

Mite and Pet Allergen Levels in Homes of Children Born to Allergic and Nonallergic Parents: The PIAMA Study

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The Prevention and Incidence of Asthma and Mite Allergy (PIAMA) study is a birth cohort study that investigates the influence of allergen exposure on the development of allergy and asthma in the first several years of life. The objectives of this study were to investigate the relationship between a family history of allergy and/or asthma and exposure of newborn children to mite and pet allergen and to study the influence of different home and occupant characteristics on mite allergen exposure. Dust was sampled from the child's mattress and the parental mattress at 3 months after birth of the index child and analyzed for mite and pet allergens. Subjects were divided in groups according to history of asthma and allergy in their parents, and allergen exposure was studied in the different groups. Cat allergen exposure was significantly lower on parental mattresses in families with allergic mothers, but dog allergen exposure was not different. Mite allergen exposure was lower on parental mattresses in families with allergic mothers. Use of mite allergen-impermeable mattress covers reduced mite allergen exposure. Some other characteristics such as age of home and mattress were also found to influence mite allergen exposure. Parental mattresses in homes of allergic mothers had lower cat and mite (but not dog) allergen loadings than mattresses in homes of nonallergic parents. Paternal (as opposed to maternal) allergy seemed to have little influence. **Key words:** allergens, infants, mites, pets. *Environ Health Perspect* 110:A693–A698 (2002). [Online 10 October 2002]

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A family history of asthma or allergy is associated with an increased risk of developing allergy and asthma (Horst and Halken 2000; Sears 1998; Strachan 1999). Allergic families are likely to take measures to decrease exposure to allergens (Brunekreef et al. 1992; van Strien et al. 1995). Previously, we showed that allergic parents of infants included in the Prevention and Incidence of Asthma and Mite Allergy (PIAMA) study more often reported taking allergen-avoidance measures and had a cat at home less often than did nonallergic parents (Wijga et al. 2001). Such selective allergen avoidance could complicate studies of the relationship between allergen exposure and development of allergic disease in children. Early allergen exposure is associated with sensitization in children (Verhoeff et al. 1994; Wahn et al. 1997), but it is still unclear whether the development of asthma is also affected (Custovic et al. 2001; Lau et al. 2000).

Allergen avoidance measures and several different housing and occupant characteristics might influence mite allergen concentrations, as has been shown in a number of studies (Chew et al. 1998, 1999; Simpson et al. 2001; van Strien et al. 1994; Wickens et al. 2001). Characteristics associated commonly with higher mite allergen concentrations were increasing numbers of occupants, older homes,

older mattresses, and dampness of the home. A large part of the variation in mite allergen concentrations is usually not explained by housing and occupant characteristics; therefore these characteristics remain relatively poor predictors of mite allergen exposure levels (Chew et al. 1999). Furthermore, *Dermatophagoides pteronyssinus* (*Der p* 1) and *D. farinae* (*Der f* 1) concentrations in house dust are weakly correlated with each other, suggesting that different housing characteristics influence concentrations of these two mite allergens (Gross et al. 2000).

In this study we investigated whether parental allergy and asthma are associated with allergen concentrations in mattress dust and which housing characteristics influence *Der p* 1 and *Der f* 1 concentrations in mattress dust.

Materials and Methods

The PIAMA study is a prospective birth cohort study, consisting of two parts: a natural history part, in which no intervention takes place, and a double-blind placebo-controlled intervention part in which the effect of mite-impermeable mattress encasings is studied. Pregnant women were recruited into the study during the first trimester of pregnancy and were selected on the basis of self-reported allergies and/or asthma, using a validated

questionnaire (Lakwijk et al. 1998) that was distributed by 52 midwife practices and obstetric clinics in the Netherlands. In total, 3,291 pregnant women were included in the natural history study (NHS), of which 472 reported an inhalant allergy and/or asthma (NHS-a, response rate 62%) and 2,819 did not report an allergy, or asthma (NHS-na, response rate 55%). Wijga et al. (2001) described recruitment and inclusion of the natural history subjects in more detail. In the intervention study, 855 pregnant women reporting allergies and/or asthma were included (response rate 42%) and randomly assigned to a placebo and an active group.

Selection criteria for the group of allergic mothers in the natural history study and in the intervention study were the same. In 810 subjects, the intervention measures were applied—416 in the active group (IS-act) and 394 in the placebo group (IS-pl). The intervention consisted of mite-impermeable mattress covers for the parents' and the child's bed in the active group and cotton mattress covers in the placebo group, applied in the third trimester of pregnancy. All subjects in the intervention study were eligible for a home visit at 3 months after the birth, and all subjects with an allergic mother and a random sample ($n = 655$) of the subjects with a nonallergic mother were eligible in the natural history study. At 3 months after the birth in 716 (367 in the active group and 349 in the placebo group) homes in the intervention study, dust samples were collected. In the natural history study, dust samples were collected in 427 homes (91%) of mothers reporting an allergy and/or asthma, and 610 homes (93%) of mothers not reporting an allergy or asthma. Allergy and asthma in the father were assessed using the same questions that were used for the mother; these questions were asked in the third trimester of pregnancy and were not used to select subjects for the different subgroups of the study. We obtained written informed consent from all parents.

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Dust sampling and analysis. Trained field-workers took dust samples from the parents' mattress and the child's mattress after the blanket (but not the bottom sheet) was removed, so dust was sampled from the entire upper surface of the sheets, on which the subjects actually slept. Dust was sampled using a Rowenta Dymbo vacuum cleaner (Rowenta, Offenbach, Germany) at 1,200 W, with an ALK-filter holder (ALK, Horsholm, Denmark). Paper filters (no. 589; Schleicher & Schuell, Dassel, Germany) were put in 500-mL disposable polyethylene butter dishes and weighed before sampling after at least 24 hr equilibration at 20°C and 50% relative humidity. At the sampling site the filter was placed in the filter holder using forceps. Sampling was done from the total mattress surface of each bed for 2 min. After sampling, the dust and the filter were put back into the butter dish and frozen at the end of the day (−20°C). After thawing and acclimatization for 24 hr, the butter dish was weighed again and the total amount of dust was recorded. Weighing was done on a Mettler 261 AT (Mettler-Toledo, Tiel, the Netherlands) analytical balance. The limit of detection for this procedure was 11 mg dust, based on repeated weighing of blank samples. The dust and the filter were extracted for 2 hr by shaking with phosphate-buffered saline (8 g NaCl, 0.2 g KCl, 1.44 g Na₂HPO₄, 0.24 g KH₂PO₄, 0.5 g NaN₃ in 1 L doubly distilled water, adjusted to pH 7.2). For 0–300 mg dust, 3 mL was used, 5 mL for 300–500 mg, 10 mL for 500–1,000 mg, and 20 mL for more than 1,000 mg. Aliquots of the extracts were stored at −20°C, until analysis.

Dust extracts were analyzed for *Der p 1*, *Der f1*, *Fel d 1*, and *Can f 1*, using reagents for a sandwich enzyme immunoassay, purchased from Indoor Biotechnologies (Cardiff, UK). As catching antibody for the *Der p 1* and *Der f1* assays mouse IgG anti-mite monoclonal antibodies 5H8 and 6A8, respectively, were used. Both assays use biotinylated Mouse IgG1 anti-mite monoclonal 4C1 as a detecting antibody. For *Fel d 1* and *Can f 1* the monoclonal antibodies 6F9 and 6E9 were used, respectively, as catching antibody; and as detecting antibodies monoclonal anti-*Fel d 1* 94/01 and polyclonal anti-*Can f 1* were used. Avidine peroxidase (DAKO, Glostrup, Denmark) was used as conjugate for *Der p 1*, *Der f1*, and *Fel d 1* assays, whereas polyclonal horse anti-rabbit IgG-peroxidase (CLB, Amsterdam, The Netherlands) was used for the *Can f 1* assay. Ortho phenylene diamine in a citric acid sodium phosphate buffer (pH 5.5) with H₂O₂ was used as substrate, and the reaction was stopped with 2 M HCl. Absorbance was read at 492 nm. All extracts were diluted 5-, 10-, and 20-fold, and more if required. The median coefficient of variation (CV) of analysis on the same day

was 7.9%, 8.1%, 10.4%, and 16.0% for *Der p 1*, *Der f1*, *Fel d 1*, and *Can f 1*, respectively. The lower limit of detection was 8 ng/mL for *Der p 1*, 6 ng/mL for *Der f1*, 0.4 mU/mL for *Fel d 1*, and 20 ng/mL for *Can f 1* for 5-fold diluted samples. Samples with undetectable amounts of allergen were given a value of two-thirds of the detection limit because the distributions were log-normal. The undetectable values were not distributed equally over the range below the limit of detection, but there will be more close to the detection limit than close to zero. To reflect this, we arbitrarily chose a value

between 0.5 and 1 at two-thirds. This was done for the results of 36%, 27%, 1%, and 60% of the samples taken from the parental mattress, and 65%, 52%, 13%, and 68% of the samples taken from the child's mattress, respectively, for *Der p 1*, *Der f1*, *Fel d 1*, and *Can f 1*. Of dust samples with an undetectable amount of dust (< 11 mg), the amount of allergen per gram dust was not calculated and is therefore missing from all analyses. This was true for two samples taken from the parental mattress and 93 (5%) samples taken from the child's mattress. About 20% of the samples were analyzed in duplicate from a second

Table 1. Number and percentage of characteristics of the 1,753 homes and their occupants in which dust samples were taken at three months after birth.

Variable, categories	No.	Percent	Missing (%)
Study group			
NHS-a	427	24.4	
NHS-na	610	34.7	
IS-placebo	349	20.0	
IS-active	367	21.0	
Age of mother at birth > 30 years	943	53.8	4.1
Age of father at birth > 30 years	1,241	70.8	5.9
Education level			
Low	733	41.8	11.2
Region in the Netherlands			
North	543	31.0	
Middle	663	37.8	
West	547	31.2	
Allergen avoidance measures	614	35.0	0.7
Carpeted infant bedroom floor	780	44.5	16.1
Carpeted parental bedroom floor	1,110	63.3	4.1
Living in apartment	267	15.2	3.1
Double-glazed windows in infant bedroom	857	48.9	16.8
Double-glazed windows in parental bedroom	950	54.2	4.3
Age of infant bed			
New	437	24.9	18.9
1–2 years		465	26.5
> 2 years		519	29.6
Age of parental bed			
< 3 years	423	24.1	9.2
3–6 years	652	37.2	
> 6 years	517	29.5	
Mechanical ventilation	915	52.2	3.9
Construction period of house			
After 1975	816	46.6	7.0
1920–1975	682	38.9	
Before 1920	133	7.8	
Damp stains (anywhere)	585	33.4	11.4
Firstborn child	874	49.9	2.9
Season of sampling			
Autumn	406	23.2	2.7
Winter	486	27.7	
Spring	512	29.2	
Summer	302	17.2	

Table 2. Median dust and allergen concentrations in children's mattresses, natural history study (interquartile range in parentheses).

Allergen	Both parents not allergic (n = 418)	Only mother allergic (n = 287)	Only father allergic (n = 162)	Both parents allergic (n = 121)
Dust (mg/m ²)	174 (94–299)	176 (100–289)	187 (106–278)	198 (109–353)
<i>Der p 1</i> (ng/m ²)	74 (37–178)	74 (37–151)	83 (38–224)	74 (40–181)
<i>Der f1</i> (ng/m ²)	57 (28–134)	63 (28–215)	60 (29–278)	74 (43–241)*
<i>Fel d 1</i> (mU/m ²)	65 (11–544)	49 (12–325)	49 (12–313)	47 (9–236)
<i>Can f 1</i> (ng/m ²)	185 (93–481)	185 (93–586)	185 (93–318)	185 (93–417)

**p* < 0.1 (Wilcoxon two-sample test, compared to both parents not allergic).

aliquot on a different day. Only for samples detectable on one or both occasions was the CV calculated. For *Der p 1*, *Der f 1*, *Fel d 1*, and *Can f 1* the median CV was 15.2%, 19.0%, 32.9%, and 37.3% respectively.

Statistical analysis. Differences in median dust and allergen levels between groups of parents with and without allergies and/or asthma in the natural history study were tested using Wilcoxon's two-sample test. We also assessed the influence of season of sampling on both mite allergens separately, using ln-transformed allergen concentrations and 3-month moving

averages, to diminish random variation (Chatfield 1996). Because sampling in the PIAMA study was done throughout the year, we had to account for season. We did so using multiple linear regression analysis, with dummy variables for the different seasons (January–March, April–June, July–September, and October–December). The months October, November, and December (autumn) were used as the reference season in all analyses. All housing and occupant characteristics were categorized and entered in multiple linear regression models, using ln-transformed dust

and mite allergen concentrations as dependent variables. We used the regression coefficient for each variable to calculate the relative difference the value of this variable made for the dependent variable (i.e., the dust or allergen concentration). The reference concentration is the concentration a subject would have had when all variables were in the reference category. Dust samples with undetectable allergen levels were included in all analyses. Because the results for allergen loads expressed in unit per square meter were similar to those expressed per gram dust, the results are presented for allergen loads expressed in units per square meter only—a more direct measure of exposure to the total amount of allergen per surface unit. To illustrate the similarity, a graphic presentation of mite allergen levels by season is presented for both expressions. *p*-Values < 0.05 were regarded as statistically significant.

Results

Table 1 shows percentages of subjects with different housing and other characteristics, possibly associated with mite allergen concentrations. Tables 2 and 3 show dust and allergen quantities per square meter for the child's bed and the parents' bed, respectively. Both tables show data from the NHS only. On the mattresses of the children, there were no differences in mite and pet allergen loadings in relation to parental allergy. The mattresses of the parents showed a slightly different picture: Cat allergen loadings were lower when the mother or both parents were allergic. Mite allergen levels may vary by season. Samples in this study were taken throughout the year. The geometric mean amounts and concentrations of *Der p 1* and *Der f 1* for both beds per month of sampling are shown in Figure 1, which shows 3-month moving averages. The graphs show that both mite allergens follow a clear seasonal pattern. Levels of both allergens were higher in autumn and reached their lowest level at the end of winter. Seasonal influence was stronger for *Der f 1* (factor 2 change) than for *Der p 1* (factor 1.5 change).

In Tables 4 and 5 various home and occupant characteristics are shown with regard to their influence on the amount of dust and *Der p 1* + *Der f 1* (*Der 1*, ng/m²). Table 4 shows that the amount of dust, as well as the amount of mite allergens per square meter from the child's bed, was significantly lower for children in the active group of the intervention study, compared to the natural history group with allergic mothers. Child's mattresses in the intervention study placebo group had comparable amounts of dust and mite allergen concentrations as mattresses in the natural history group with allergic mothers. Other characteristics associated with higher concentrations of *Der 1* in dust

Table 3. Median dust and allergen concentrations in parents' mattresses, natural history study (interquartile range in parentheses).

Allergen	Both parents not allergic (n = 427)	Only mother allergic (n = 291)	Only father allergic (n = 165)	Both parents allergic (n = 121)
Dust (mg/m ²)	268 (169–426)	256 (154–370)*	284 (186–393)	252 (169–370)
<i>Der p 1</i> (ng/m ²)	132 (33–850)	94 (30–502)#	161 (40–1,078)	76 (30–568)
<i>Der f 1</i> (ng/m ²)	88 (28–667)	88 (26–611)	144 (29–574)	91 (25–425)
<i>Fel d 1</i> (mU/m ²)	64 (16–367)	40 (12–311)#	50 (17–326)	24 (11–101)**
<i>Can f 1</i> (ng/m ²)	111 (67–295)	95 (63–363)	95 (71–249)	88 (64–233)

p* < 0.1; *p* < 0.01; #*p* < 0.05 (Wilcoxon two-sample test, compared to both parents not allergic).

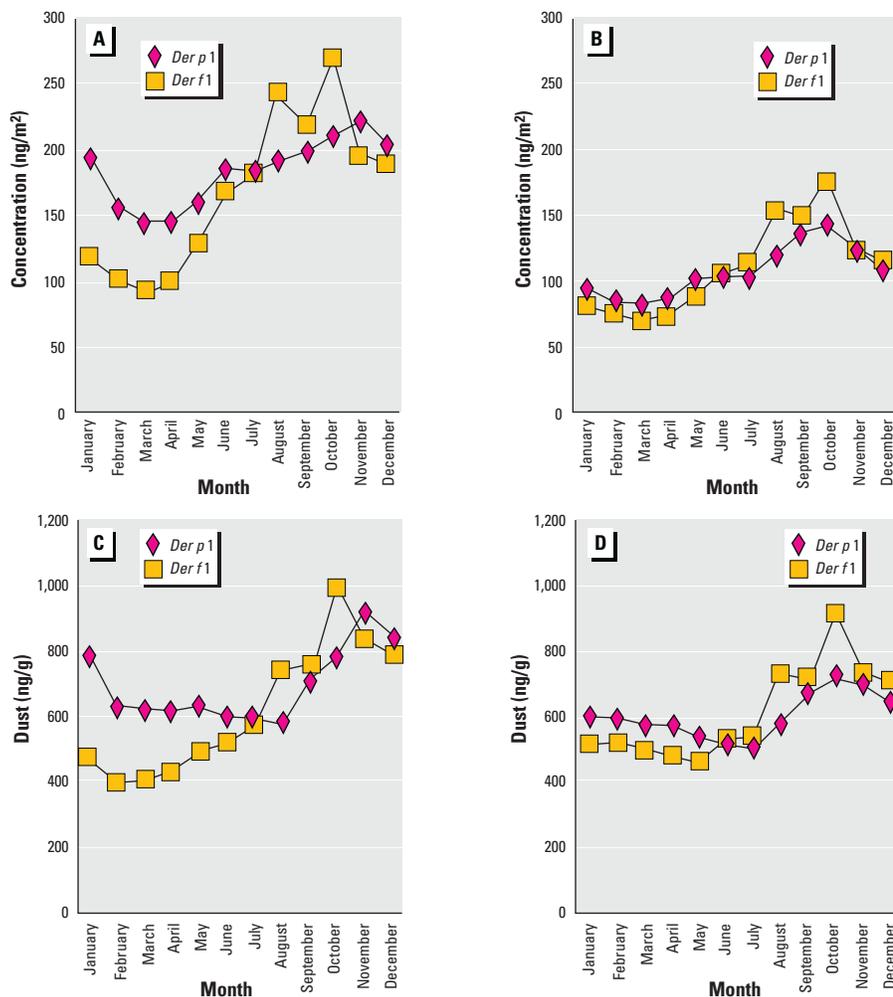


Figure 1. Seasonal variation in mite allergen concentration in the child's (B,D) and parents' (A,C) mattresses in the natural history group (3-month moving averages are shown).

from the child's bed were age of the mattress, absence of double-glazed windows in the child's bedroom, season, and the child having older siblings. Table 5 shows that the amount of dust as well as both mite allergen concentrations in the parents' bed, were significantly lower in the intervention study active group, compared to the natural history group with allergic mothers. Placebo mattress covers lowered *Der 1* loadings as well, and dust and *Der 1* loadings were higher on mattresses of nonallergic than allergic mothers. In addition, *Der 1* levels varied with season and region, were higher in older mattresses and houses, and lower when the child was firstborn. Despite the fact that many determinants were investigated, only a small fraction of the variance in *Der 1* loadings could be explained by our models.

Table 6 shows that the overwhelming determinant of cat and dog allergen in the child's mattress was presence of a cat or dog in the home. In addition, there was a modest influence of the presence of mattress covers and mechanical ventilation (with dog allergen), and age of mattress (with cat allergen). Table 7 shows the results for the parents' mattresses. Again, the influence of the presence of a cat or dog in the home is overwhelming. Presence of mattress covers were more important on parents' than on babies' mattresses; few other factors reached significance.

Discussion

This study showed that in the PIAMA birth cohort, children of mothers with inhalant allergy and/or asthma were born into an environment with lower cat allergen concentrations in mattress dust of parents, which was completely explained by a lower prevalence of cat ownership. *Der 1* loadings were also lower on parents' mattresses in families with allergic mothers. Several home characteristics such as age of home and mattress were shown to increase mite allergen concentrations. Families with allergic fathers but not allergic mothers did not have lower mattress loadings of any allergen compared to families in which no parent was allergic.

Wijga et al. (2001) showed that parents with an allergy reported taking allergen-avoidance measures while furnishing their homes. This study shows that mite allergen levels on parents' mattresses are indeed lower when the mother is allergic. Once maternal allergy was taken into account, however, reported allergen-avoidance measures had no further influence. In previous studies, the *Der p 1* concentration in mattress dust from homes of allergic subjects was also found to be lower than in homes of nonallergic subjects (van Strien et al. 1995; Verhoeff et al. 1994).

Parents' but not children's mattresses in families with allergic mothers had less cat

allergen, as was expected, since Wijga et al. (2001) showed that families in which both parents are allergic were less likely to own a cat than families without parental allergies. The difference between allergic and nonallergic mothers disappeared after taking the difference in cat ownership into account.

For dog allergen there was no difference in the allergen concentration of mattress dust between families with or without maternal allergies and/or asthma. This corresponds to the fact that owning a dog was not influenced by allergies and/or asthma reported by the parents (Wijga et al. 2001).

Table 4. Relative difference in dust and total mite allergen (*Der p 1* + *Der f 1*) on the child's mattress, in relation to various housing and occupant characteristics.^a

Variable	Contrast	Dust 168 mg/m ^{2b}	<i>Der p 1</i> + <i>Der f 1</i> 248 ng/m ^{2b}
Study group	NHS-na vs. NHS-a	0.9 (0.8–1.1)	1.0 (0.8–1.2)
	IS-pl vs. NHS-a	1.0 (0.9–1.2)	1.0 (0.8–1.2)
	IS-act vs. NHS-a	0.8 (0.7–0.9)**	0.8 (0.6–0.9) [#]
Age of mother at birth > 30 years	Yes vs. no	1.1 (1.0–1.3) [#]	1.2 (1.0–1.5) [#]
Age of father at birth > 30 years	Yes vs. no	0.9 (0.8–1.1)	1.0 (0.8–1.2)
Education level	High vs. low	1.0 (0.9–1.1)	1.1 (1.0–1.3)
Region in the Netherlands	Middle vs. north	0.8 (0.7–0.9)**	0.9 (0.8–1.1)
	West vs. north	0.8 (0.7–0.9)**	0.8 (0.7–1.0)*
Allergen avoidance measures taken	No vs. yes	1.1 (1.0–1.2)	1.0 (0.9–1.2)
Carpeted bedroom floor	Yes vs. no	1.0 (0.9–1.1)	1.1 (0.9–1.2)
Living in apartment	Yes vs. no	1.0 (0.9–1.2)	1.2 (0.9–1.6)
Double-glazed windows	Yes vs. no	0.9 (0.8–1.1)	0.8 (0.7–1.0) [#]
Age of mattress	1–2 years vs. new	1.1 (1.0–1.3)*	1.1 (0.9–1.3)
	> 2 years vs. new	1.2 (1.0–1.4) [#]	1.8 (1.4–2.2)**
Mechanical ventilation	No vs. yes	0.9 (0.8–1.0)*	0.9 (0.7–1.1)
Construction period of house	1920–1975 vs. after 1975	1.1 (1.0–1.3)	1.1 (0.9–1.4)
	Before 1920 vs. after 1975	1.0 (0.8–1.3)	1.2 (0.9–1.7)
Damp stains (anywhere)	Yes vs. no	1.1 (1.0–1.2)	1.1 (1.0–1.3)*
Firstborn child	Yes vs. no	0.9 (0.8–1.0) [#]	0.6 (0.5–0.8)**
Season of sampling	Winter vs. autumn	0.9 (0.8–1.0)	0.7 (0.6–0.9)**
	Spring vs. autumn	1.1 (1.0–1.3)	0.7 (0.6–0.9)**
	Summer vs. autumn	1.1 (1.0–1.3)	1.0 (0.8–1.3)
No.		1,083	1,024
Adjusted R ²		0.05	0.14

^aConcentration ratio between presence and absence of characteristic described in table. ^bConcentration is the reference concentration a subject would have had when all variables in the model assume the reference value (0). **p* < 0.1; ***p* < 0.01; [#]*p* < 0.05.

Table 5. Relative difference in dust and total mite allergen (*Der p 1* + *Der f 1*) on the parents' mattress, in relation to various housing and occupant characteristics.^a

Variable	Contrast	Dust 385 mg/m ^{2b}	<i>Der p 1</i> + <i>Der f 1</i> 381 ng/m ^{2b}
Study group	NHS-a vs. NHS-a	1.1 (1.0–1.2) [#]	1.4 (1.1–1.8) [#]
	IS-pl vs. NHS-a	0.9 (0.8–1.0)	0.7 (0.6–1.0)*
	IS-act vs. NHS-a	0.7 (0.6–0.8)**	0.4 (0.3–0.5)**
Age of mother at birth > 30 years	Yes vs. no	1.0 (0.9–1.1)	1.1 (0.9–1.4)
Age of father at birth > 30 years	Yes vs. no	0.9 (0.8–1.0)	0.9 (0.7–1.2)
Education level	High vs. low	1.0 (0.9–1.0)	1.0 (0.9–1.3)
Region in the Netherlands	Middle vs. north	1.0 (0.9–1.1)	0.7 (0.5–0.8)**
	West vs. north	0.6 (0.6–0.7)**	0.5 (0.4–0.6)**
Allergen avoidance measures taken	No vs. yes	0.9 (0.8–1.0)	1.1 (0.9–1.3)
Carpeted bedroom floor	Yes vs. no	0.9 (0.8–1.0)**	0.9 (0.8–1.1)
Living in apartment	Yes vs. no	1.1 (1.0–1.3)*	1.1 (0.8–1.5)
Double-glazed windows	Yes vs. no	0.9 (0.8–1.0)*	0.9 (0.7–1.0)
Age of mattress	3–6 years vs. < 3 years	1.0 (0.9–1.1)	1.9 (1.5–2.4)**
	> 6 years vs. < 3 years	1.0 (0.9–1.1)	1.7 (1.3–2.2)**
Mechanical ventilation	No vs. yes	1.0 (0.9–1.1)	1.0 (0.8–1.3)
Construction period of house	1920–1975 vs. after 1975	1.1 (0.9–1.2)	1.5 (1.2–1.9)**
	Before 1920 vs. after 1975	0.9 (0.8–1.1)	1.3 (0.9–2.0)
Damp stains (anywhere)	Yes vs. no	1.0 (0.9–1.1)	1.2 (0.9–1.4)
Firstborn child	Yes vs. no	1.0 (0.9–1.1)	0.8 (0.6–0.9) [#]
Season of sampling	Winter vs. autumn	0.9 (0.8–1.0)	0.7 (0.5–0.8)**
	Spring vs. autumn	0.9 (0.8–1.0)	0.6 (0.5–0.8)**
	Summer vs. autumn	1.0 (0.9–1.1)	1.1 (0.8–1.4)
No.		1,135	1,081
Adjusted R ²		0.14	0.17

^aConcentration ratio between presence and absence of characteristic described in table. ^bConcentration is the reference concentration a subject would have had when all variables in the model assume the reference value (0). **p* < 0.1; ***p* < 0.01; [#]*p* < 0.05.

Mite allergen concentrations were low in this study compared to earlier studies we conducted in the Netherlands (van Strien et al. 1994, 1995). Concentrations of mite allergen in children's mattresses were comparable,

however, to concentrations found by Custovic et al. (2000) on babies' mattresses, and also comparable to the levels found by Wahn et al. (1997). A direct comparison between samples taken in previous studies and samples taken in

the PIAMA study is fairly difficult because the subjects as well as dust sampling and analysis were different. More study of the changes in mite allergen concentrations and the possible reasons for these changes (Simpson et al. 2001) is justified.

Table 6. Relative difference in cat and dog allergen (Fel d 1 and Can f 1) on the child's mattress, in relation to various housing and occupant characteristics.^a

Variable	Contrast	Fel d 1 31 mU/m ^{2b}	Can f 1 249 ng/m ^{2b}
Cat or dog in home	Yes vs. no	14.4 (11.4–18.2)**	9.1 (7.7–10.8)**
Study group	NHS-na vs. NHS-a	0.9 (0.7–1.2)	1.0 (0.8–1.1)
	IS-pl vs. NHS-a	1.2 (0.9–1.7)	1.0 (0.8–1.2)
	IS-act vs. NHS-a	0.8 (0.6–1.1)	0.8 (0.7–0.9) [#]
Age of mother at birth > 30 years	Yes vs. no	1.2 (0.9–1.5)	1.0 (0.9–1.2)
Age of father at birth > 30 years	Yes vs. no	0.9 (0.7–1.2)	0.9 (0.8–1.1)
Education level	High vs. low	0.9 (0.7–1.1)	1.0 (0.9–1.2)
	Middle vs. north	0.8 (0.6–1.0)*	1.0 (0.9–1.2)
Region in the Netherlands	West vs. north	0.8 (0.6–1.1)	0.9 (0.8–1.1)
	No vs. yes	1.0 (0.8–1.3)	1.0 (0.9–1.1)
Allergen avoidance measures taken	Yes vs. no	0.9 (0.7–1.1)	1.0 (0.8–1.1)
Carpeted bedroom floor	Yes vs. no	1.1 (0.8–1.6)	1.0 (0.8–1.2)
Living in apartment	Yes vs. no	0.9 (0.7–1.1)	0.9 (0.8–1.0)*
Double-glazed windows	Yes vs. no	1.3 (1.0–1.7) [#]	1.1 (0.9–1.2)
Age of mattress	1–2 years vs. new	1.4 (1.0–1.9) [#]	1.0 (0.9–1.2)
	> 2 years vs. new	0.9 (0.7–1.1)	0.8 (0.7–1.0) [#]
Mechanical ventilation	No vs. yes	1.1 (0.8–1.5)	1.1 (0.9–1.3)
Construction period of house	1920–1975 vs. after 1975	0.9 (0.5–1.4)	0.9 (0.7–1.2)
	Before 1920 vs. after 1975	1.1 (0.9–1.4)	1.0 (0.9–1.2)
Damp stains (anywhere)	Yes vs. no	1.2 (0.9–1.5)	1.0 (0.9–1.2)
Firstborn child	Yes vs. no	0.8 (0.6–1.0)*	0.9 (0.8–1.1)
Season of sampling	Winter vs. autumn	0.9 (0.7–1.2)	1.0 (0.8–1.2)
	Spring vs. autumn	0.7 (0.5–1.0)*	0.9 (0.8–1.1)
	Summer vs. autumn	1,031	1,021
No.		0.35	0.40
Adjusted R ²			

^aConcentration ratio between presence and absence of characteristic described in table. ^bConcentration is the reference concentration a subject would have had when all variables in the model assume the reference value (0). **p* < 0.1; ***p* < 0.01; [#]*p* < 0.05.

Table 7. Relative difference in cat and dog allergen (Fel d 1 and Can f 1) on the parents' mattress, in relation to various housing and occupant characteristics.^a

Variable	Contrast	Fel d 1 48 mU/m ^{2b}	Can f 1 183 ng/m ^{2b}
Cat or dog in home	Yes vs. no	15.8 (13.4–18.6)**	20.3 (17.3–23.8)**
Study group	NHS-na vs. NHS-a	1.1 (0.9–1.4)	1.1 (1.0–1.3)
	IS-pl vs. NHS-a	1.0 (0.8–1.2)	0.8 (0.6–0.9)**
	IS-act vs. NHS-a	0.6 (0.5–0.8)**	0.6 (0.5–0.7)**
Age of mother at birth > 30 years	Yes vs. no	1.0 (0.8–1.2)	1.0 (0.8–1.1)
Age of father at birth > 30 years	Yes vs. no	0.8 (0.6–0.9)**	0.9 (0.8–1.0)
Education level	High vs. low	1.1 (0.9–1.3)	0.9 (0.8–1.0) [#]
	Middle vs. north	0.9 (0.7–1.1)	1.0 (0.9–1.1)
Region in the Netherlands	West vs. north	0.7 (0.5–0.8)**	0.8 (0.7–1.0) [#]
	No vs. yes	0.9 (0.7–1.1)	0.9 (0.8–1.1)
Allergen avoidance measures taken	Yes vs. no	0.8 (0.7–0.9)**	0.8 (0.7–0.9)**
Carpeted bedroom floor	Yes vs. no	1.3 (1.0–1.7) [#]	1.1 (0.9–1.3)
Living in apartment	Yes vs. no	0.9 (0.8–1.1)	0.9 (0.8–1.0)*
Double-glazed windows	Yes vs. no	0.9 (0.8–1.1)	1.0 (0.9–1.1)
Age of mattress	1–2 years vs. new	0.9 (0.8–1.1)	0.9 (0.8–1.1)
	> 2 years vs. new	1.0 (0.8–1.2)	1.0 (0.9–1.1)
Mechanical ventilation	No vs. yes	1.2 (1.0–1.5)	1.1 (0.9–1.3)
Construction period of house	1920–1975 vs. after 1975	1.1 (0.8–1.6)	1.0 (0.7–1.2)
	Before 1920 vs. after 1975	1.0 (0.9–1.2)	0.9 (0.8–1.0)
Damp stains (anywhere)	Yes vs. no	0.9 (0.8–1.1)	1.1 (0.9–1.2)
Firstborn child	Yes vs. no	1.0 (0.8–1.2)	0.9 (0.8–1.1)
Season of sampling	Winter vs. autumn	1.0 (0.8–1.2)	0.9 (0.8–1.1)
	Spring vs. autumn	1.0 (0.8–1.2)	0.9 (0.8–1.1)
	Summer vs. autumn	1.0 (0.8–1.3)	1.1 (0.9–1.3)
No.		1,028	1,064
Adjusted R ²		0.54	0.61

^aConcentration ratio between presence and absence of characteristic described in table. ^bConcentration is the reference concentration a subject would have had when all variables in the model assume the reference value (0). **p* < 0.1; ***p* < 0.01; [#]*p* < 0.05.

Different home and subject characteristics were studied with regard to their influence on mite allergen concentrations. This revealed that even at low concentrations some characteristics were still associated with mite allergen levels. Firstborn children had, on average, lower mite allergen concentrations in dust from their own beds, and the parents also had lower mite allergen concentrations in dust from their beds. This effect was not caused by the use of new mattresses because the age of the mattress was included in all models, but it could have been caused by the use of new bedding for the child's bed and the parents' bed.

Chew et al. (1999) showed that dust from mattresses in apartments had significantly lower mite allergen concentrations. In this study, parents' mattress *Der p 1* concentrations were lower, but *Der f 1* concentrations were significantly higher (data not shown), with a net result that *Der 1* levels were not significantly higher in apartments. *Der p 1* concentrations seemed to be influenced more by housing characteristics associated with dampness and the age of the house, whereas *Der f 1* was more influenced by seasonal changes and age of the mattress (data not shown). Overall, the characteristics studied here explained only about 10% of the variation in mite allergen concentrations, whereas in a previous study 25% of the variation in the *Der p 1* concentration of dust from the beds of schoolchildren was explained by the same type of characteristics (van Strien et al. 1994). This is likely related to the much lower allergen levels in this study. Comparison of children using mite-impermeable mattress covers with similarly selected children without mattress covers showed that mite allergen loadings were lower in dust from the parents' mattress as well as children's mattresses. For children's mattresses, this seemed primarily an effect of smaller dust loadings, but for parents' mattresses, the effect on mite allergen loadings was much larger than for dust loadings.

In conclusion, cat allergen exposure was lower in parents' mattresses in families of children born to allergic parents, and dog allergen was not affected. Mite allergen exposure was lower on the parents' mattress in families with allergic mothers compared to nonallergic mothers. Only a low percentage of the variation in mite allergen concentrations could be explained by housing and occupant characteristics. The major determinant of pet allergen loadings was having a pet in the home.

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