

Current asthma and respiratory symptoms among pupils in relation to dietary factors and allergens in the school environment

Abstract The aim was to study asthma and allergy in relation to diet and the school environment. Pupils (5–14 years) in eight schools received a questionnaire, 1014 participated (68%). Settled dust was collected on ALK-filters and analyzed for allergens from cat (Fel d 1), dog (Can f 1), horse (Equ cx), house dust mites (Der p 1, Der f 1), and cockroach (Bla g 1) by ELISA. In total, 6.8% reported cat allergy, 4.8% dog allergy, 7.7% doctor's diagnosed asthma and 5.9% current asthma, and 7.8% reported wheeze. Current asthma was less common among those consuming more fresh milk ($P < 0.05$) and fish ($P < 0.01$). Poly-unsaturated fatty acids was associated with more wheeze ($P < 0.05$), olive oil was associated with less doctors' diagnosed asthma ($P < 0.05$). Totally, 74% of the classrooms had mean $\text{CO}_2 < 1000$ ppm. The median concentration per gram dust was 860 ng/g Fel d 1, 750 ng/g Can f 1 and 954 U/g Equ cx. Horse allergen was associated with more wheeze ($P < 0.05$), daytime breathlessness ($P < 0.05$), current asthma ($P < 0.05$) and atopic sensitization ($P < 0.05$). Dog allergen was associated with wheeze ($P < 0.05$) and daytime breathlessness ($P < 0.05$). The associations between allergens and respiratory symptoms were more pronounced among those consuming margarine, not consuming butter, and with a low intake of milk. In conclusion, cat, dog and horse allergens in schools could be a risk factor for asthma and atopic sensitization, and dietary factors may interact with the allergen exposure.

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Practical Implications

Previous school studies performed by us in mid-Sweden, showed that most classrooms did not fulfill the ventilation standards. In this study, most of the classrooms fulfilled the ventilation standard, but despite that had widespread allergen contamination. Most previous studies have focused on cat allergen, but our study has shown that also dog and horse allergens can be risk factors for asthma and allergy in schools. As allergens are transported from other environments, mainly the home environment, the main prevention should be to minimize transfer of allergens. This could be achieved by reducing contacts with furry pets and horses, or using different clothes at home and at school (e.g. school uniforms). Increased cleaning in the schools may reduce allergen levels, but the efficiency of this measure must be evaluated in further intervention studies. Finally, our study supports the view that dietary habits among pupils should not be neglected and interaction between dietary factors and indoor allergen exposure needs to be further investigated.

Introduction

The large international study on asthma and allergies in children (Asher et al., 1995) has demonstrated large differences in the prevalence of asthma and allergies in the world. Moreover, there has been an increase of asthma and atopic sensitization in many industrialized countries (von Mutius, 2000; Schneider and Freeman, 2001) including Sweden. In one study of Swedish primary-school children, asthma increased from 2.5 to 5.7% during the period 1979–1991 (Åberg et al., 1995). The reasons for the increase are still unknown,

but it has been suggested that indoor environmental exposure and dietary factors may influence the development of asthma and allergy. Exposure to allergens from furry pets in the school is common in the western world, and pupils may react with asthmatic symptoms (Rönmark et al., 1998; Smedje et al., 1997) and develop more doctors' diagnosed asthma (Smedje and Norbäck, 2001). However, it is still unclear if allergen exposure is a risk factor or a protective factor, with respect to new onset of atopic sensitization (Apter, 2003; Simpson and Custovic, 2003).

Besides the home, the school environment is the most important indoor environment for children. There is a growing concern about the school environment with respect to asthma and allergy (Daisy et al., 2003; Munir et al., 1993; Smedje and Norbäck, 2001; Smedje et al., 1997; Taskinen et al., 1997). Measurements in schools have shown that the air exchange rate often is low, resulting in high concentrations of carbon dioxide (CO₂) (Fox et al., 2003; Meyer et al., 2004; Ruotsalainen et al., 1995; Smedje and Norbäck, 2000) and particle exposure (Fox et al., 2003; Lee and Chang, 2000; Smedje et al., 1997; Tortolero et al., 2002). Other problems in schools are high room temperature (Ruotsalainen et al., 1995; Smedje et al., 1997), poor cleaning (Smedje and Norbäck, 2001) and widespread contamination of cat and dog allergens in schools (Elfman et al., 2000; Munir et al., 1993; Perzanowski et al., 1999; Smedje and Norbäck, 2001). Some studies also report presence of allergens from house dust mites (*Dermatophagoides pteronyssinus*), cockroach (*Blattella germanica*) and mouse (*Mus musculus*) (Amr et al., 2003; Tortolero et al., 2002) in schools. Moreover, the school environment may contain indoor pollutants such as molds, bacteria, airborne dust, volatile organic compounds (VOC), VOC of microbial origin (MVOC) and formaldehyde (Meyer et al., 2004; Smedje et al., 1997; Taskinen et al., 1997; Tortolero et al., 2002).

There is some evidence that dietary factors may influence the development of asthma and allergy (Helm, 2004; Romieu and Trenga, 2001). A high intake of antioxidants (e.g. selenium, vitamin C and vitamin E), fruits and vegetables can be beneficial (Denny et al., 2003; Romieu and Trenga, 2001) and there is some evidence that dietary lipids may influence asthma and allergy. A high intake of omega-3 essential fatty acids, mainly from fat fish, can be protective for various diseases including asthma (Romieu and Trenga, 2001). Moreover, recent studies suggest a protective effect of higher consumption of milk (Wickens et al., 2002; Woods et al., 2003), milk fat/butter (Wijga et al., 2003) and yoghurt (Wickens et al., 2002) on asthma and allergy. On the contrary, a high consumption of fast food (Hijazi et al., 2000) has been associated with a higher risk for asthma. There are few investigations on interaction between dietary factors and environmental pollution. It has been suggested that smokers or subjects living in areas with high ambient air pollution levels, needs a higher intake of dietary antioxidants (Romieu and Trenga, 2001). In one study from Scotland, subjects with seasonal allergy had more allergic symptoms during pollen season if they had a lower intake of zinc. In addition, those with the lowest intake of vitamin C, manganese and magnesium had more increased bronchial hyper-responsiveness (Soutar et al., 1997). These limited data suggests that there could be an interaction between dietary factors and different types of pollutants, with

respect to respiratory health effects. To our knowledge, there are very few studies on interaction between diet and indoor air pollution, including allergen exposure.

In the Swedish School Environment Project, we have undertaken a number of studies on asthmatic and sick building syndrome symptoms among school personnel and pupils, and have related these to the school environment. In the current study, we have investigated current asthma and self-reported allergy among primary school pupils in relation to dietary factors as well as selected indoor exposures in the classrooms. The first aim was to study associations between room temperature, relative air humidity, building ventilation flow, CO₂, allergen levels and formaldehyde in the classrooms, and current asthma, respiratory symptoms and reports on pollen and furry pet allergy (atopic sensitization) among the children. The second aim was to study the associations between age, gender, and dietary factors, and current asthma, respiratory symptoms and reports on atopic sensitization. The third aim was to study possible interaction between dietary factors and indoor exposures in the school, particularly allergen levels, with respect to current asthma and respiratory symptoms.

Materials and methods

The study population

In Sweden, the compulsory school comprises nine forms (six in the primary school and three in the junior high school). The vast majority of Swedish children attend public schools. The main aim was to study all children aged 6–13 within one municipality (Knivsta) in a cross-sectional study. All eight primary schools (1–6th form), belonging to Knivsta municipality, a part of the rural outskirts of Uppsala city, were included in the study. In 2000, the headmasters were contacted and all schools agreed to participate.

Information on asthma and allergy

All pupils in the eight primary schools ($n = 1482$) received a questionnaire in Swedish in April–May 2000, of which 1014 (68%) participated. The questionnaire was mailed to the parents, with instructions to answer the questions in co-operation with the child. It was noted if the father, mother, or both had filled in the questionnaire. It included a set of questions on doctor's diagnosed asthma, allergies, and current asthma and respiratory symptoms, obtained from the European Community Respiratory Health Survey (ECRHS) (Burney et al., 1994; Janson et al., 2001), and a previous Swedish school study (Smedje et al., 1997). There was one question on type of current dwelling, used as a proxy for socio-economic status (SES). Moreover, there was one set of questions asking

about asthma including doctor' diagnosed asthma (cumulative incidence), current asthma medication and asthma attacks during the last 12 months. Current asthma was defined as having either current asthma medication or having had an asthma attack during the last 12 months, a definition previously used in the ECRHS study (Plaschke et al., 2000). There was another set of questions asking about airway symptoms related to asthma during the last 12 months without using the phrase 'asthma'. These symptoms included: (i) wheezing or whistling in the chest, (ii) at least one daytime attack of shortness of breath during exercise or while resting, (iii) at least one nighttime awakening with attacks of breathlessness or tightness in the chest. The question on wheeze was phrased 'Have your child ever had wheeze or whistling in the chest during the last 12 months.' Wheeze is a well-known concept in Swedish language. Moreover, the questionnaire contained questions about atopic sensitization including allergy to cat, dog and pollen used in previous school investigations (Smedje and Norbäck, 2001). Finally, there was one 'yes/no' question on food allergy and/or intolerance, asking those who said yes to specify the types of food they reacted to.

Information on dietary habits

There were seven questions about current consumption of meat, fish, fruit, vegetables, fresh milk, fermented milk products and fast food such as hamburgers. There were five alternatives given for each type of food item, intended to measure the frequency of consumption. In the statistical calculations, a consumption score was used, as follows: 0 = never consumed, 1 = less than once a week, 2 = once a week, 3 = more than once a week, 4 = daily consumption. Moreover, there were five yes/no questions about use of different types of cooking oils or fat; use of butter, margarine, olive oil, rape seed oil and poly-unsaturated oils.

Assessment of exposure

Initial measurements were performed in May and the first week in June 2000, 1–2 weeks after the questionnaire investigation was completed. Measurements were performed in three arbitrary selected classrooms in each school, representing different buildings. One of the schools only had two classrooms, of which both were included. Details on constructions, materials, type of ventilation system and cleaning routines were noted. The classrooms were inspected for signs of building dampness including visible mould growth on indoor surfaces as well as other signs of building dampness. In each classroom, room temperature, relative air humidity, air exchange rate (ac/h), the concentration of carbon dioxide (CO₂), airborne particles (PM₁₀) and formaldehyde were measured. The measurements were

made during normal activities, with closed windows and doors. Average concentration for each school was calculated and used in the statistical models. Outdoor measurements of temperature, relative humidity and CO₂ were performed during the same period and by the same method as for the indoor measurements. Repeated measurements of room temperature, relative air humidity, CO₂, and air exchange rate, cat allergen in air and allergens in settled dust were performed 6 months later during winter conditions (December 2000). As the symptom questions cover the last 12 months, average exposures were calculated for summer and winter conditions, and used in the epidemiological analysis.

Temperature, relative air humidity and CO₂ were measured with Q-TrakTM IAQ Monitor (TSI Incorporated, St Paul, Minnesota, USA), sampling 1 min average values. Airborne particles (PM₁₀) were measured by Dust-TrakTM (Model 8520) with a sensor type 90 degree light scattering laser photometer, measuring particles from approximately 1–10 micrometer (TSI Incorporated). The instruments were regularly calibrated by Comfort Control, the Swedish service laboratory for TSI equipment. The air exchange in the classrooms was measured with a tracer-gas decay method using acetone as tracer gas (Anundi et al., 1992). Concentration of formaldehyde was measured with glass fiber filters impregnated with 2,4-dinitrophenylhydrazine (Andersson et al., 1981), the air sampling rate being 0.2 l/min during 4 h. The filters were analyzed by liquid chromatography.

Allergen measurements

Settled dust was collected from desks, chairs and the floor by a 400 W vacuum cleaner provided with a special dust collector (ALK Abello, Copenhagen, Denmark) equipped with a Millipore filter (pore size 6 µm). The filter is made of cellulose acetate, and according to the manufacturer it retains 74% of particles 0.3–0.5 µm, 81% of particles 0.5–1.0 µm, 95% of particles 1–10 µm and about 100% of larger particles (> 10 µm). Vacuum cleaning was performed for totally 4 min per sample, 2 min on the floor and 2 min on other surfaces (desks, chairs) as in previous school studies (Smedje et al., 1997). Each classroom was divided into two halves, one near the corridor and one near the windows, and one sample was collected from each half. The filters were sealed in plastic bags and stored at –20°C until extraction.

The total amount of dust was weighed in each sample. Samples of settled dust (100 mg) were extracted in 2 ml of phosphate-buffered saline containing 0.05% Tween 20 (1/20 W/v) for 2 h at room temperature. Samples were centrifuged at 4500 rpm for 10 min followed by another at 10,000 rpm for 10 min. The supernatant was transferred to Micro-tubes and stored

frozen at -20°C until analyzed for the content of allergen. Allergen levels were determined using two-site sandwich ELISA for cat (Fel d 1), dog (Can f 1), cockroach (Bla g 1) (Indoor Biotechnologies Ltd, Manchester, UK) and horse allergen (Equ c x) (Mabtech, Stockholm, Sweden) (Emenius et al., 2001) using monoclonal antibodies. The assays were basically performed according to the protocols provided by the manufacturer except for the dog assay where the horseradish peroxidase labeled goat anti-rabbit immunoglobulin was from Dakopatts, Denmark. Allergen concentrations were expressed as ng/g dust, except for horse allergen concentrations which were expressed as Units/g dust, where 1 Unit is equal to 1 ng protein of a horsehair and dander extract used as standard (Allergon, Valinge, Sweden and NIBSC, Hertfordshire, UK). Protein determination was performed on the standard with the micro-BCA method (Pierce, Rockford, IL, USA) using BSA as standard.

Statistical methods

The chi-square test was used when analyzing differences in asthma and atopic sensitization between boys and girls. Unpaired *t*-test was used to study age trends, by comparing mean age in children with and without a particular symptom. Median and inter-quartile range was calculated for allergens, as they were not normally distributed. Multivariate statistical analysis was performed by multiple logistic regression analysis. Mean exposure levels were calculated for each school and used in the regression models. For measurements performed both in May and December, a mean of both sampling periods were used. Initially, when the influence of different dietary factors was evaluated, two different logistic regression models were applied. First, a simple model was used, adjusting for age and gender only, introducing each of the seven dietary variables and five types of fat consumption separately in the model. Finally, a complex model was used with age, gender and all 12 dietary variables kept at the same time in the model. Finally, associations between the school environment, and asthma and allergy were evaluated, adjusting for age and gender only, introducing each of the exposure variables separately in the model.

Odds ratios (ORs) for the polychotomous dietary variables were calculated in the following way: the dietary variables were rated in five frequencies (never, less than weekly, weekly, more than once a week, daily consumption), coded 0, 1, 2, 3, 4. The OR was calculated for a change of one step. All school exposure factors were continuous variables so the estimated ORs depended on the units of these variables. Statistical calculations were mainly made by the SPIDA statistical package from the Statistical Laboratory, Macquarie University, Australia (Gebbski et al., 1992). Co-linearity

diagnostics available in SPIDA were applied. Initially, some co-linearity problems were detected for room temperature, but they were eliminated by centering room temperature, by subtracting this variable with the mean value. Interaction terms in logistic regression analysis were tested statistically, using the STATA program (Stata Corporation, College Station, TX, USA). In all statistical analysis, two tailed tests and a 5% level of significance was applied.

Results

Questionnaire data on asthma and allergy

In total, 1482 subjects received the questionnaire, of which 1014 (68%) completed and returned it. The median age was 9 years (range 5–14 years) and 51% were girls. The questionnaire can be divided into three different items of questions, which are on current airway symptoms, on asthma and atopic sensitization (Table 1). The most common respiratory symptom was wheeze. Most of the subjects with daytime attacks of breathlessness had that after exercise (3.9%), while attack of breathlessness at rest was less common (1.7%). Boys had more doctor's diagnosed asthma ($P < 0.01$), more often asthma medication ($P < 0.01$), more current asthma ($P < 0.05$), more dog allergy ($P < 0.05$) and pollen allergy ($P < 0.05$) than girls, but when asking about respiratory symptoms without using the word 'asthma', no significant gender differences were observed. At increased age, the pupils reported more daytime attacks of breathlessness ($P < 0.01$), but less nocturnal attacks of breathlessness ($P < 0.05$). Moreover, at higher age, the pupils reported more pollen allergy ($P < 0.01$) and more atopic sensitization ($P < 0.05$). When comparing questionnaires filled in by the mother with those filled in by the fathers, no significant differences in reports on asthma, respiratory symptoms or allergy was noted. In total, 81% of the pupils lived in single family houses or semi-detached houses, 13% lived in apartments in multi-family houses, and 5% lived on a farm. None of the health outcomes for asthma and allergy described in Table 1, was significantly associated with type of dwelling.

Dietary factors

The dietary questionnaire contained seven comprehensive questions on frequency of consumption of different types of food products: meat, fish, fruits, vegetables, fresh milk, fermented milk products and fast food (Table 2). Fish consumption more than once a week (7.5%) and fast food consumption more than once a week (0.5%) was uncommon. In contrast consumption of fresh milk and fruit more than once per week was very common, 90.2 and 84.8%, respectively.

Table 1 Current airway symptom, asthma, and reports on atopic sensitization among pupils in Knivsta ($n = 1014$)

	Boys (%) ($n = 492$)	Girls (%) ($n = 522$)	2-tailed (P -value ^a)	5–8 years (%) ($n = 355$)	9–11 years (%) ($n = 448$)	12–14 years (%) ($n = 200$)	Total (%)
Questions on current airway symptoms							
Wheeze or whistling in the chest	8.6	7.1	NS	8.8	7.0	8.0	7.8
Daytime attacks of breathlessness	4.4	4.6	NS	2.8	4.8	7.1**	4.5
Nocturnal attacks of breathlessness	2.3	1.7	NS	2.9	1.8	1.0*	2.0
At least one airway symptom ^b	10.5	8.7	NS	10.0	9.1	9.7	9.5
Questions on asthma							
Ever had doctors' diagnosed asthma	10.2	5.4**	<0.01	7.1	7.6	9.0	7.7
Current asthma medication	6.3	3.9**	<0.05	5.6	4.7	6.6	5.3
Current asthma attacks	3.6	2.6	NS	2.2	3.6	3.9	3.1
Current asthma ^c	7.9	4.1*	<0.05	6.2	5.2	7.2	5.9
Questions on atopic sensitization							
Cat allergy	8.0	5.6	NS	6.8	7.0	6.6	6.8
Dog allergy	6.1	3.5*	<0.05	4.0	5.8	4.0	4.8
Pollen allergy	10.7	7.0*	<0.05	6.0	9.4	12.7**	8.8
Pollen or furry pet allergy	14.0	10.4	NS	10.0	12.3	16.2*	12.2

* $P < 0.05$; ** $P < 0.01$.^a Calculated by Chi-square test for fourfold contingency tables.^b Wheeze or whistling in the chest, daytime attacks of breathlessness, or nocturnal attacks of breathlessness the last 12 months.^c Current asthma medication or asthma attacks during the last 12 months.**Table 2** Consumption of different types of food products, in the total material of Knivsta pupils ($n = 1014$)

Type of food products	Frequency of consumption (%)				
	Never	Less than once a week	Once a week	More than once a week	Every day
Meat	0.4	2.2	27.8	59.1	10.5
Fish	1.5	21.3	69.7	7.5	0
Fruits	0.5	5.3	9.5	17.2	67.6
Vegetables	1.2	6.1	10.9	21.8	60.0
Fresh milk	3.0	3.4	3.5	4.7	85.5
Fermented milk products	4.8	20.6	16.0	23.4	35.3
Fast food	0.8	82.6	16.2	0.5	0
			No (%)		Yes (%)
Butter			81.6		18.4
Margarine			19.0		81.0
Olive oil			44.5		55.5
Rapeseed oil			64.8		35.2
Poly-unsaturated oils			72.8		27.2

Consumption of fermented milk products more than once per week was common (58.7%). Moreover, the questionnaire contained yes/no questions on consumption of five types of fats. In total 18.4% were consuming butter, 81.0% margarine, 55.0% olive oil, 35.2% rapeseed oil and 27.2% consumed poly-unsaturated oils such as corn, sunflower or soybean oils. There was strong inverse relationship ($P < 0.001$) between butter and margarine consumption but some subjects (12%) had mixed use of both butter and margarine.

Data on the relationships between diet and respiratory symptoms are given in Tables 3 and 4.

We applied two types of regression models. Model I evaluated each dietary item separately, adjusting only for age and gender. Model II kept age, gender and all 12 dietary variables at the same time in the model. Both types of models gave mostly similar results, so we present data from model II in Tables 3 and 4, and mention results from model I in the text when there is a difference between the two models. Nighttime breathlessness was less common among those consuming more fish ($P < 0.05$). Those consuming poly-unsaturated oils had more often wheeze ($P < 0.05$). When using Model I, those consuming fresh milk more often had significantly less wheeze (OR = 0.78; 95% CI 0.64–0.95; $P < 0.05$). The OR was similar in model II, but not statistically significant. Pupils consuming fish more often had less doctor's diagnosed asthma ($P < 0.01$) and less current asthma ($P < 0.01$). Those consuming milk more often had less doctors' diagnosed asthma ($P < 0.05$) and less current asthma ($P < 0.05$). Finally, those consuming fruits more often reported more atopic sensitization (OR = 1.30; 95% CI 1.01–1.67; $P < 0.05$). The results were similar in model I and II.

In our material, 114 subjects (11.4%) reported allergy/intolerance to any type of food. Most of these reactions were against different types of vegetables and fruits. Milk allergy or lactose intolerance was reported by 27 subjects (2.7%) and only four subjects reported fish allergy (0.4%). As it can be assumed that subjects with food allergy/intolerance have different food habit, and may avoid some food products, we reanalyzed associations, excluding subjects reporting any type of food allergy/intolerance. Most of the negative associations between fish consumption and asthma remained

Table 3 Relationship between dietary factors, respiratory symptoms, and asthma

Frequency of consumption	Wheeze	Daytime breathlessness	Nighttime breathlessness	Doctors' asthma	Current asthma	Atopic sensitization (self-reported)
Meat						
All subjects	0.95 (0.67–1.35)	1.07 (0.65–1.74)	1.25 (0.65–2.41)	0.85 (0.59–1.23)	0.95 (0.62–1.44)	0.98 (0.73–1.32)
No FAI	0.91 (0.59–1.41)	0.94 (0.52–1.67)	1.01 (0.48–2.12)	0.64 (0.41–0.99)*	0.69 (0.41–1.18)	0.86 (0.59–1.24)
Fish						
All subjects	0.80 (0.52–1.24)	0.91 (0.51–1.64)	0.36 (0.17–0.78)*	0.54 (0.35–0.84)**	0.51 (0.31–0.84)**	0.95 (0.67–1.36)
No FAI	0.77 (0.43–1.35)	0.84 (0.40–1.78)	0.45 (0.18–1.15)	0.44 (0.25–0.76)**	0.37 (0.19–0.72)**	1.09 (0.69–1.73)
Fruit						
All subjects	1.14 (0.82–1.59)	1.06 (0.72–1.57)	1.32 (0.65–2.70)	1.61 (1.12–2.32)*	1.52 (1.00–2.30)*	0.89 (0.70–1.14)
No FAI	1.07 (0.71–1.62)	0.89 (0.57–1.40)	1.22 (0.54–2.78)	1.61 (1.05–2.46)*	1.63 (0.96–2.77)	0.99 (0.72–1.34)
Vegetable						
All subjects	0.92 (0.70–1.21)	0.90 (0.63–1.29)	0.88 (0.52–1.50)	0.86 (0.66–1.13)	0.81 (0.59–1.10)	1.30 (1.01–1.67)*
No FAI	0.98 (0.69–1.40)	0.97 (0.62–1.49)	1.08 (0.56–2.09)	0.88 (0.63–1.22)	0.86 (0.58–1.28)	1.36 (0.99–1.87)
Fresh milk						
All subjects	0.83 (0.66–1.03)	0.96 (0.68–1.36)	0.93 (0.56–1.56)	0.75 (0.61–0.94)*	0.77 (0.59–0.99)*	0.94 (0.76–1.15)
No FAI	0.94 (0.66–1.34)	1.24 (0.64–2.42)	0.94 (0.45–1.96)	0.98 (0.66–1.44)	0.85 (0.56–1.28)	1.04 (0.75–1.43)
Fermented milk						
All subjects	1.01 (0.83–1.23)	1.02 (0.79–1.32)	1.15 (0.78–1.71)	1.02 (0.84–1.25)	1.22 (0.96–1.56)	0.97 (0.83–1.13)
No FAI	0.96 (0.75–1.23)	1.01 (0.74–1.38)	1.19 (0.76–1.87)	0.97 (0.76–1.24)	1.09 (0.78–1.49)	0.93 (0.77–1.12)
Fast food						
All subjects	1.02 (0.57–1.81)	1.57 (0.78–3.14)	1.67 (0.57–4.85)	1.20 (0.66–2.17)	1.53 (0.80–2.92)	0.77 (0.46–1.30)
No FAI	0.87 (0.41–1.87)	1.70 (0.73–3.95)	1.67 (0.49–5.64)	1.62 (0.81–3.22)	2.15 (0.98–4.71)	0.92 (0.49–1.73)

Totally 1014 subjects, and 882 subjects did not report food allergy or food intolerance (no FAI).

Adjustment for age, gender, and all other dietary factors at the same time (type of fat and other dietary factors), by logistic regression.

Food consumption was coded 0–4 where 0 = never eaten and 4 = daily consumption. OR is calculated for a change of diet by one unit.

* $P < 0.05$, ** $P < 0.01$.

Table 4 Relationship between consumption of different types of fat, respiratory symptoms, and asthma

Type of fat	Wheeze	Daytime breathlessness	Nighttime breathlessness	Doctors' asthma	Current asthma	Atopic sensitization (self-reported)
Butter						
All subjects	0.95 (0.51–1.79)	0.79 (0.32–1.97)	0.59 (0.13–2.73)	0.68 (0.32–1.44)	0.44 (0.17–1.17)	1.20 (0.73–1.96)
No FAI	0.93 (0.42–2.02)	0.60 (0.17–2.06)	0.77 (0.16–3.65)	0.71 (0.29–1.79)	0.28 (0.06–1.24)	1.21 (0.66–2.22)
Margarine						
All subjects	0.68 (0.38–1.23)	1.23 (0.51–2.96)	NA	1.01 (0.51–1.98)	0.79 (0.37–1.68)	0.86 (0.52–1.42)
No FAI	0.42 (0.21–0.85)*	1.18 (0.38–3.66)	NA	0.99 (0.42–2.32)	0.66 (0.25–1.73)	0.84 (0.45–1.57)
Olive oil						
All subjects	0.94 (0.57–1.55)	1.36 (0.71–2.62)	1.75 (0.66–4.68)	0.65 (0.38–1.09)	0.77 (0.42–1.40)	1.01 (0.67–1.52)
No FAI	0.65 (0.34–1.22)	0.95 (0.43–2.08)	1.49 (0.50–4.42)	0.47 (0.25–0.91)*	0.48 (0.22–1.08)	0.68 (0.41–1.11)
Rape seed oil						
All subjects	1.61 (0.96–2.67)	1.27 (0.66–2.44)	1.52 (0.57–4.05)	1.51 (0.89–2.57)	1.66 (0.90–3.08)	1.00 (0.66–1.52)
No FAI	1.70 (0.90–3.21)	1.47 (0.67–3.23)	1.41 (0.47–4.27)	1.79 (0.94–3.38)	1.94 (0.88–4.28)	1.18 (0.72–1.93)
Poly-unsaturated oils						
All subjects	1.91 (1.14–3.19)*	0.95 (0.46–1.97)	0.64 (0.20–2.03)	0.71 (0.39–1.31)	1.16 (0.61–2.20)	1.04 (0.67–1.63)
No FAI	1.84 (0.97–3.53)	1.00 (0.41–2.45)	0.72 (0.19–2.67)	0.71 (0.34–1.51)	1.15 (0.49–2.70)	0.76 (0.42–1.36)

Totally 1014 subjects, and 882 subjects did not report food allergy or food intolerance (no FAI).

Adjustment for age, gender, and all dietary factors at the same time (type of fat consumption and other dietary factors), by logistic regression.

NA, not available (too few subjects with combination of the two factors).

* $P < 0.05$; ** $P < 0.01$.

significant. There was still a negative association between frequency of fish consumption and doctors' diagnosed asthma ($P < 0.01$), current asthma ($P < 0.01$), while the association between fish consumption and nocturnal attacks of breathlessness was

no longer significant ($P = 0.10$). The positive association between frequency of fruit consumption and doctors' diagnosed asthma remained significant ($P < 0.05$), and the positive association between vegetable consumption and atopic sensitization was

close to significant ($P = 0.06$). Finally, when excluding pupils with food allergy/intolerance, some new associations were observed in model II. Subjects consuming meat more often had less doctors' diagnosed asthma ($P < 0.05$), those consuming margarine had less wheeze ($P < 0.05$), and those consuming olive oil had less doctors' diagnosed asthma ($P < 0.05$). Finally, those consuming fast food more often had more current asthma. The association was significant in model I, adjusting for age and gender only ($P < 0.05$), and close to significance in model II ($P = 0.06$). Some studies indicate that the farm environment could be protective for asthma and allergy, and living on a farm could be associated with different food habits, and different SES. Re-running the logistic regression models, controlling for both age, gender, farm environment, and all 12 dietary factors did not change the results shown in Tables 3 and 4 (data not shown).

The school environment

The mean age of the buildings was 46 years (range 1–103 years). Mechanical ventilation, with supply and exhaust air systems, without air humidification, were found in seven schools (88%), while one had natural ventilation only. In total, 14 of the classrooms had displacement ventilation, while eight classrooms had mixing supply-exhaust ventilation systems. Five of the school buildings (63%) were made of wood, while the other three were of concrete constructions. All classrooms had hard floor coverings made either from polyvinyl chloride or linoleum. None of the classrooms had visible signs of dampness, mold growth or moldy odor. Most of the classrooms had daily floor cleaning, either by dry mopping or wet mopping, and desks were wiped by the pupils 1–5 times a week.

Environmental data are given in Table 5. The mean room temperature was 1.8°C higher in May, and the maximum temperature reached 26.6°C in May, but only 22.5°C in December. The mean relative air humidity was 41% in May and 31% in December. The mean air exchange rate was slightly lower in May (4.5 ac/h) as compared with December (5.6 ac/h), and the mean concentration of carbon dioxide was slightly higher in May. Most of the classrooms (74%) had an average CO₂ level below 1000 ppm both in May and December, but in some classrooms CO₂ exceeded 100 ppm in the end of the lecture. The number of pupils in the classrooms was counted only in May. On average, there were 21 pupils in the classrooms during the measurements, ranging from 0 to 45 pupils. Formaldehyde and particles (PM₁₀) were measured only in May. The formaldehyde levels were low in all classrooms ($< 6\text{--}16\text{ }\mu\text{g}/\text{m}^3$) and there were considerable variation of indoor particle concentration (PM₁₀) ($12\text{--}544\text{ }\mu\text{g}/\text{m}^3$), mean $94\text{ }\mu\text{g}/\text{m}^3$. Mean outdoor temperature during the hygienic measurements in May was

Table 5 Average indoor climate and air pollutants in 23 classrooms in Knivsta schools

	<i>n</i>	M (s.d.)	Min–Max value
Room temperature(°C)			
May	23	23.2 (1.5)	21.0–26.6
December	23	21.4 (0.6)	20.2–22.5
Relative air humidity (%)			
May	23	41 (7)	27–51
December	23	31 (8)	20–46
Air exchange rate (turnovers per hour)			
May	23	4.5 (2.0)	0.5–8.1
December	23	5.6 (2.4)	0.6–10.9
Carbon dioxide (ppm)			
May	23	815 (216)	540–1275
December	23	761 (196)	400–1170
Formaldehyde ($\mu\text{g}/\text{m}^3$)			
May	23	7.1 (3.6)	<6–16
PM 10 ($\mu\text{g}/\text{m}^3$)			
May	23	94 (95)	12–544

M (s.d.), arithmetic mean with standard deviation.

Formaldehyde and PM₁₀ only measured in May.

16°C (range 12–23°C), and mean outdoor humidity was 57% (range 36–77%). All classrooms had cat allergen and most had dog and horse allergens (Table 6). The median concentration per gram dust was 860 ng/g Fel d 1 (range $< 200\text{--}4700\text{ ng/g}$), 750 ng/g Can f 1 ($< 200\text{--}6200$), and 945 U/g Equ cx ($< 200\text{--}31\text{ }000\text{ U/g}$). House dust mite allergens (Der p 1, Der f 1), cockroach (Bla g 1) and mold allergen (Alt a 1) were not detected ($< 200\text{ ng/g}$) in any sample from the 23 classrooms. Median value for total amount of dust per sample was 232 mg (range 40–2652 mg).

The relationship between indoor school environment, respiratory symptoms, asthma and atopic sensitization are shown in Table 7. There were no associations between room temperature, relative air humidity, and wheeze, daytime breathlessness, nocturnal breathlessness, any type of respiratory symptoms, doctor's diagnosed asthma, asthma medication, current asthma, or reports on atopic sensitization (not shown in the table). There was a negative association

Table 6 Allergen levels in settled dust in 23 classrooms in Knivsta schools

	<i>n</i>	Median (IQR)	Min–Max value
Cat allergen concentration (ng/g dust)	92	860 (450–1425)	<200–4700
Dog allergen concentration (ng/g dust)	92	750 (443–3000)	<200–6200
Horse allergen, concentration (U/g dust)	92	945 (535–2200)	<200–31 000
Cat allergen amount (ng/filter)	92	421 (149–979)	4–8009
Dog allergen amount (ng/filter)	92	322 (111–983)	11–6002
Horse allergen amount (U/filter)	92	398 (156–1125)	6–30 008
Total amount of dust (mg/filter)	92	232 (143–790)	40–2652

Median (IQR), Median with inter-quartile range.

Totally two dust samples per classroom in May and December.

For statistical calculations, sample values below the detection limit of 200 ng/g dust (cat and dog) and 200 U/g (horse) were set to 100.

Table 7 Relationship between school environment and respiratory symptoms ($n = 1014$)

Type of indoor exposure	Wheeze	Daytime breathlessness	Nighttime breathlessness	Doctors' asthma	Current asthma	Atopic sensitization (self-reported)
Carbon dioxide ^a	0.86 (0.72–1.03)	0.86 (0.68–1.09)	0.67 (0.45–0.98)*	0.87 (0.73–1.05)	0.90 (0.73–1.11)	0.91 (0.79–1.05)
Air exchange rate (turnovers/h) ^b	1.21 (0.94–1.57)	1.38 (0.94–2.03)	1.32 (0.79–2.20)	1.00 (0.79–1.27)	1.08 (0.81–1.44)	1.14 (0.92–1.40)
Respirable dust (PM10) ^c	0.98 (0.99–1.01)	1.00 (0.99–1.01)	0.98 (0.96–1.00)	1.00 (0.99–1.01)	1.00 (0.99–1.01)	0.99 (0.94–1.05)
Fel d 1 concentration in dust ^d	1.28 (0.73–2.24)	1.54 (0.75–3.18)	1.74 (0.60–5.07)	1.55 (0.88–2.74)	1.62 (0.84–3.15)	1.24 (0.78–1.96)
Fel d 1 amount per sample ^e	1.71 (0.73–4.02)	3.07 (0.95–9.94)	2.57 (0.54–12.32)	2.09 (0.88–5.01)	2.29 (0.82–6.37)	1.20 (0.58–2.47)
Can f 1 concentration in dust ^d	1.36 (0.92–2.01)	1.48 (0.91–2.42)	2.05 (0.95–4.43)	1.38 (0.93–2.04)	1.48 (0.93–2.34)	1.24 (0.91–1.70)
Can f 1 amount per sample ^e	1.94 (1.01–3.75)*	2.51 (1.08–5.85)*	3.41 (0.91–12.69)	1.79 (0.93–3.44)	2.06 (0.95–4.48)	1.37 (0.81–2.30)
Equ cx concentration in dust ^f	1.14 (1.00–1.31)*	1.17 (0.99–1.37)	1.31 (0.98–1.76)	1.08 (0.95–1.24)	1.17 (1.00–1.37)*	1.11 (1.00–1.23)
Equ cx amount per sample ^g	1.26 (1.01–1.57)*	1.31 (1.01–1.70)*	1.46 (0.90–2.38)	1.14 (0.92–1.42)	1.30 (1.00–1.68)*	1.15 (1.00–1.37)
Total dust per sample ^h	1.01 (0.87–1.17)	1.08 (0.87–1.34)	1.00 (0.77–1.31)	1.01 (0.87–1.18)	1.02 (0.85–1.22)	0.94 (0.83–1.07)

* $P < 0.05$; ** $P < 0.01$.

Adjustment for age and gender by a multiple logistic regression.

^{a,b} Odds ratio expressed as change of coefficient per 1 turnover/h.^c Odds ratio expressed as change of coefficient per 10 $\mu\text{g}/\text{m}^3$ dust.^d Odds ratio expressed as change of coefficient per μg of allergen/g dust.^e Odds ratio expressed as change of coefficient per μg of allergen per sample.^f Odds ratio expressed as change of coefficient per 1000 U of allergen/g dust.^g Odds ratio expressed as change of coefficient per 1000 U of allergen per sample.^h Odds ratio expressed as change of coefficient per 100 mg dust.

between CO₂-levels and nocturnal breathlessness, otherwise O₂, air exchange rate, particle concentration (PM10) in the indoor air, or amount of settled dust in the classrooms was not significantly associated with any of the studied health parameters.

In schools with higher amount (ng/sample) of dog allergen (Can f 1) sampled on the ALK-filters, daytime ($P < 0.05$) as well as nighttime breathlessness ($P < 0.05$) was more common. Moreover, we found associations between horse allergen levels (Equ cx) and different health parameters. A higher amount of Equ cx in the samples was related to more wheeze ($P < 0.05$), daytime breathlessness ($P < 0.05$) and current asthma ($P < 0.05$). A higher concentration of Equ cx in the dust was related to more wheeze ($P < 0.05$), current asthma ($P < 0.05$), and reports on atopic sensitization ($P < 0.05$) (Tables 6 and 7). In addition, we found a significant association between concentration of Equ cx in the school dust and reports on atopic sensitization (OR = 1.11; 95% CI 1.00–1.23; $P < 0.05$). There were no significant associations between amount of cat allergen (Fel d 1) in the samples, concentration of Fel d 1 in the dust, and any of the health parameters.

Interaction between dietary factors and allergen levels

The associations between respiratory symptoms and allergen levels were more pronounced, and statistically significant, only in subgroups with particularly dietary habits (Table 8). Among children who did not have a daily intake of fresh milk, the association between current asthma and levels of dog and horse allergen was significant ($P < 0.05$), while there were no significant associations among children with a daily

intake of fresh milk. Among children who did not consume butter, there was an association between wheeze and both cat ($P < 0.05$), dog ($P < 0.01$) and horse allergen levels ($P < 0.01$). Moreover, there was an association between daytime attacks of breathlessness and both dog ($P < 0.05$) and horse allergen levels ($P < 0.05$), as well as an association between current asthma and horse allergen levels ($P < 0.05$). Among children consuming butter, none of these associations existed. Finally, among those consuming margarine, there was an association between wheeze and both dog ($P < 0.05$) and horse allergen levels ($P < 0.05$). Moreover, there was an association between daytime attacks of breathlessness and both cat ($P < 0.05$), dog ($P < 0.05$) and horse allergen levels ($P < 0.05$), as well as an association between current asthma and dog ($P < 0.05$) and horse allergen levels ($P < 0.05$). Among children not consuming margarine, none of these associations were significant. Statistical testing of interaction terms in multiple logistic regression analysis revealed interaction ($P < 0.1$) between all types of allergen exposure and consumption of butter, with respect to wheeze (Table 8).

Discussion

The ventilation in the schools was generally good, but the contamination of cat, dog and horse allergens in the classrooms was abundant and in schools with higher levels of horse and dog allergens, asthma and respiratory symptoms was more common. Moreover, pupils consuming milk and fish more often, and those consuming margarine and olive oil had less asthma symptoms, while those consuming more fruit and

Table 8 Relationship between wheeze, daytime breathlessness, and current asthma and amount of allergens in the dust samples, stratified for frequency of consumption of milk, butter and margarine ($n = 1014$). Odds ratio expressed as change of coefficient per μg or 1000 U of allergen per sample.

	Wheeze	Daytime breathlessness	Current asthma
Less than daily milk consumption ($n = 146$)			
Amount of Fel d1	2.18 (0.43–10.1)	16.67 (0.58–476)	6.51 (0.77–54.99)
Amount of Can f 1	2.64 (0.69–10.1)	18.31 (0.77–436)	7.74 (1.09–55.11)*
Amount of Equ cx	1.46 (0.88–2.41)	2.46 (0.93–6.54)	2.51 (1.19–5.30)*
Daily milk consumption ($n = 860$)			
Amount of Fel d1	1.21 (0.43–3.42)	2.26 (0.62–8.26)	1.45 (0.44–4.79)
Amount of Can f 1	1.46 (0.68–3.14)	2.02 (0.82–4.98)	1.41 (0.59–3.37)
Amount of Equ cx	1.15 (0.89–1.49)	1.26 (0.95–1.66)	1.14 (0.85–1.52)
No consumption of butter ($n = 824$)			
Amount of Fel d1	2.68 (1.05–6.84)*	3.38 (0.96–119)	2.42 (0.83–7.04)
Amount of Can f 1	2.65 (1.28–5.51)**	2.66 (1.07–6.60)*	2.16 (0.96–4.85)
Amount of Equ cx	1.44 (1.12–1.84)**	1.38 (1.04–1.83)*	1.36 (1.04–1.80)*
Consumption of butter ($n = 186$)			
Amount of Fel d1	0.17 (0.02–1.73)	1.59 (0.06–45.9)	1.27 (0.04–45.70)
Amount of Can f 1	0.44 (0.08–2.33)	1.73 (0.17–17.64)	1.38 (0.10–19.66)
Amount of Equ cx	0.61 (0.31–1.22)	1.00 (0.50–1.97)	0.83 (0.34–2.05)
No consumption of margarine ($n = 191$)			
Amount of Fel d1	1.57 (0.25–9.93)	0.51 (0.02–12.0)	0.80 (0.07–9.81)
Amount of Can f 1	1.26 (0.35–4.59)	0.63 (0.09–4.28)	0.72 (0.15–3.57)
Amount of Equ cx	1.08 (0.71–1.66)	0.82 (0.44–1.53)	0.95 (0.57–1.59)
Consumption of margarine ($n = 819$)			
Amount of Fel d1	1.78 (0.68–4.67)	4.17 (1.15–15.1)*	2.92 (0.94–9.06)
Amount of Can f 1	2.28 (1.06–4.91)*	3.51 (1.34–9.19)*	2.88 (1.17–7.07)*
Amount of Equ cx	1.32 (1.02–1.73)*	1.47 (1.09–1.97)*	1.43 (1.05–1.95)*

Missing information on milk consumption for eight subjects and on butter and margarine consumption for four subjects.

Adjustment for age and gender by a multiple logistic regression.

P-value for interaction terms between butter and cat ($P = 0.04$), butter and dog ($P = 0.07$), and butter and horse ($P = 0.06$) in relation to wheeze. For all other interaction terms, $P > 0.1$.

* $P < 0.05$, ** $P < 0.01$.

poly-unsaturated oil had more asthma. Finally, we found an interaction between dietary factors and allergen exposure in the school, as the associations between allergen exposure and respiratory symptoms were more pronounced among those with less consumption of fresh milk and milk fat, and more pronounced among those consuming margarine.

Epidemiological studies can be affected by selection bias. In this study, we included all primary schools in one suburban municipality outside of Uppsala city. The hygienic measurements were performed in arbitrary chosen classrooms representing different buildings in all schools. The response rate was 68%, which is somewhat lower than in previous school studies from Uppsala (e.g. Smedje et al., 1997). This could maybe due to the fact that this questionnaire was more extensive. Information bias is another problem in epidemiological studies. Self-reported asthma, and doctor's diagnosed asthma is commonly used in epidemiological studies and has a high specificity, but the sensitivity is not as high. Thus, a majority of those

reporting asthma and allergy in our study could be expected to actually have asthma or allergic sensitization, but some underestimation of the true prevalence could be expected. Validation studies from Scandinavian school children have shown that the prevalence of self-reported pollen and pet allergy is higher than the prevalence of positive skin prick tests (Hattevig et al., 1987; Bråbäck et al., 1994; Dotterud et al., 1995), indicating that use of questionnaire data on allergy in school children could lead to an overestimation, compared to if allergy testing is used as the gold standard.

Information on symptoms and diet was collected by the same questionnaire, answered by the parents in cooperation with the child. Some of the questionnaires were answered by the mother, others by the father, or both parents together. We found no significant difference in symptom reporting, or dietary information, when comparing answers from mothers and fathers. When a number of statistical tests are performed, some of the findings could be chance findings. In our study, OR were similar in different statistical models, and some findings were significant below the 1% level.

The exposure measurements were all carried out by professional environmental engineers shortly (2–4 weeks) after the questionnaires had been answered. In addition, the same calibrated direct-reading instruments were used in all schools, and all environmental samples were analyzed in the same batch in the laboratories. Thus, there should be no serious information bias regarding symptom reporting or exposure measurements. When performing a number of statistical tests, there is a risk for mass significance. However, we found mostly similar results using different types of statistical models. Finally, a cross-sectional study has certain limitations with respect to causality, e.g. if there is selection effects over time in relation to exposure or dietary factors. In the home environment, it is difficult to study effects of allergen exposure from pets, because of a complex pattern of avoidance of pet keeping, and removal of pets, for health reasons (Brunekreef et al., 1992). Such selection effects are less likely in the school environment. We found some indications of health-related avoidance behavior in relation to milk allergy/lactose intolerance, but not fish and fruit consumption. In conclusion, we consider the study to have sufficient internal validity, and the results should not be seriously biased by information or selection bias, or because of chance findings.

We found more asthma and more dog and pollen allergy in boys, totally 10.2% of the boys and 5.4% of the girls had ever had doctor's diagnosed asthma. The gender difference is in agreement with previous studies (Forsberg et al., 1997); Morgan and Martinez, 1992; Rönmark et al., 1998), showing a higher onset of asthma in younger boys. With increasing age the incidence is higher in girls, while in adolescence the

gender difference disappears (Åberg and Engström, 1990; Larsson, 1995; Strachan et al., 1996). In our study, the prevalence of self-reported cat and dog allergy was 6.8 and 4.8%, respectively, with no significant age trend.

In our dietary questionnaire, the majority of the children reported daily consumption of fresh milk, fruits and vegetables, while the consumption of fish and fast food was less prevalent. Our data suggested a protective effect of more frequent fish consumption with respect to asthma symptoms, and the effect was consistent even when excluding subjects reporting food allergy/intolerance. In some countries, there may be cultural beliefs on which type of food that is suitable for asthmatics, but to our knowledge there are no such ideas in Sweden. A high intake of omega-3 essential fatty acids, a fatty acid mainly from fat fish, has been shown to be protective for asthma (Romieu and Trenga, 2001; Simopoulos, 2002). In Sweden, fat fish such as salmon and herring is a significant part of the total fish consumption, but we have no information on how much the school children consume fat fish. A protective effect of fish consumption has been demonstrated in previous studies, with respect to asthma (Fluge et al., 1998; Hodge et al., 1996; Nafstad et al., 2003) and bronchial hyper-responsiveness (Peat et al., 1992). In contrast, a Japanese study showed a higher prevalence of fish consumption in those with asthmatic symptoms (Takemura et al., 2002). Besides being healthy food, fat fish may contain environmental contaminants such as mercury or polychlorinated biphenyls. In Sweden, this has been a problem for herring from the Baltic Sea (Kiviranta et al., 2003), but the contaminants are associated with other health effects than asthma.

We found an association between fast food consumption and asthma symptoms, which was significant when adjusting for age and gender only. This is in agreement with a previous study from Saudi Arabia (Hijazi et al., 2000). Unexpectedly, we found a positive association between frequent fruit consumption and asthma, which was significant even when excluding those with food allergy/intolerance. We have no explanation for this finding, which is in contrast to most other studies showing a protective effect of fruit consumption (e.g. Denny et al., 2003; Romieu and Trenga, 2001). Initially we found that consumption of milk was protective for asthma, which is in agreement with some previous studies (Wickens et al., 2002; Woods et al., 2003). The study by Wickens reported a protective effect of unpasteurized milk. We did not ask about pasteurized/unpasteurized milk in the questionnaire, but all milk sold on the Swedish food market is pasteurized. Some farm children may drink unpasteurized milk, but this is probably rare in Swedish farms nowadays. As the association was less pronounced, and not statistically significant, when excluding subjects

with food allergy/intolerance, we conclude that the association could partly be due to milk avoidance among those with milk allergy/intolerance.

The majority of the families consumed margarine (81%) and olive oil (55%) but butter was rarely used (18%). This illustrates the trend of internationalization of dietary habits, as olive oil is not generally a part of traditional Swedish cooking. When restricting the analysis to subjects without food allergy/intolerance, we found a negative association between margarine consumption and wheeze, and between olive oil consumption and asthma. Two previous studies have shown that margarine consumption in children was a risk factor for atopic sensitization (Bolte et al., 2001) and wheeze (Farchi et al., 2003). It should be noted that in many countries, e.g. Sweden, there is an inverse relationship between use of margarine and butter, suggesting that the risk factor of using margarine could be linked to lower consumption of milk fat from butter. We also found a protective effect of olive oil consumption, with respect to asthma, but only when excluding subjects with food allergy/intolerance. In addition, we found that consumption of poly-unsaturated oils was a risk factor for wheeze, but the association was not significant when excluding those with food allergy/intolerance. These results concerning consumption of different types of oils needs to be confirmed in other studies. There seems to be little information in the literature on respiratory effects of oil consumption, other than fish oil. In studies on health effects of omega-3-fatty acids, olive oil or poly-unsaturated oils are usually used as placebo (Mickleborough et al., 2003).

The measurements in the schools showed room temperatures ranging from 20 to 23°C in the winter (December) and from 21 to 27°C in spring (May). This is in agreement with other school studies, showing room temperatures above >22°C in the classrooms, particularly in the warm part of the year (Ruotsalainen et al., 1995; Smedje et al., 1997). The relative humidity showed less seasonal variation, ranging from 20 to 46% R.H. in December and 27 to 51% R.H. in May. Similar relative air humidity has been measured in previous school studies in Sweden and Finland (Ruotsalainen et al., 1995; Smedje et al., 1997). Most of our classrooms (74%) had sufficient ventilation both in winter and summer, with average CO₂-levels below 1000 ppm, which is in accordance with the current ventilation standard in Sweden (AFS, 1993, p. 5). In some classrooms, however, CO₂ exceeded 1000 ppm in the end of the lecture. Previous school studies have shown higher CO₂-levels (Ruotsalainen et al., 1995; Smedje et al., 1997). In our schools, most classrooms had the new type of displacement ventilation system. Introduction of displacement ventilation in classrooms have been shown to reduce mean CO₂-levels from 1050 to 780 ppm in the classrooms (Smedje and Norbäck,

2000). We found no significant associations between indoor climate, air exchange, or CO₂-levels and asthma, respiratory symptoms or allergy, except for a negative association between CO₂-levels and nighttime breathlessness. We have no explanation for this finding, but it could be due to chance, as it did not influence daytime breathlessness, when the children are exposed to the school environment.

Our allergen measurements showed frequent contamination of both cat, dog and horse allergens in settled dust in classrooms. Similar findings concerning cat (Almqvist et al., 1999; Amr et al., 2003; Karlsson et al., 2002; Munir et al., 1993; Perzanowski et al., 1999; Smedje and Norbäck, 2001) and dog allergen (Amr et al., 2003; Munir et al., 1993; Perzanowski et al., 1999; Smedje and Norbäck, 2001) have been previously reported from Swedish schools. Cat allergen contamination in schools has been reported from New Zealand (Patchett et al., 1997) and Germany (Ritz et al., 2002), while schools in Shanghai were almost free from cat, dog and horse allergens (Mi et al., 2002). Our finding of frequent horse allergen contamination in classrooms is a new finding. We have no information about the prevalence of horse ownership in the families, but horse ownership could be expected to be common. Knivsta is a rural suburb of Uppsala with many white collar workers who are interested in 'rural life'. We found only one previous publication on horse allergen contamination using the same ELISA method dealing with horse allergens in ambient air near stables (Emenius et al., 2001). We found an association between dog and horse allergen contamination in the schools, and current asthma and respiratory symptoms. To our knowledge, there are no previous studies

showing associations between airway symptoms and these allergens. Some previous studies have indicated that cat allergen (Smedje and Norbäck, 2001) and cockroach allergen contamination (Amr et al., 2003) could be risk factors for asthma in school children.

In conclusion, both dietary factors and allergen exposure in the classrooms can be of importance for asthmatic symptoms in school children. The role of dietary habits of school pupils should not be neglected in work to counteract the increase of asthma in the society. A more frequent consumption of fish, and olive oil could be beneficial, while consumption of fast food and poly-unsaturated oils could be dietary risk factors. The role of milk consumption is more uncertain, it could be protective but also cause milk allergy and lactose intolerance. As we found less association between allergen levels and respiratory symptoms among children consuming butter and among those with a more frequent intake of fresh milk, it is possible that there is a protective effect linked to intake of milk fat. The ventilation measurements confirmed that use of the new type of displacement ventilation enables the schools to keep CO₂-levels below 1000 ppm, in accordance with current Swedish ventilation standards. In addition, thermal conditions in Swedish schools can be unfavorable, with too high temperatures in the end of the spring semester. Cat, dog and horse allergens were found at high levels in most of the classrooms, and exposure to dog and horse allergens could be a risk factor for asthma and atopic sensitization. Most previous studies have focused on contamination of cat allergen in schools, but our study has shown that dog and horse allergens can also be risk factors for asthma and allergy in school children.

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