

A comparative study of asthma, pollen, cat and dog allergy among pupils and allergen levels in schools in Taiyuan city, China, and Uppsala, Sweden

Abstract We compared the school environment, asthma and allergy in 10 schools in Taiyuan, China, with eight schools in Uppsala, Sweden. In total 2193 pupils (mean age 13 years) participated. Chinese pupils had more respiratory symptoms, particularly daytime breathlessness after exercise (29.8% vs. 7.1%; $P < 0.001$), while cat allergy (1.2% vs. 6.6%; $P < 0.001$) and dog allergy (1.3% vs. 4.0%; $P < 0.01$) was less common. Cumulative incidence of asthma (1.8% vs. 9.5%; $P < 0.001$) and doctor's diagnosed asthma (1.2% vs. 9.0%; $P < 0.001$) were less common in China, indicating an under-diagnosis of asthma. Chinese classrooms were colder (mean 14.7 vs. 21.4°C), more humid (mean 42% vs. 31% RH) and had higher CO₂-levels (mean 2211 vs. 761 ppm). Levels of cat (Fel d1), dog (Can f1) allergens were low in settled dust from China (< 200 ng/g dust), but high in airborne dust on Petri-dishes (GM 16.8 ng/m²/day for Fel d1 and 17.7 for Can f1). The Swedish settled dust contained cat, dog and horse allergens in high levels (median 1300 ng/g, 1650 ng/g, 1250 U/g dust, respectively). In conclusion, there were large differences in the school environment, and in respiratory symptom and allergy. Allergen measurements in settled dust only may largely underestimate the classroom exposure.

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Practical Implications

There is a need to improve the school environment, both in China and Sweden. The Swedish schools contained high levels of cat, dog and horse allergens and more amounts of open shelves and textiles that can accumulate dust and allergens. The air measurements indicated that Chinese schools may contain significant amounts of cat and dog allergen, and analysis of settled dust only may not reflect the true allergen exposure. Since the Chinese schools had no mechanical ventilation, they could not fulfill the ventilation standard in winter, and hence there is a need for improving the ventilation. The great discrepancy between respiratory symptoms and reports on asthma, and the high prevalence of attacks of breathlessness without wheeze, may have implication for future questionnaire studies on asthma in China.

Introduction

Asthma has increased since the mid-1970s in industrialized countries, especially in younger generations (Aberg et al., 1995; von Mutius, 2000; Sennhauser et al., 2005). Two large international epidemiology studies have shown a wide variation of asthma and allergies in the world (Asher et al., 1998; Chinn et al., 1997; ECRHS, 1996). Even in developing countries, the prevalence is higher in urbanized and westernized areas (Keeley et al., 1991; Van Niekerk et al., 1979; Zhao et al., 2003).

Asthma, especially in young people, is related to atopic sensitization (Chipps, 2004) as well as irritant exposure (Delfino, 2002; Levetin and Van de Water, 2001). In Asia, there are a few studies on asthma and allergy. Recent studies from China have demonstrated a positive association between keeping cats and dogs at home and childhood asthma (Salo et al., 2004; Zheng et al., 2002). Most studies in China on asthma and allergy are from the more developed areas, e.g. Beijing, Shanghai, Guangzhou and Chongqing (Chen et al., 1998; Zhao et al., 2003; Zheng et al., 2002), and a few from less developed areas, except Urumqi (Chen et al.,

1998; Zhao et al., 2000). Taiyuan city is an important industrial area rich in coal, steel and iron, with heavy air pollution (Cheng et al., 2002). Satellite monitoring has demonstrated that this area has the highest pollution of NO₂ in the world (Richter et al., 2005).

School is an important public indoor environment for children. Several European countries have reported wide spread contamination of cat and dog allergens in schools due to transfer of allergens by the children's clothes (Almqvist et al., 2001; Patchett et al., 1997). Some schools also have house dust-mite (Foarde and Berry, 2004), cockroach (Chew et al., 2005; Foarde and Berry, 2004), mouse (Chew et al., 2005) and horse allergens (Kim et al., 2005). However, there are no publications available on allergen levels in Chinese schools except one study from Shanghai (Mi et al., 2002), and a few international comparisons of the school environment in different countries.

The first aim of the study was to compare self-reported asthma, asthmatic symptoms and pollen or pet allergies among pupils in the schools in Taiyuan, China, with similar data from schools in Uppsala, Sweden. The second aim was to measure allergens levels in settled and airborne dust from Taiyuan schools, and to compare them with the Uppsala schools, with very different ventilation and heating systems, different pet keeping, and different outdoor air pollution. Associations between environmental factors in the schools and asthmatic symptoms in the Swedish study have been published previously (Kim et al., 2005). Associations between environmental factors in the Chinese schools and asthmatic symptoms will be published separately.

Materials and methods

Selection of population

Ten junior high schools within Taiyuan city were arbitrarily selected from the whole city area. The headmasters were contacted and all agreed to participate. The schools had 4–7 first-year classes (equal to form 7 in the Swedish school system). In schools with more than five classes, five classrooms were selected to be on various floors and different parts of the building. In schools with four classes, all were selected. In total, 46 first-year high school classes were included containing 2209 students aged between 11 and 15 years. Allergen measurements in settled dust were performed in 39 classrooms, and seven classrooms could not be sampled because they did not have electric power. The study protocol was approved by the Ethics Committee of the Uppsala University.

For comparison with Swedish schools, we used data from a previous study (Kim et al., 2005). It comprised eight primary schools (1st–6th form) in Knivsta, Uppsala county, situated in mid-Sweden. In each school, three classes were selected, except in one school

which only had two classes. Allergen measurements in settled dust were performed in all 23 classrooms with the same method and sampling strategy as later used in China. In order to get children of comparable age groups, only children aged between 12 and 14 years were included in the medical part of this study.

Information on asthma, asthma symptoms and allergy

A self-administered questionnaire was distributed to the pupils. The same questionnaire was used in China and Sweden, translated from Swedish to Chinese, and back-translated to Swedish by another person. Standardized questions were adapted from the International Study of Asthma and Allergies in Childhood (ISAAC) (Asher et al., 1995), the European Community Respiratory Health Survey (ECRHS) (Burney et al., 1994) and Swedish school studies (Smedje et al., 1997). One set of questions asked about asthma (ever asthma, doctor's diagnosed asthma and current asthma). Current asthma was defined as either having current asthma medication or an asthma attack during the last 12 months (Plaschke et al., 2000). Other questions dealt with airway symptoms during the last 12 months, without using the phrase 'asthma'. It included questions on wheezing or whistling in the chest, daytime attacks of breathlessness (at rest and after exercise) and nocturnal attacks of breathlessness. Finally, there were questions about cat, dog and pollen allergy.

Classroom inspection and indoor and outdoor climate

The room volume (m³), shelf factor (m/m³) and fleece factor (m²/m³) were calculated in each classroom. The shelf factor (m/m³) is defined as the length of open shelves in relation to the room volume, and fleece factor (m²/m³) as the surface area of fabrics in relation to the room volume (Skov et al., 1990). Temperature, relative air humidity (RH %) and CO₂ concentration were measured both indoors and outdoors by a direct reading instrument (Q-TrakTM IAQ-monitor; TSI Incorporated, St Paul, MN, USA). The personal outdoor air supply rate (A) was calculated from the estimated equilibrium CO₂ concentration (C_{mean} , ppm) by the formula below. The equilibrium CO₂ concentration was estimated manually from the CO₂-graphs

$$A = P / (C_{\text{mean}} - C_0) \times (10^6 / 3600).$$

Where P denotes the personal emission rate of CO₂ in L/s, and C_0 denotes the CO₂ level in the outdoor air (Norbäck et al., 1992). In the calculations, we assumed a personal CO₂ emission equal to the sedentary office worker (18 L/h) and used the mean outdoor CO₂ concentration. For practical reasons, indoor climate measurements could only be performed in 24 of 46

classrooms in China, but in all 23 classrooms in Sweden.

Allergen measurements

Two samples of settled dust were collected from each classroom, one from the corridor side and one from the window side. Dust was collected by a vacuum cleaner with 400 W electric power equipped with a special dust collector (ALK Abello, Copenhagen, Denmark) fitted with a Millipore filter (pore size 6 μ m). Vacuum cleaning was performed for 4 min for each sample, 2 min on the floor and 2 min on the desks and chairs. The filters were stored at -20°C until extraction.

The dust on the ALK-filters was weighed, and 100 mg of fine dust was extracted with 2 ml of phosphate buffered saline (PBS) containing 0.05% Tween 20 (1/20 w/v) for 2 h at room temperature with continuous rotation. The extraction was centrifuged at 2500 g for 10 min followed by another centrifugation at 7000 g for 10 min. The supernatants were stored at -20°C until analysis.

Airborne dust was collected on one Petri-dish in each classroom, placed on the top of the blackboard (about 2 m height) in the front of the classroom and kept open for 7 days (Karlsson et al., 2002). The extraction of allergens was started by adding 3 ml of PBS with 1% bovine serum albumin (BSA) into the base part of the Petri-dishes. After 1 h of gentle stirring, the solution was transferred from the base part to the lid, and left for another 1 h at room temperature. Evaporation was minimized by keeping the Petri-dish closed. The liquid was transferred to an Eppendorf tube and centrifuged at 7000 g for 10 min. The supernatants were stored at -20°C until analysis.

Two-site sandwich ELISA was applied to determine allergen levels of cat (Fel d 1), dog (Can f 1), house dust-mite (Der p 1 and Der f 1), cockroach (Bla g 2) (Indoor Biotechnologies Ltd, Manchester, UK) and horse (Equ c x) (Mabtech, Stockholm, Sweden) (Emenius et al., 2001) for both settled dust and Petri-dish samples by using monoclonal antibodies. The dog allergen assay is a monoclonal/polyclonal ELISA, using anti-Can f 1 mAb 6E9 for allergen capture and the polyclonal rabbit anti-Can f 1 for detection. The procedures basically followed the methods provided by the manufacturers with the exception for the dog allergen assay where the horseradish peroxidase-labelled goat anti-rabbit immunoglobulin was from DakoCytomation Norden AB, Stockholm, Sweden. The allergen level is expressed as ng/g dust, except for horse allergen concentration which is expressed as U/g dust, where 1 Unit equals to 1 ng protein of a horse hair and dander extract used as standard (Allergon, Valinge, Sweden and NIBSC, Hertfordshire, UK). Determination of protein concentration for horse standard was performed according to the micro-BCA

method (Peirce, Rockford, IL, USA) using BSA as standard. Samples with intra-assay CV > 10% were re-assayed.

Petri-dish samples with low levels of cat allergen (Fel d 1 $\leq$ 1.0 ng/ml) by conventional ELISA were further analysed by amplified ELISA, using a commercial signal amplification kit (AMPAKTM; DakoCytomation Norden AB) basically according to the manufacturer's protocol and Karlsson et al., 2002. The standard curve range was 5.0–320 pg/ml.

Statistical methods

Data were analysed by Statistical Package for the Social Sciences (SPSS). Differences in allergen levels and indoor factors between China and Sweden were tested by Mann–Whitney *U*-test. Odds ratio (OR) with 95% confidence interval (95% CI) was calculated and differences in asthma or allergy were tested by Chi-square analysis. Correlation between age groups, ventilation and allergen levels in the Swedish schools was tested by Kendal Tau-beta rank correlation test. Two tailed tests and a 5% level of significance was applied.

Results

In total, 2209 pupils in China received the questionnaire and 1993 participated (90.2% response rate). There were 49.3% girls, and the average age was 13 years old (s.d. = 0.64, range 11–15 years). In Sweden, the response rate was 68%, and there were 200 pupils within the same age range in total (average = 13 years, range 12–14), among which 51% were girls.

Prevalence of asthma, asthma symptoms and allergy

One-third of the pupils in China and one-tenth of the pupils in Sweden have had a respiratory symptom the last 12 months. The prevalence of wheeze was similar in both countries, while daytime breathlessness after exercise was much more common in China, with OR value of 5.95 (95% CI 3.36–10.5). Reports on allergies were less common in China (OR = 0.24; 95% CI 0.16–0.37), both for cat, dog and pollen allergy. Chinese pupils had lower prevalence of 'ever asthma' (OR = 0.18, 95% CI 0.10–0.32), 'doctor's diagnosed asthma' (OR = 0.12, 95% CI 0.06–0.23), 'current asthma' (OR = 0.10, 95% CI 0.04–0.20), and current asthma medication (OR = 0.07; 95% CI 0.03–0.17) (Table 1). Gender differences were calculated only in the Chinese group (Table 2). Daytime breathlessness after exercise was more common in girls (OR = 1.62, 95% CI 1.32–1.97). Data on gender difference among the Swedish pupils (5–14 years) have been published (Kim et al., 2005) and boys had more doctor's diagnosed asthma and current asthma than girls.

Table 1 Prevalence of asthma, asthma symptoms and allergy in Taiyuan, China, and Uppsala, Sweden

	China (<i>n</i> = 1993) (%)	Sweden (<i>n</i> = 200) (%)	OR (95% CI)
Questions on asthma			
Ever asthma	1.8	9.5	0.18 (0.10–0.32)***
Doctor's diagnosed asthma	1.2	9.0	0.12 (0.06–0.23)***
Asthma attacks in the last 12 months	0.4	3.9	0.10 (0.04–0.29)***
Current asthma medication	0.5	6.0	0.07 (0.03–0.17)***
Current asthma ^a	0.7	7.2	0.10 (0.04–0.20)***
Questions on current airway symptoms (in the last 12 months)			
Wheezing or whistling in the chest	8.4	8.0	1.08 (0.63–1.84) ^{NS}
Daytime attacks of breathlessness	29.8	7.1	5.71 (3.29–9.92)***
Daytime attacks of breathlessness at rest	5.4	2.5	2.26 (0.91–5.62) ^{NS}
Daytime attacks of breathlessness after exercise	27.7	6.6	5.95 (3.36–10.5)***
Nocturnal attacks of breathlessness	2.1	1.0	2.23 (0.54–9.28) ^{NS}
At least one airway symptom ^b	33.9	9.7	5.36 (3.31–8.68)***
Questions on allergies			
Cat allergy	1.2	6.6	0.17 (0.08–0.33)***
Dog allergy	1.3	4.0	0.30 (0.13–0.68)**
Pollen allergy	2.1	12.7	0.17 (0.10–0.26)***
Furry pet or pollen allergy	3.8	16.2	0.24 (0.16–0.37)***

^aCurrent asthma is defined as either having current asthma medication or having had an asthma attack during the last 12 months.

^bSymptoms defined as either wheezing or whistling in the chest, daytime attacks of breathlessness or nocturnal attacks of breathlessness.

NS, not significant; ***P* = 0.002; ****P* < 0.001.

Table 2 Gender differences of asthma, asthma symptoms and allergy among pupils in Taiyuan, China

	Boys (<i>n</i> = 1005) (%)	Girls (<i>n</i> = 976) (%)	OR (95% CI)
Questions on asthma			
Ever asthma	2.1	1.4	0.68 (0.34–1.34)
Doctor's diagnosed asthma	1.2	1.1	0.95 (0.42–2.16)
Asthma attacks in the last 12 months	0.5	0.3	0.62 (0.15–2.60)
Current asthma medication	0.4	0.6	1.56 (0.44–5.53)
Current asthma	0.7	0.7	1.03 (0.36–2.94)
Questions on current airway symptoms in the 12 months			
Wheezing or whistling in the chest	9.6	7.2	0.73 (0.53–1.00)
Daytime attacks of breathlessness	25.8	34.0	1.50 (1.24–1.83)***
Daytime attacks of breathlessness at rest	4.6	6.1	1.37 (0.92–2.03)
Daytime attacks of breathlessness after exercise	23.4	32.4	1.62 (1.32–1.97)***
Nocturnal attacks of breathlessness	1.8	2.5	1.39 (0.75–2.58)
At least one airway symptom	32.7	37.9	1.45 (1.20–1.75)***
Questions on allergies			
Cat allergy	1.0	1.3	1.37 (0.60–3.13)
Dog allergy	1.1	1.4	1.34 (0.61–2.97)
Pollen allergy	1.8	2.3	1.29 (0.69–2.41)
Furry pet or pollen allergy	3.2	4.3	1.40 (0.87–2.23)

****P* < 0.001.

School environment in China and Sweden

In the Chinese classrooms, the mean CO₂ concentration was 2211 ppm (range 789–4170 ppm), mean room temperature was 14.7°C (range 11.2–18.4°C) and mean RH was 42% (31–62%) (Table 3). The mean personal outdoor airflow rate was 3.6 l/s, and only 13% of the classrooms fulfilled the recommended ventilation standard of 8 l/s per person (ASHRAE, 1999). None of the Chinese classrooms had any open shelves (shelf factor 0 m²/m³), and the fleece factor was low (mean 0.03 m²/m³). In the Swedish classrooms, the mean CO₂ concentration was

761 ppm (400–1170 ppm), mean room temperature was 21.4°C (20.2–22.5°C), and mean RH was 31% (20–46%). The mean personal outdoor airflow rate was 14.8 l/s, and 91% of the classrooms were above the 8 l/s per person standard. In the Swedish schools, the mean shelf factor was 0.10 m²/m³ (0–0.22) and the mean fleece factor was 0.08 m²/m³ (0.01–0.36). All differences were significant between China and Sweden except mean room volume which was similar. Most of the classrooms in China had concrete floors without any paint, and in a few cases tiles. The Swedish classroom floor coatings were either PVC or linoleum. None of the schools in China or Sweden

Table 3 Indoor and outdoor climate in schools in Taiyuan, China, and Uppsala, Sweden

	China			Sweden			
	<i>n</i> ^a	Mean (s.d.)	Minimum to maximum	<i>n</i> ^a	Mean (s.d.)	Minimum to maximum	<i>P</i> -value
Indoor climate and room inspection							
Number of students	46	48 (8)	33–60	23	20 (7)	8–43	<0.001
Classroom volume (m ³)	46	193 (18)	161–225	23	202 (87)	82–470	0.16
CO ₂ (ppm)	24	2211 (1005)	789–4170	23	761 (196)	400–1170	<0.001
Outdoor air supply rate (l/s person) ^b	24	3.6 (2.8)	1.3–10.4	22 ^c	14.8 (7.0)	6.2–31.7	<0.001
Temperature (°C)	24	14.7 (2.2)	11.2–18.4	23	21.4 (0.6)	20.2–22.5	<0.001
Relative humidity (%)	24	42 (10)	31–62	23	31 (8)	20–46	<0.001
Fleece factor (m ² /m ³)	23 ^c	0.03 (0.03)	0–0.14	23	0.08 (0.08)	0.01–0.36	0.001
Shelf factor (m/m ³)	23 ^c	0 (0)	0–0	23	0.10 (0.06)	0–0.22	<0.001
	<i>n</i> ^d	Mean (s.d.)	Minimum to maximum	<i>n</i> ^d	Mean (s.d.)	Minimum to maximum	<i>P</i> -value
Outdoor climate							
CO ₂ (ppm)	10	522 (26)	480–559	8	368 (21)	345–395	<0.001
Temperature (°C)	10	−1.8 (2.1)	−5.5–2.6	8	5.0 (4.8)	0–13.7	0.002
Relative humidity (%)	10	52 (11)	30–64	8	82 (20)	34–97	0.006

^aNumber of classrooms.^bCalculated from the estimated equilibrium concentration of CO₂.^cOne classroom was missing due to practical reasons.^dNumber of schools.

had wall-to-wall carpets or visible signs of molds or dampness.

Allergen levels in settled and airborne dust

Allergen levels were generally very low in settled dust in Chinese classrooms (Table 4). In total five samples (6%), all from different classrooms, contained traces of cat allergen (Fel d1) and two samples (3%) contained traces of dog allergen (Can f1). None of the Chinese dust samples contained horse allergen (Equ cx). Most of the Swedish dust samples contained cat, dog and horse allergens and often at high levels. All 46 samples (100%) contained cat allergen, 44 (96%) contained dog allergen and 42 (91%) contained horse allergen. Median levels for cat, dog and horse allergens in dust were 1300 ng/g, 1650 ng/g and 1250 U/g dust, respectively. The differences of allergen levels between Sweden and China were highly significant ($P < 0.001$). When comparing the amount of allergen per dust filter, the same results were obtained,

with lower cat, dog and horse allergen levels in China ($P < 0.001$). One dust sample from China (1%) contained Der f1 (323 ng/g dust), none contained Der p1. None of the Swedish samples contained house dust-mite allergens (Der f1 or Der p1) (< 100 ng/g dust). Cockroach allergen (Bla g1) was not detected in any dust sample from the two countries (< 100 ng/g dust).

Airborne allergen assay was carried out for 44 samples, collected on Petri-dishes only in Chinese classrooms and expressed as ng/m²/day. Fel d1 and Can f1 were detected in 93% (41/44) (> 0.01 ng/ml) and 55% (24/44) (> 0.39 ng/ml) of all samples, respectively. The GM values across 10 schools were 16.82 and 17.74 ng/m²/day for cat and dog allergens with a range of 0.17–225.62 and 6.79–139.87 ng/m²/day, respectively. Mite (Der f1, Der p1), horse (Equ cx) and cockroach allergens (Bla g1) were not detected in any air sample (< 0.39 ng/ml). Two schools had GM values of cat allergen > 50 ng/m²/day, and one had dog allergen > 50 ng/m²/day (Table 5).

Table 4 Allergen levels in settled dust in Taiyuan, China, and Uppsala, Sweden^a

	China (<i>n</i> = 78)		Sweden (<i>n</i> = 92)		<i>P</i> -value
	Median (IQR)	Minimum to maximum	Median (IQR)	Minimum to maximum	
Cat allergen (Fel d 1) concentration (ng/g dust)	<100 (<100–<100)	<100–177	1300 (868–2325)	290–4700	<0.001
Dog allergen (Can f 1) concentration (ng/g dust)	<200 (<200–<200)	<200–527	1650 (785–2300)	<200–6200	<0.001
Horse allergen (Equ c x) concentration (U/g dust)	<200 (<200–<200)	<200–<200	1250 (695–2800)	<200–31000	<0.001
Cat allergen amount (ng/filter)	60 (28–83)	5–241	421 (149–979)	4–8009	<0.001
Dog allergen amount (ng/filter)	120 (57–165)	10–1150	322 (111–983)	11–6002	<0.001
Horse allergen amount (U/filter)	110 (57–160)	10–483	398 (156–1125)	6–30008	<0.001
Total dust (mg/filter)	1108 (565–1604)	98–4828	794 (562–1201)	235–2652	0.102

^aFor values less than the detection limit, half of the detection limit value was used for calculation and statistical test.

Table 5 GM airborne allergen levels (ng/m²/day) in Petri-dish samples in 10 schools in China

School number	Number of classrooms	Cat ^a	Dog ^b
1	5	2.54	9.52
2	4	0.55	6.79
3	4	32.52	60.20
4	4	61.99	16.45
5	4	59.60	14.85
6	5	34.35	13.34
7	5	20.22	11.49
8	3	16.80	13.02
9	5	46.80	41.59
10	5	19.20	34.62
For all schools			
Median	44	38.28	15.79
IQR	44	5.76–72.53	6.79–40.08
Minimum to maximum	44	0.17–225.62	6.79–139.87
GM	44	16.82	17.74
GSD	44	6.62	2.67

^aAllergen concentration values less than the detection limit of 0.01 ng/ml by amplified ELISA were set to 0.005 ng/ml for statistical calculation.

^bAllergen concentration values less than the detection limit of 0.39 ng/ml by conventional ELISA were set to 0.195 ng/ml for statistical calculation.

GM, geometric mean; GSD, geometric s.d.

Associations between allergens, ventilation and age groups

There was an association between cat and dog allergen in the air (Tau beta 0.36; $P = 0.001$). Moreover, there was a negative correlation between personal outdoor airflow rate (l/s) and dog allergen in the air (Tau beta -0.33 ; $P = 0.04$), but no significant correlation with airborne cat allergen (Tau beta -0.21 ; $P = 0.16$). In the Swedish schools, the association between age groups (mean age of the pupils in each classroom) and allergen levels in the settled dust were investigated, but no correlations were found for cat (Tau beta 0.02; $P = 0.89$), dog (Tau beta 0.03; $P = 0.77$) or horse allergens (Tau beta -0.15 ; $P = 0.18$) in the settled dust.

Discussion

We compared asthma, allergy and the school environment for Chinese and Swedish pupils. Schools in these two countries had great differences in type of ventilation, heating systems, allergen contamination, and outdoor air pollution. There were large differences in the prevalence of asthmatic and allergic symptoms, school environment, and school pet allergen contamination between China and Sweden. There are a very few international publications on the school environment in China (Lee and Chang, 2000; Mi et al., 2002, 2006; Zhao, 1991) and no previous publication on allergen levels in schools in northern China.

The response rate was high in both countries with 68% in Sweden and 90% in China. The mean age of the pupils was the same (13 years), and the proportion of girls was similar. All indoor measurements were done with the same methods and instruments, and

sampling was done in winter time in both countries. Collection of allergen samples was done in the same way in both countries and the allergen analyses were done in the same laboratory in Sweden. Thus, both questionnaire data and environmental data should be comparable from a methodological point of view.

The questionnaire study showed significant differences in the prevalence of asthma and allergy. In Taiyuan, 33.9% of the pupils had at least one airway symptom while the cumulative incidence of asthma (1.8%), doctor's diagnosed asthma (1.2%) and asthma medication (0.5%) was very low. Self-reported asthma and doctor's diagnosed asthma are commonly used in epidemiological studies and has a high specificity, but lower sensitivity. However, the asthma prevalence found in this cohort study is similar to the one found in a large prospective national survey performed in year 2000 among 287,329 pupils (aged 0–14 years) across 27 cities in China. The overall prevalence of asthma in that study was 0.92% among 63,619 pupils aged 12–15 years (boys 1.12% and girls 0.71%) (Chen, 2004). Previous studies in five Chinese cities using the ISAAC protocol among pupils aged 13–14 years old reported a higher cumulative incidence of asthma (ever asthma) when compared with our study. They found 7.1% in Shanghai, 7.1% in Chongqing, 6.9% in Beijing, 5.4% in Urumqi and 3.9% in Guangzhou in 1994–1995 (Asher et al., 1998). This could be partly explained by the different economic development levels and life styles, since most cities in the ISAAC study in China were from the most developed areas.

For the Swedish pupils in our study, the cumulative incidence of asthma was 9.5% and 9.0% had doctor's diagnosed asthma. This asthma prevalence data is comparable with previous data from Uppsala (Smedje et al., 1997). Sweden has a low level of outdoor air pollution, with an annual mean of 2 $\mu\text{g}/\text{m}^3$ SO₂ (Kunzli et al., 2004), 22.3 $\mu\text{g}/\text{m}^3$ NO₂ (Hazenkamp-Von Arx et al., 2004) and 20 $\mu\text{g}/\text{m}^3$ PM₁₀ (Kunzli et al., 2004) in Uppsala. In Taiyuan city, the mean levels of SO₂ and NO₂ in winter can be 700 $\mu\text{g}/\text{m}^3$ and 52 $\mu\text{g}/\text{m}^3$, respectively, and the annual mean levels of PM₁₀ can be 252 $\mu\text{g}/\text{m}^3$ according to measurements from our research group and the local monitoring station (unpublished data). This indicates that despite very high levels of outdoor air pollution in Taiyuan (Mestl and Fang, 2003; Richter et al., 2005), the children still has a low prevalence of self-reported asthma, asthma diagnosis and asthma medication.

When asking about asthma symptoms by using the word 'asthma', differences in asthma prevalence may reflect either differences in diagnostic criteria, different access to medical services, or lack of awareness of asthma in the society. When asking about symptoms without using the word 'asthma', a different pattern was obtained. There were no differences in wheezing, but a great difference in daytime attacks of breathless-

ness. Chinese pupils had much higher prevalence of daytime attacks of breathlessness after exercise. Usually, breathlessness in combination with wheeze is considered to be a sign of asthma in children, e.g. in the ISAAC study, and the ISAAC study does not ask about breathlessness without wheeze. In our study, the attacks of breathlessness could possibly be due to the heavy outdoor air pollution (winter SO_2 around $700 \mu\text{g}/\text{m}^3$). A high prevalence of daytime attacks of breathlessness after exercise (20.9%) has also been reported from a Shanghai school study (Mi et al., 2006). Associations between daytime breathlessness and environmental factors in the school have been reported from China (Mi et al., 2006; Norbäck et al., 2002) and Sweden (Kim et al., 2005). Since we did not perform any clinical investigation, the reason for the high prevalence of breathlessness in Chinese children remains unclear, but it could be a sign of bronchial hyper-responsiveness (BHR). There is a lack of population based studies on BHR in China. We found one population study from Hong Kong, showing that 18–30% that of the children had BHR when the SO_2 -levels were $100\text{--}120 \mu\text{g}/\text{m}^3$, and BHR decreased substantially when SO_2 -levels were reduced to $20\text{--}30 \mu\text{g}/\text{m}^3$ after an environmental intervention (Wong et al., 1998).

In western countries, pet allergy is common (Chipps, 2004). In our Chinese data, only 1.2% reported cat allergy and 1.3% reported dog allergy. In Sweden, cat and dog allergy were five and three times more common, respectively. This study did not include allergy testing, but previous validation studies from Europe have demonstrated fairly good agreement in children. However, the prevalence of self-reported pollen or pet allergy tended to be higher than the prevalence by positive skin prick tests (Hattevig et al., 1987; Braun-Fahrlander et al., 1997; Dotterud, et al., 1995). This indicates that questionnaire data may overestimate the prevalence in Scandinavia, if allergy testing is used as the golden standard. To our knowledge, there are no corresponding validation studies from China. Recent studies on pet allergy in China showed that cat allergy is common, but we found no previous publications on dog allergy in China. One recent study performed among children aged 13–14 years from Beijing demonstrated that 10.8% of urban children in Beijing and 3.7% of suburban children outside of Beijing had cat allergy, demonstrated by a positive skin prick test (Zhao et al., 2003). Another study among Chinese children (aged 9–11 years) found 5.6% cat allergy in Beijing, 4.3% in Guangzhou and 3.7% in Hong Kong, by skin prick test (Chen et al., 2003). Since our questionnaire study from Taiyuan found much lower prevalence of cat allergy (1.2%), there may be an underestimation of the true prevalence in Taiyuan, but it is unlikely that recall bias should explain the large difference in pet allergy between China and Sweden.

The school environment is an important place for the young generation. Recent review articles have shown that the school environment can affect both health (Daisey et al., 2003), learning ability and performance (Mendell and Heath, 2005). Compared with the Swedish schools, the classrooms in Taiyuan were colder, more humid and had poor ventilation as indicated by the higher CO_2 levels. In total, 22 of 24 Chinese classrooms (92%) had mean CO_2 levels above the recommended ventilation standard of 1000 ppm for indoor air (ASHRAE, 1999). Consequently, the calculated average personal outdoor air supply rate was low (3.6 l/s) and only 13% of the classrooms fulfilled the standard of 8 l/s (ASHRAE, 1999). Since there was no mechanical ventilation in any school, the only way to ventilate the classrooms is by opening the windows. In north China, windows are usually kept closed in winter-time. Moreover, there were on average twice as many pupils in the Chinese classrooms in a similar size classroom as in the Swedish ones. Sweden has also a cold climate in winter, but the population density is less in the classrooms and almost all classrooms had mechanical ventilation systems, which can reduce the CO_2 levels and other air pollutants (Smedje and Norbäck, 2000). None of the classrooms studied in China or Sweden had any visible signs of molds or damp spots. The reason could be the low indoor air humidity in both countries, which do prevent water condensation. This is in contrast to school studies from Taiwan and Finland, where indoor mold growth was common (Immonen et al., 2001; Su et al., 2001; Taskinen et al., 1999).

We found large differences in allergen levels in settled dust between China and Sweden. Settled dust from Taiyuan had only trace amounts of cat and dog allergen and no horse allergen. This is in agreement with a previous study from Shanghai (Mi et al., 2002). Most of our Swedish classrooms contained high levels of both cat, dog and horse allergen, which is consistent with previous school studies (Tranter, 2005). A correlation between the number of pet owners and allergen level in the classroom has been demonstrated (Almqvist et al., 1999). We did not have information on pet keeping in our Chinese study and there are a few publications on pet keeping in China. In an epidemiological study among 15-year-old pupils in Wuhan, China, 19.9% kept cats and 21.3% kept dogs at home (Salo et al., 2004). Another study from Guangdong province reported that pet keeping was common among asthmatic adults of which 43.1% had cats at home and 61.7% had cat or dog (Tang et al., 2000). Pet keeping is becoming more and more popular in China (Zhang et al., 2003), especially in the larger cities, despite the governmental policy to charge a high annual fee for dog keeping (Sylvan et al., 2001).

Allergen measurements in settled dust are commonly used as a proxy-variable for indoor allergen exposure

in schools (Tranter, 2005). However, measurements of airborne allergens should be a better predictor for personal exposure, particularly for allergens with small particle size like cat and dog allergen (Custovic et al., 1997, 1998; O'Meara and Tovey, 2000). Surprisingly, we found high allergen levels in the air in Chinese classrooms, as measured by the Petri-dish method (Karlsson et al., 2002). Unfortunately, we did not use the Petri-dish method in the Swedish schools, but other studies have demonstrated that cat, dog and horse allergens can be detected in Swedish classrooms by this method (Karlsson et al., 2002; Norbäck et al., 2006). If we compare our geometric mean levels of cat allergen in Taiyuan schools ($16 \text{ ng/m}^2/\text{day}$) with previous data from Stockholm, Sweden (Karlsson et al., 2002), they are comparable. They report GM values of $14.7 \text{ ng/m}^2/\text{day}$ in schools with $\leq 10\%$ cat owners, and $58 \text{ ng/m}^2/\text{day}$ for classrooms with $>20\%$ cat owners. The highest levels in Chinese schools were comparable with the level in the Swedish schools with frequent pet ownership ($>20\%$). This illustrates that exposure to cat and dog allergen in Chinese schools should not be neglected, and that allergen analysis in settled dust may not be the most suitable proxy-variable for personal allergen exposure in some indoor environments. We can only speculate on the discrepancy between airborne and settled dust measurements. We have found no data in the literature on matrix effects of the ELISA method for cat and dog allergen. The dust seemed to have different composition. The dust from China was completely black and most probably contained a large proportion of coal or coal-combustion particles. The Swedish school dust was light gray and contained more textile and paper particles. If the Chinese settled dust contains a large proportion of fine particles originating from outdoor air pollution, it might be more easily re-dispersed into the air. This means that low allergen

levels in settled dust, even below the detection limit, may generate significant airborne concentrations. The effects of the dust composition on the allergen analysis results, as well as on the airborne allergen exposure, need to be further investigated.

Pet allergens are easily transported to the school environment, and therefore allergen measurements can reflect the general pet allergen exposure in the society. Moreover, among children without pets at home, the school may be the main site of exposure. During a 4-year follow-up period it was shown that children in schools with a higher concentration of cat allergen also had a higher risk for asthma diagnosis (Smedje and Norbäck, 2001). Moreover, cross-sectional studies have shown association between asthmatic symptoms and cat allergen (Smedje et al., 1997), dog and horse allergen (Kim et al., 2005) in settled dust in schools. Finally, pet allergen exposure at school can cause acute asthma attacks in sensitized children (Almqvist et al., 2001; Lonnkvist et al., 1999).

In conclusion, we could demonstrate large differences in asthma, respiratory symptoms and self-reported allergy between pupils from Taiyuan and Uppsala. Chinese pupils had more respiratory symptoms, particularly daytime attacks of breathless after exercise, but less reports on pollen and pet allergy, and much less asthma diagnosis and asthma medication. The great discrepancy between respiratory symptoms and reports on asthma, including the high prevalence of attacks of breathlessness without wheeze, may have implication for future questionnaire studies on asthma, especially in areas with high levels of outdoor air pollution. Chinese schools seem to contain significant amounts of cat and dog allergen when sampling airborne dust, and analysis of allergens in settled dust may largely underestimate the allergen exposure.

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