Platts-Mills T, Thomas W, Aalberse R, Vervloet D, Chapman M. Dust mite allegens and asthma: report of a second international workshop. J Allergy Clin Immunol 1992: 89: 1046–60.
16. Peat J, Tovey E, Toelle B, et al. House dust mite allergens. A major risk factor for childhood asthma in Australia. Am J Respir Crit Care Med 1996: 153: 141–6.
17. Sears M, Herbison G, Holdaway M, Hewitt C, Flannery EM, Silva P. The relative risks of sensitivity to grass pollen, house dust mite and cat dander in the development of childhood asthma. Clin Exp Allergy 1989: 19: 419–24.
18. Sporik R, Holgate S, Platts-Mills T, Cogswell J. Exposure to house-dust mite allergen (Der p 1) and the development of asthma in childhood. N Engl J Med 1990: 323: 502–7.
19. Leung R, Ho P, Lam C, Lai C. Sensitization to inhaled allergens as a risk factor for asthma and allergic diseases in Chinese population. J Allergy Clin Immunol 1997: 99: 594–9.
20. Burrows B, Martinez F, Halonen M, Barbee R, Cline M. Association of asthma with serum IgE levels and skin-test reactivity to allergens. N Engl J Med 1989: 320: 271–7.
21. Wahn U, Lau S, Bergmann R, et al. Indoor allergen exposure is a risk factor for sensitization during the first three years of life. J Allergy Clin Immunol 1997: 99: 763–9.
22. Warner A, Bjorksten B, Munir A, Moller C, Schou C, Kjellman N-IM. Childhood asthma and exposure to indoor allergens: low mite levels are associated with sensitivity. Pediatr Allergy Immunol 1996: 7: 61–7.
23. Rowntree S, Cogswell J, Platts-Mills T, Mitchell E. Development of IgE and IgG antibodies to food and inhalant allergens in children at risk of allergic disease. Arch Dis Child 1985: 60: 727–35.
24. Sawyer G, Kemp T, Shaw R, et al. Biologic pollution in infant bedding in New Zealand: high allergen exposure during a vulnerable period. J Allergy Clin Immunol 1998: 102: 765–70.
25. Van Strien R, Verhoeff A, Brunekreef B, Van Wijnen J. Mite antigen in house dust: relationship with different housing charcteristics in the Netherlands. Clin Exp Allergy 1994: 24: 843–53.
26. Shaheen S. Changing patterns of childhood infection

and the rise in allergic disease. Clin Exp Allergy 1995: 25: 1034–7.
27. Von Mutius E, Martinez F, Fritzsch C, Nicolai T, Reitmeir P, Thiemann HH. Skin test reactivity and number of siblings. BMJ 1994: 308: 692–5.
28. Marks G, Tovey E, Toelle B, Wachinger S, Peat J, Woolcock A. Mite allergen (Der p 1) concentration in houses and its relation to the presence and severity of asthma in a population of Sydney schoolchildren. J Allergy Clin Immunol 1995: 96: 441–8.
29. Custovic A, Taggart S, Francis H, Chapman M, Woodcock A. Exposure to house dust mite allergens and the clinical activity of asthma. J Allergy Clin Immunol 1996: 98: 64–72.
30. Andrae S, Axelson O, Bjorkstem B, Fredriksson M, Kjellman N-IM. Symptoms of bronchial hypereactivity and asthma in relation to environmental factors. Arch Dis Child 1988: 63: 473–8.
31. Brunekreef B, Dockery D, Speizer F, Ware J, Spengler J, Ferris B. Home dampness and respiratory morbidity in children. Am Rev Respir Dis 1989: 140: 1363–7.
32. Brunekreef B. Associations between questionnaire reports of home dampness and childhood respiratory symptoms. Sci Total Environ 1992: 127: 79–89.
33. Lindfors A, Wickman M, Hedlin G, Pershagen G, Rietz H, Nordvall S. Indoor environmental risk factors in young asthmatics: a case–control study. Arch Dis Child 1995: 73: 408–12.
34. Verhoeff A, Van Strien R, Van Wijnen J, Brunekreef B. Damp housing and childhood respiratory symptoms: The role of sensitization to dust mites and molds. Am J Epidemiol 1995: 141: 103–10.