

Symptoms of Asthma and the Home Environment. The ISAAC I and III Cross-Sectional Surveys in Münster, Germany

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Key Words

Asthma · Cross-sectional survey · Environmental tobacco smoke · Indoor environment · ISAAC · Molds · Pets

Abstract

Background: The indoor home environment has been shown to be associated with the presence of respiratory symptoms and atopic disease. **Methods:** Two cross-sectional surveys (1995–2000) were conducted, using data from the ISAAC phase I and III surveys, collected in Münster, Germany (n = 6,996, response 81.8%). We analyzed the prevalence ratio (PR) for several indoor exposures and asthma-related outcomes in 6- to 7-year-old children, adjusting for potential confounders. **Results:** Positive associations were observed regarding exposure to molds, environmental tobacco smoke, cooking with gas and space heating with fossil fuels, but most associations were not statistically significant. Surprisingly, presence of a carpet was negatively associated with most respiratory conditions. When restricting the analysis to participants without avoidance of a carpet due to a history of atopic disease, the protective associations disappeared. Mostly, present pet ownership did not show positive associations with respiratory symptoms. However, ownership at different times in life revealed positive as-

sociations, particularly in regard to birds owned in the first year of life (PR 1.51, 95% CI 1.11–2.06, for sleep disturbance due to wheeze and PR 1.28, 95% CI 1.01–1.63, for wheeze during the last 12 months, respectively). **Conclusions:** Only few indoor factors were positively associated with the studied outcomes. The change of associations in participants that reported allergy-related avoidance of carpets suggests that the observed effects are a result of asthmatics' changed behavior. The effect of allergy-related change in behavior and the results observed concerning the ownership of pets at different ages underline the need of establishing a precise temporal relationship between disease and exposure.

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Introduction

During the last decades, the prevalence of asthma and allergic disease has increased in many western countries, accompanying changes in lifestyle and environmental exposures [1]. A lot of research focused on outdoor exposures, such as exposure to air pollution caused by traffic and industrial sources, but with the increasing tendency for people to spend most of their times indoors, the focus has turned to the indoor environment as a main factor in asthma pathogenesis [2].

Subsequent studies reported associations between asthma and atopic disease and several factors related to the home environment, such as molds, pets, NO₂-producing sources, environmental tobacco smoke (ETS) or house dust mite in carpets, bedding or animal dander [3].

However, results have been conflicting depending on the exposure under observation, timing of exposure and study methods [4]. Exposure to NO₂-producing sources for example, such as gas heaters, gas cooking stoves or ETS, is influenced by proximity to the source or ventilation of the house, which renders assessment of individual exposure rather difficult.

Exposure to pet animals has been shown to be positively associated with childhood asthma and allergy [5, 6]. Other studies found that pets did not exert an effect on the occurrence of asthma [7], especially in younger children [8]. A protective effect of exposure in early childhood was described against sensitization to cats or dogs in adulthood [9–11].

We have shown earlier, based on data from the International Study of Asthma and Allergy in Childhood (ISAAC) phase I and III in Münster, that all symptoms of asthma among 6- to 7- and 13- to 14-year-old children increased in the period between 1995 and 2000 [12]. In this study, we want to expand these observations by examining the role of several indoor factors to asthma symptoms in the younger age group.

Material and Methods

Study Subjects and Data Collection

The methods of the worldwide ISAAC project and ISAAC Münster have been described in detail elsewhere [12, 13]. Briefly, the current study relies on data from two surveys, conducted 5 years apart, using identical methods and study instruments to assess trends in the prevalence of wheezing and atopic symptoms in 6- to 7-year-old children and factors related to it [12]. A representative sample of schools in Münster was drawn, and pupils with the highest proportion of children in the respective age groups were asked to participate.

Information was collected by parental report after obtaining written consent. As outcome, we analyzed questions from the ISAAC core questionnaire regarding the prevalence of respiratory symptoms during the last 12 months. Symptoms under consideration are current wheeze (wheezing during the last 12 months), speech-limiting wheeze, sleep disturbance due to wheeze, exercise-induced wheeze, number of severe wheezing attacks (<4 vs. ≥4), nocturnal cough and current asthma (wheezing during the last 12 months plus a diagnosis of asthma).

Potential risk factors in the study are the presence of furry and feathery pets (dogs, cats, rodents and birds) at the time of the survey and during the first year of life, presence of dampness or molds in the child's bedroom, exposure to ETS in the apartment (rare vs.

frequent) and type of heating (electricity, oil, coal, gas, wood). In addition, in ISAAC phase I only, we solicited information on energy source for cooking (electricity, gas) and space heating with fossil fuels, defined as heating with a fireplace inside of the apartment as opposed to central heating with the fire place in the cellar or even a different building.

Data Analysis

As potential confounders we included the following variables: survey (1st, 2nd), parental atopy and social economic status. Parental atopy was defined as a history of asthma, hay fever or atopic eczema in either one of the parents. Social economic status was considered high when one parent had a formal school education of at least 12 years. As potential confounders we also tested number of older siblings (<3 vs. ≥3), own bedroom, duration of exclusive breast feeding without supplementary food (<5 months vs. ≥5 months) and frequency of residential truck traffic (rare vs. frequent). Consistent with earlier reports from Münster [12], we included only students with known German nationality and known sex, rendering a total of 6,996 questionnaires for analysis.

We added each of the variables separately to the model. Although inclusion of other environmental exposures did not change the associations, we decided to mutually adjust for passive smoking, frequency of truck traffic and fossil fuel for heating in the analysis of NO₂-producing indoor sources, and for molds and presence of furry/feathery pets in the analysis of bedroom carpets, pets and molds.

We also asked the parents whether they had removed a pet or carpet from the child's bedroom because of an existing atopic disease of the child or a family history of atopy, using the following question: 'Was a carpet/pet removed because of an allergic disease of the child or a positive family history of allergy?' With a second question, parents were requested to mention the kind of pet that had been removed.

We calculated prevalence ratios (PRs) by performing a binomial regression with a log link function to assess correlates of indoor factors, as recommended for cross-sectional studies [14, 15]. All analyses were done using SAS 8.02 statistical package.

Results

The study population consisted of 3,617 (51.7%) male and 3,379 female (48.3%) children. Other study characteristics and the frequencies of the indoor factors and outcomes under investigation are given in table 1. The overall response among all children in both ISAAC surveys was 81.8%.

The PRs for the relation between asthma symptoms and different indoor exposures are shown in tables 2 and 3. Only few indoor factors were positively associated with asthma-related respiratory symptoms. Notably, exposure to passive smoking showed positive associations with respiratory symptoms in girls and with cough in boys, adjusting for survey, parental atopy, parental education, for heating with fossil fuels and truck traffic. However, re-

sults only reached statistical significance at the 95% level for wheeze in girls (PR 1.45, 95% CI 1.14–1.85, table 2) and for speech-limiting wheeze (PR 2.10, 95% CI 1.10–4.04, results not shown) and was marginally significant for exercise-induced wheeze in girls with a PR of 1.39 (95% CI 0.98–1.98, table 3) and cough in boys (PR 1.21, 95% CI 0.99–1.47, results not shown).

Regarding heating with fossil fuels, no significant positive associations were detected when the analysis was restricted to type of energy source for heating. When we considered space heating with fossil fuels, positive associations were observed. Unfortunately, information on space heating was only solicited in the first survey. Furthermore, space heaters were rare in the study population, and therefore, wide confidence intervals were observed and results did not reach statistical significance in most cases. The strongest associations were observed with regard to coal stoves in the apartment with PRs ranging from 1.89 (95% CI 0.72–4.93) for cough (results not shown) to 3.93 (95% CI 1.49–10.39) for nighttime awakening due to wheeze in boys and 1.42 (95% CI 0.40–5.0) for cough to 13.46 (95% CI 1.76–103.1) for current asthma in girls (table 2). Mutual adjustment for heating with other combustion sources did not alter the results.

Cooking with gas was positively associated with respiratory symptoms exclusively in girls, but not with current asthma (tables 2, 3). Again, as information on gas cooking was only available for the first survey, associations showed wide confidence intervals and mostly were not statistically significant, except for cough in girls (PR 1.60, 95% CI 1.13–2.27, results not shown), and marginally significant for wheeze and exercise-induced wheeze (PR 1.52, 95% CI 0.93–2.47, and PR 1.79, 95% CI 0.97–3.27, respectively) (tables 2, 3).

When we constructed a score for NO₂-producing sources (gas cooking, space heating with fossil fuels, ETS, frequent truck traffic), no consistent dose-response relationships were observed according to frequency of exposure (first survey data only).

PRs for molds were elevated for most outcomes but in general were not statistically significant, ranging from 0.44 (95% CI 0.06–3.14) for speech-limiting wheeze to 1.46 (95% CI 1.05–2.01) for cough in girls (results not shown) and 1.09 (95% CI 0.49–2.44) for speech-limiting wheeze to 1.60 (95% CI 1.03–2.48) for sleep disturbance due to wheeze in boys (table 3).

The straightforward analysis of the relation between symptoms of asthma and the presence of carpets in the child's bedroom revealed protective effects against most studied outcomes (table 4). However, 429 parents had

Table 1. Descriptive statistics of the study population (ISAAC phase I and III data 1994/95 and 1999/2000), n = 6,996

	n	%
Sex		
Male	3,617	51.7
Female	3,379	48.3
Energy source for heating		
Gas	3,609	51.6
Coal	70	1.0
Oil	1,880	26.9
Wood	443	6.3
Electricity	544	7.8
Dampness/molds, yes	367	5.3
Passive smoking, yes	1,466	21.0
Presence of furry/feathery pet animals		
At date of interview	3,279	46.9
Cats	742	10.6
Dogs	1,070	15.3
Birds	1,042	14.9
Rodents	1,620	23.2
During first year of life	2,147	30.7
Cats	684	9.8
Dogs	960	13.7
Birds	855	12.2
Rodents	448	6.4
Carpet in child's bedroom, yes	5,571	79.6
Cooking ¹		
With electricity	3,038	87.6
With gas	378	10.9
Space heating ¹		
Coal	26	0.8
Wood	83	2.4
Oil	100	2.9
Gas	481	13.9
Wheezing during last 12 months, yes	804	11.5
Speech-limiting wheeze during last 12 months, yes	162	2.3
Number of wheeze attacks during last 12 months, ≥ 4	192	2.7
Any sleep disturbance due to wheeze during last 12 months	457	6.5
Any exercise-induced wheeze during last 12 months	459	6.6
Night cough during last 12 months, yes	1,046	15.0
Current asthma, yes	187	2.7

¹ Based on phase I data only (n = 3,467).

reported removal of a carpet due to a positive family history of atopic disease or an existing atopy in the child. When analyses were restricted to participants who had not reported allergy-related avoidance of carpets, the negative associations disappeared for all respiratory outcomes.

Table 2. PR with 95% confidence intervals for the association between several indoor factors and wheeze during the last 12 months and current asthma among 6- to 7-year-old children (ISAAC phase I and III data)

	Current wheeze					Current asthma				
	n	PR				n	PR			
		boys	95% CI	girls	95% CI		boys	95% CI	girls	95% CI
Heating ¹										
Gas	6,033	0.85	0.71–1.02	0.80	0.65–1.0	6,098	0.76	0.51–1.12	0.74	0.44–1.23
Coal	6,033	1.10	0.45–2.73	0.75	0.20–2.83	6,098	1.11	0.16–7.57	2.40	0.35–16.42
Oil	6,034	1.10	0.90–1.34	0.90	0.71–1.15	6,099	1.28	0.85–1.93	0.80	0.43–1.45
Wood	6,031	1.04	0.72–1.50	1.0	0.65–1.53	6,098	0.89	0.40–2.0	1.57	0.69–3.58
Molds ²	6,087	1.27	0.89–1.81	1.29	0.85–1.95	6,153	1.14	0.51–2.54	1.01	0.32–3.18
Furry/feathery pets ²	6,087	0.86	0.72–1.03	1.14	0.93–1.42	6,153	0.87	0.59–1.27	0.67	0.39–1.15
Cats	6,084	0.96	0.72–1.29	1.28	0.94–1.74	6,150	0.86	0.45–1.63	1.27	0.58–2.77
Dogs	6,083	0.91	0.70–1.18	1.27	0.97–1.66	6,149	0.62	0.33–1.18	1.09	0.54–2.21
Birds	6,086	0.84	0.64–1.11	0.91	0.66–1.25	6,152	0.64	0.34–1.22	1.04	0.47–2.32
Rodents	6,087	0.90	0.72–1.12	1.05	0.83–1.34	6,153	0.98	0.62–1.55	0.43	0.19–0.94
Passive smoking ¹	6,034	0.94	0.74–1.19	1.45	1.14–1.85	6,099	0.77	0.44–1.35	1.17	0.61–2.24
Cooking with gas ^{3,4}	2,947	0.55	0.31–0.98	1.52	0.93–2.47	2,989	– ⁵	–	0.77	0.17–3.46
Space heating ^{3,4}										
Gas	2,946	1.13	0.76–1.68	1.02	0.62–1.69	2,985	2.03	0.95–4.33	1.56	0.50–4.82
Coal	2,947	2.56	1.0–6.55	2.46	0.70–8.70	2,986	3.59	0.56–23.11	13.46	1.76–103.14
Wood	2,946	1.40	0.63–3.15	1.36	0.53–3.51	2,985	1.11	0.16–7.78	– ⁵	– ⁵
Oil	2,947	0.82	0.32–2.10	0.95	0.31–2.87	2,986	– ⁵	–	1.76	0.24–12.81

¹ Adjusted for survey (1st, 2nd), social economic status, parental atopy, heating with fossil fuels, passive smoking, truck traffic.

² Adjusted for survey (1st, 2nd), social economic status, parental atopy, molds, pets.

³ Phase I data only.

⁴ Adjusted for social economic status, parental atopy, cooking with gas, space heating, passive smoking, truck traffic.

⁵ No convergence or not estimable due to small strata.

The presence of feathery or furry pets in the household was not significantly associated with asthma-related respiratory symptoms. Considering groups of pets separately (cats, dogs, birds and rodents), most pets did not produce positive associations, except for cats and dogs, the presence of which showed elevated associations with some symptoms. A significant positive association concerning the presence of a cat and exercise-induced wheeze (PR 1.63, 95% CI 1.08–2.46) was found in girls (table 3).

Restriction to participants with allergy-motivated pet avoidance neither changed results for all pets taken together nor for single pet species (results not shown). However, when pet ownership at different life stages was considered, results differed from the preliminary analysis. In birds (table 5), we observed elevated PRs for asthma symptoms when analyses were restricted to participants who owned a bird only during the first year of life.

A similar, but less consistent pattern was seen for dogs, with elevated PRs for speech-limiting wheeze, wheeze af-

ter exercise, a high number of wheeze attacks and current asthma. Cat ownership during the first year of life showed associations close to unity or even below unity. Present ownership without ownership of a cat during the first year of life revealed elevated PRs, but again associations were not strong enough to reach statistical significance. PRs for rodents as a separate pet group were close to unity for all modes of ownership and all studied outcomes. Life-long ownership of pets was not positively associated with any of the studied outcomes (all results not shown).

Constructing a score for ownership of more than one pet (cats, dogs and birds) did not reveal consistently elevated results or a dose-response relationship. Mutual adjustment for other pet species did not alter the results either. Inclusion of other potential confounders did not influence the results, and we neither observed joint confounding effects.

Table 3. PR with 95% confidence intervals for the association between several indoor factors and severe symptoms of asthma among 6- to 7-year-old children (ISAAC phase I and III data)

	Sleep disturbance due to wheeze					Exercise-induced wheeze				
	n	PR				n	PR			
		boys	95% CI	girls	95% CI		boys	95% CI	girls	95% CI
Heating ¹										
Gas	6,026	0.78	0.60–1.0	0.63	0.47–0.84	5,959	0.79	0.62–1.02	0.69	0.51–0.94
Coal	6,026	1.43	0.49–4.21	0.62	0.09–4.24	5,958	0.86	0.23–3.29	1.40	0.37–5.38
Oil	6,027	1.06	0.80–1.40	1.01	0.74–1.38	5,959	1.21	0.93–1.57	1.03	0.73–1.44
Wood	6,026	1.44	0.92–2.25	0.99	0.56–1.74	5,958	1.11	0.69–1.77	1.49	0.90–2.48
Molds ²	6,082	1.60	1.03–2.48	1.30	0.74–2.27	6,005	1.22	0.74–2.0	1.39	0.77–2.50
Furry/feathery pets ²	6,082	0.99	0.77–1.28	1.13	0.85–1.50	6,005	0.87	0.68–1.11	1.27	0.94–1.72
Cats	6,079	1.17	0.81–1.70	1.17	0.76–1.79	6,002	0.86	0.57–1.30	1.63	1.08–2.46
Dogs	6,078	0.91	0.63–1.30	1.33	0.93–1.88	6,001	0.79	0.54–1.15	1.32	0.90–1.93
Birds	6,081	0.98	0.69–1.40	0.77	0.49–1.20	6,004	0.82	0.57–1.18	1.20	0.80–1.81
Rodents	6,082	0.95	0.70–1.28	1.16	0.85–1.58	6,005	0.98	0.74–1.32	1.08	0.76–1.52
Passive smoking ¹	6,027	1.06	0.77–1.46	1.27	0.91–1.76	5,959	0.97	0.70–1.34	1.39	0.98–1.98
Cooking with gas ^{3,4}	2,939	0.50	0.22–1.14	1.29	0.64–2.63	2,902	0.26	0.10–0.71	1.79	0.97–3.27
Space heating ^{3,4}										
Gas	2,938	1.13	0.65–1.97	0.55	0.23–1.29	2,902	1.74	1.10–2.73	0.92	0.48–1.77
Coal	2,939	3.93	1.49–10.39	2.74	0.40–18.78	2,902	2.35	0.67–8.20	4.0	1.07–14.92
Wood	2,938	2.44	1.07–5.56	1.86	0.61–5.68	2,901	1.27	0.43–3.75	1.12	0.29–4.42
Oil	2,939	1.15	0.38–3.45	1.64	0.54–5.03	2,902	0.35	0.05–2.40	0.53	0.08–3.73

¹ Adjusted for survey (1st, 2nd), social economic status, parental atopy, heating with fossil fuels, passive smoking, truck traffic.

² Adjusted for survey (1st, 2nd), social economic status, parental atopy, molds, pets.

³ Phase I data only.

⁴ Adjusted for social economic status, parental atopy, cooking with gas, space heating, passive smoking, truck traffic.

Discussion

The study utilizes data from a representative, large sample at two points in time using identical methods. We studied the association between indoor exposures with several asthma-related respiratory symptoms taken from two school-based surveys, conducted 5 years apart (1994/1995 and 1999/2000) in Münster, Germany. Only few indoor factors showed consistent and statistically significant positive associations with the outcomes under observation.

In our study, positive associations with asthma symptoms regarding the use of gas for cooking were observed in girls. Use of gas for cooking and a gas stove for heating are important sources of indoor NO₂ exposure and have been shown to be associated with asthma or reduced lung function in some [16–19], but not all studies [20, 21]. Unfortunately, we did not solicit information on the use of a ventilation fan or whether the door of the child's bedroom was closed at night, as these can influence exposure.

Closing the bedroom door was associated with a lower risk of asthma in the study by Ponsonby et al. [19]. However, ventilation of cooking fumes with an extractor fan in the kitchen did not reduce the risk of symptoms in two other studies [18, 22].

In the analyses of the relation between heating with fossil fuels and asthma symptoms, an association was only found for space heating. Space heating was defined as a stove or oven with a fireplace in the apartment, therefore causing direct exposure to people living in the dwelling, as opposed to central heating with the fire place in the cellar or even a different building. However, space heating was rare in our population (13.9% of the ISAAC phase I population had stoves heated with gas and only 0.8% used coal stoves for heating), and therefore, the analyses showed wide confidence intervals. Adjustment for other indoor sources of NO₂ (stoves heated with other fossil fuels, cooking with gas or passive smoking) did not alter the results.

Table 4. PR and 95% confidence intervals for the association between presence of a carpet in the bedroom and respiratory symptoms in 6- to 7-year-old children (ISAAC phase I and III, adjusted for survey (1st, 2nd), sex, social economic status, parental atopy, pets and molds)

	All participants		No report of carpet avoidance		Carpet during first year of life/no report of allergy-related avoidance	
	n	PR (95% CI)	n	PR (95% CI)	n	PR (95% CI)
Current wheeze	6,045	0.75 (0.64–0.88)	5,647	0.97 (0.79–1.20)	5,619	0.82 (0.65–1.03)
Current asthma	6,112	0.52 (0.37–0.72)	5,713	0.93 (0.57–1.52)	5,686	0.53 (0.33–0.86)
Speech-limiting wheeze	6,054	0.68 (0.47–0.98)	5,655	1.19 (0.69–2.06)	5,628	0.57 (0.35–0.93)
Sleep disturbance	6,040	0.84 (0.67–1.05)	5,642	1.26 (0.92–1.72)	5,615	0.99 (0.70–1.39)
Wheeze after exercise	5,966	0.69 (0.56–0.86)	5,576	1.00 (0.75–1.35)	5,549	0.80 (0.58–1.11)
Cough	5,982	0.98 (0.84–1.13)	5,590	1.19 (0.99–1.44)	5,565	1.13 (0.90–1.41)
Number of wheeze attacks (<4 vs. ≥4)	6,052	0.64 (0.46–0.90)	5,654	1.44 (0.82–2.52)	5,626	0.53 (0.33–0.86)

Removal of carpet due to atopy: n = 429 (6.1%).

Table 5. PR and 95% confidence intervals for the association between different modes of pet bird ownership and avoidance and respiratory symptoms in 6- to 7-year-old children (ISAAC phase I and III, adjusted for survey (1st, 2nd), sex, social economic status, parental atopy and molds)

	Bird present, all participants		Bird in first year of life only		No bird in first year of life		Bird at both times	
	n	PR (95% CI)	n	PR (95% CI)	n	PR (95% CI)	n	PR (95% CI)
Current wheeze	6,086	0.87 (0.70–1.07)	5,055	1.28 (1.01–1.63)	5,176	0.86 (0.65–1.12)	6,117	0.98 (0.72–1.34)
Current asthma	6,152	0.75 (0.45–1.23)	5,112	1.52 (0.92–2.53)	5,236	0.93 (0.52–1.66)	6,182	0.60 (0.25–1.45)
Sleep disturbance	6,081	0.88 (0.66–1.16)	5,052	1.51 (1.11–2.06)	5,172	0.90 (0.63–1.29)	6,112	0.99 (0.65–1.50)
Wheeze after exercise	6,004	0.96 (0.73–1.26)	4,982	1.35 (0.97–1.88)	5,108	1.04 (0.74–1.46)	6,034	0.91 (0.59–1.41)
Number of wheeze attacks (<4 vs. ≥4)	6,091	1.07 (0.69–1.64)	5,062	1.33 (0.77–2.30)	5,183	1.25 (0.75–2.10)	6,122	0.97 (0.48–1.96)
Speech-limiting wheeze	6,095	0.56 (0.32–0.98)	5,064	1.32 (0.77–2.28)	5,184	0.92 (0.51–1.66)	6,126	0.12 (0.02–0.82)
Cough	6,021	0.99 (0.83–1.17)	5,000	1.04 (0.83–1.32)	5,122	1.0 (0.81–1.25)	6,051	0.94 (0.71–1.23)

In a previous study, heating with coal or wood as opposed to central or other heating systems was inversely related to the presence of asthma in a rural population in southern Germany [21]. Unfortunately, in our data, information on farm residence was not solicited in both surveys. However, living on a farm can imply a whole array of lifestyle specificities that can affect asthma risk rather than a single factor [23, 24].

Exposure to ETS in boys and home dampness or mold stains were positively associated with most asthma-related respiratory conditions. Our results are in line with two meta-analyses showing positive associations between

ETS and respiratory symptoms and asthma in children [25, 26]. We have also previously shown that ETS exposure affects asthma morbidity, leading to more intensive health care utilization by asthmatic children [27].

As for molds, quantitative measurements of total or viable molds, as opposed to reported molds or wet stains, failed to detect consistent positive associations in the majority of studies [28]. Notwithstanding, a recent prospective study showed significant positive associations of wheeze in children with measured fungi (odds ratio 1.23, 95% CI 1.01–1.49) [29]. Dampness can influence the growth of house dust mite as well. Because house dust

mite can also be found in animal dander, carpets and bedding material [30], we investigated the influence of a carpet in the child's bedroom and the ownership of pets at different stages of life on the risk of asthma symptoms. Surprisingly, in our data, the presence of a carpet in the child's bedroom revealed negative associations with all studied outcomes. However, when we restricted the analysis to participants that did not report allergy-related avoidance of a carpet, these protective associations disappeared. The same pattern was seen with type of bedding and asthma symptoms, pointing at the importance of accounting for allergy-related avoidance behavior when looking at exposure to indoor factors for childhood asthma [31]. This is also supported by the fact that our data showed that the presence of a carpet in the first year of life was not related to all asthma symptoms, suggesting that the protective effect observed in the preliminary analysis was biased because of allergy-related avoidance of a carpet in later life. However, a protective effect for exposure to a carpet in the first year of life was still seen for speech-limiting wheeze, number of wheeze attacks and current asthma. It is noteworthy that speech-limiting wheeze and number of wheeze attacks relate to disease severity rather than prevalence and may therefore be influenced in part by other unexplored factors, such as asthma medication.

Studies on the association between pet ownership and atopic disease have yielded inconsistent results, depending on the study design and establishment of time sequence between exposure and disease. A recent meta-analysis, only including studies that considered some sort of control for time sequence to reduce bias because of allergy-motivated avoidance, found a slightly elevated pooled odds ratio for asthma symptoms in regard to the exposure to pets [8]. This association became stronger with increasing age of the studied children. In our study, present ownership of furry or feathery pets was not associated with asthma symptoms even after exclusion of children with reported allergy-related removal of pets. However, when considering ownership exclusively during the first year of life, associations with most asthma symptoms became positive for birds and dogs, but not for cats and rodents.

These results are in contrast to observations of Hesselmar et al. [10] who reported a lower incidence and prevalence of asthma and a lower sensitization to cats and dogs in children who were exposed to pets in their first year of life. However, the studied population in Hesselmar's report was older (12–13 years) than ours, which might account for these different findings due to

the known effect of age on asthma risk [4]. On the other hand, another study found no association with sensitization to cat allergen in current adult cat owners, but a protective effect against sensitization to cat allergen in adults that had owned a cat during infancy was also reported [32]. Platts-Mills et al. [33] suggested that production of IgG4 antibodies in response to high exposure to cat allergen early in life can modulate allergic immune responses toward a form of immunological tolerance to cat allergen.

Of particular interest in our study were the gender differences in PRs observed for some exposures, such as ETS, certain pets or cooking with gas, but the picture was not consistent. Exposure to gas cooking, for example, was associated with increased risk of asthma symptoms in girls only, which was also observed by other researchers [22, 34]. A greater risk for the development of asthma symptoms following exposure to gas cookers could be due to a greater susceptibility of girls for gas components generated by cooking stoves (e.g. NO₂). In contrast, a male predominance was found for the association between gas heaters in the analysis of gas heaters and other heating stoves with open fire places and asthma symptoms. Taken together, these findings suggest that the gender difference in asthma risk is more likely due to gender difference in behavior rather than gender difference in susceptibility to indoor exposures. It is likely that girls spend more time in the kitchen during cooking time (e.g. helping their mothers) than boys [18]. However, due to the low prevalence of stoves heated with gas and the fact that information on cooking with gas was only requested in the first survey, confidence intervals were wide and PRs were mostly nonsignificant.

The main limitation of our study lies in the cross-sectional design. The lack of time sequence between disease and exposure can affect risk assessment which was controlled for by the consideration of allergy-related avoidance behaviors for some exposures (carpets and pets). Secondly, cross-sectional surveys are also prone to reporting bias. Asthmatics could be more aware of potential hazardous environmental influences, which would lead to preferential reporting of symptoms, and therefore, stronger associations with the exposures of interest. Such an information bias could explain part of our results since the observed associations with some symptoms were more marked for reported respiratory symptoms than for a diagnosis of asthma. However, we cannot rule out differential overreporting of exposures either, and the fact that we did not solicit sufficient information on some variables may also cause misclassification in the exposure

variables, which might lead to spurious associations in the analyses.

In summary, as demonstrated in previous studies as well, our study confirmed the assumption that certain indoor factors contribute to the burden of asthma in children 6–7 years of age. However, despite our large sample size and the high number of asthmatic subjects, most effect estimates were only slightly elevated or showed wide confidence intervals due to a low prevalence of exposure.

Although our results are limited by the cross-sectional design of our study, we were partially able to control for change of behavior, demonstrating a strong influence of allergy-related strategies of avoidance on asthma symptoms regarding carpets and pet birds. However, the addition of objective markers of exposure to allergens in the home and measures to assess their change in level of exposure accounting for other factors that can affect aller-

gen levels in the house may help to clarify the role of indoor exposures in symptoms of asthma. In addition, future long-term prospective studies, which are able to establish a temporal relationship between exposure and disease and apply more specific inquiries, are desirable in order to help detect strategies of allergen avoidance and to further reduce biases associated with cross-sectional data.

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References

- Maziak W: Asthma and the exposure-disease tenet. *J Clin Epidemiol* 2002;55:737–740.
- Jones AP: Asthma and the home environment. *J Asthma* 2000;37:103–124.
- Bardana EJ Jr: Indoor pollution and its impact on respiratory health. *Ann Allergy Asthma Immunol* 2001;87(suppl 3):33–40.
- Wright AL: The epidemiology of the atopic child: Who is at risk for what? *J Allergy Clin Immunol* 2004;113(suppl):S2–S7.
- Strachan DP, Carey IM: Home environment and severe asthma in adolescence: A population based case-control study. *BMJ* 1995;311:1053–1056.
- McConnell R, Berhane K, Gilliland F, Islam T, Gauderman WJ, London SJ, Avol E, Rappaport EB, Margolis HG, Peters JM: Indoor risk factors for asthma in a prospective study of adolescents. *Epidemiology* 2002;13:288–295.
- Lau S, Illi S, Sommerfeld C, Niggemann B, Bergmann R, von Mutius E, Wahn U: Early exposure to house-dust mite and cat allergens and development of childhood asthma: A cohort study. Multicentre Allergy Study Group. *Lancet* 2000;356:1392–1397.
- Apelberg BJ, Aoki Y, Jaakkola JJ: Systematic review: Exposure to pets and risk of asthma and asthma-like symptoms. *J Allergy Clin Immunol* 2001;107:455–460.
- Roost HP, Kunzli N, Schindler C, Jarvis D, Chinn S, Perruchoud AP, Ackermann-Liebrich U, Burney P, Wuthrich B: Role of current and childhood exposure to cat and atopic sensitization. European Community Respiratory Health Survey. *J Allergy Clin Immunol* 1999;104:941–947.
- Hesselmar B, Aberg N, Aberg B, Eriksson B, Bjorksten B: Does early exposure to cat or dog protect against later allergy development? *Clin Exp Allergy* 1999;29:611–617.
- de Meer G, Toelle BG, Ng K, Tovey E, Marks GB: Presence and timing of cat ownership by age 18 and the effect on atopy and asthma at age 28. *J Allergy Clin Immunol* 2004;113:433–438.
- Maziak W, Behrens T, Brasky TM, Duhme H, Rzehak P, Weiland SK, Keil U: Are asthma and allergies in children and adolescents increasing? Results from ISAAC phase I and phase III surveys in Munster, Germany. *Allergy* 2003;58:572–579.
- The International Study of Asthma and Allergies in Childhood (ISAAC) Steering Committee: Worldwide variation in prevalence of symptoms of asthma, allergic rhinoconjunctivitis, and atopic eczema: ISAAC. *Lancet* 1998;351:1225–1232.
- Zocchetti C, Consonni D, Bertazzi PA: Relationship between prevalence rate ratios and odds ratios in cross-sectional studies. *Int J Epidemiol* 1997;26:220–223.
- Behrens T, Taeger D, Wellmann J, Keil U: Different methods to calculate effect estimates in cross-sectional studies. A comparison between prevalence odds ratio and prevalence ratio. *Methods Inf Med* 2004;43:505–509.
- Butland BK, Strachan DP, Anderson HR: The home environment and asthma symptoms in childhood: Two population based case-control studies 13 years apart. *Thorax* 1997;52:618–624.
- Garrett MH, Hooper MA, Hooper BM, Abramson MJ: Respiratory symptoms in children and indoor exposure to nitrogen dioxide and gas stoves. *Am J Respir Crit Care Med* 1998;158:891–895.
- Jarvis D, Chinn S, Luczynska C, Burney P: Association of respiratory symptoms and lung function in young adults with use of domestic gas appliances. *Lancet* 1996;347:426–431.
- Ponsonby AL, Couper D, Dwyer T, Carmichael A, Kemp A, Cochrane J: The relation between infant indoor environment and subsequent asthma. *Epidemiology* 2000;11:128–135.
- Zacharasiewicz A, Zidek T, Haidinger G, Waldhor T, Suess G, Vutuc C: Indoor factors and their association to respiratory symptoms suggestive of asthma in Austrian children aged 6–9 years. *Wien Klin Wochenschr* 1999;111:882–886.
- von Mutius E, Illi S, Nicolai T, Martinez FD: Relation of indoor heating with asthma, allergic sensitization, and bronchial responsiveness: Survey of children in south Bavaria. *BMJ* 1996;312:1448–1450.
- Chapman RS, Hadden WC, Perlin SA: Influences of asthma and household environment on lung function in children and adolescents: The third national health and nutrition examination survey. *Am J Epidemiol* 2003;158:175–189.
- von Mutius E: The environmental predictors of allergic disease. *J Allergy Clin Immunol* 2000;105:9–19.
- Maziak W: Asthma and farming. *Lancet* 2002;359:623–624.

- 25 Cook DG, Strachan DP: Summary of effects of parental smoking on the respiratory health of children and implications for research. *Thorax* 1999;54:357–365.
- 26 Peat JK, Dickerson J, Li J: Effects of damp and mould in the home on respiratory health: A review of the literature. *Allergy* 1998;53:120–128.
- 27 Maziak W, von Mutius E, Keil U, Hirsch T, Leupold W, Rzehak P, Behrens T, Weiland SK: Predictors of health care utilization of children with asthma in the community. *Pediatr Allergy Immunol* 2004;15:166–171.
- 28 Kolstad HA, Brauer C, Iversen M, Sigsgaard T, Mikkelsen S: Do indoor molds in nonindustrial environments threaten workers' health? A review of the epidemiologic evidence. *Epidemiol Rev* 2002;24:203–217.
- 29 Belanger K, Beckett W, Triche E, Bracken MB, Holford T, Ren P, McSharry JE, Gold DR, Platts-Mills TA, Leaderer BP: Symptoms of wheeze and persistent cough in the first year of life: Associations with indoor allergens, air contaminants, and maternal history of asthma. *Am J Epidemiol* 2003;158:195–202.
- 30 Li CS, Wan GH, Hsieh KH, Chua KY, Lin RH: Seasonal variation of house dust mite allergen (Der pI) in a subtropical climate. *J Allergy Clin Immunol* 1994;94:131–134.
- 31 Behrens T, Maziak W, Weiland SK, Siebert E, Rzehak P, Keil U: The use of synthetic bedding in children. Do strategies of change influence associations with asthma? *J Asthma*, in press.
- 32 Oryszczyn MP, Annesi-Maesano I, Charpin D, Kauffmann F: Allergy markers in adults in relation to the timing of pet exposure: The EGEA study. *Allergy* 2003;58:1136–1143.
- 33 Platts-Mills T, Vaughan J, Squillace S, Woodfolk J, Sporik R: Sensitisation, asthma, and a modified Th2 response in children exposed to cat allergen: A population-based cross-sectional study. *Lancet* 2001;357:752–756.
- 34 Corbo GM, Forastiere F, Agabiti N, Dell'Orco V, Pistelli R, Aebischer ML, Valente S, Perucci CA: Effect of gas cooking on lung function in adolescents: Modifying role of sex and immunoglobulin E. *Thorax* 2001;56:536–540.