

Respiratory symptoms, asthma and allergen levels in schools – comparison between Korea and Sweden

Abstract We studied reports on respiratory symptoms, asthma and atopic sensitisation in relation to allergen contamination in Korean schools and compared with data from a previous Swedish study performed in eight primary schools. Korean pupils ($n = 2365$) in 12 primary schools first completed a questionnaire. Then airborne and settled dust were collected from 34 classrooms and analyzed for allergens by ELISA. In both countries, boys reported more symptoms. The prevalence of wheeze was similar, while daytime [odds ratio (OR) = 14.0, 95% confidence interval (CI) = 9.0–21.9] and nocturnal breathlessness (OR = 3.1, 95% CI = 1.5–6.4) were much higher among Korean students. In Korean schools, dog allergen (Can f 1) was the most common followed by mite allergen (Der f 1), while cat (Fel d 1), dog, and horse allergen (Equ cx) were abundant in Sweden. Moreover, CO₂ levels were high in most Korean schools (range 907–4113 ppm). There was an association between allergen levels in dust and air samples, and number of pet-keepers in the classrooms. In conclusion, allergen contamination in Korean schools may be an important public issue.

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Practical Implications

This study showed that furry pet allergen contamination was common in both Korean and Swedish schools. In addition, house dust-mite (Der f 1) allergen contamination was common in Korean schools, probably because of transport of allergen from other environments. Transfer should therefore be minimized. Korean schools had high CO₂ levels and the concept of mechanical ventilation should be introduced. Measurement of airborne allergen levels is quite new and seems to be a more convenient and correct way to monitor allergen exposure in classrooms.

Introduction

There has been a considerable increase in the prevalence of asthma and allergy among children in recent years. Research has therefore paid special attention to the school environment as a second source, besides the home environment, for exposure to allergens (Tranter, 2005). Previous studies have demonstrated contamination with cat and dog allergens in the classrooms, which could cause symptoms of asthma and allergy (Almqvist et al., 2001; Kim et al., 2005; Munir et al., 1993; Perzanowski et al., 1999). Some studies also reported presence of allergens from house dust-mites *Dermatophagoides pteronyssinus* and *D. farinae* (Der p 1/Der f 1), cockroach (*Blattella germanica*, Bla g 1), and mouse (Mus m 1) (Amr et al., 2003; Bates and Mahaffy, 1996; Tortolero et al., 2002) in schools. Despite the increase of prevalence of allergic disease

in Korea (Hong et al., 2004), there are only a few studies published on allergen levels in the Korean indoor environment. One study from various parts of Korea showed that *D. farinae* was found in 20.6% and *D. pteronyssinus* in 6.5% of homes, while other house dust-mite species were rare (Ree et al., 1997). Another study in Busan and Seoul showed that *B. germanica* was the dominant cockroach species found in residences (Lee et al., 2003). Lately, allergen levels of Der f 1 and Bla g 1 have been studied in Korean homes, both in bedroom dust and air (Park et al., 2002), and levels of Der f 1 have been compared in buckwheat pillows and synthetic pillows (Nam et al., 2004). Sensitization to house dust-mite, but not to German cockroach, seemed to play a considerable role in reduced pulmonary function among asthmatic children (Choi et al., 2005). According to our knowledge, there are no epidemiological or descriptive studies available on

indoor environment in Korean schools. On the whole, there are only a few studies published on comparison of allergen levels in schools in different parts of the world.

The first aim was to measure allergen concentrations in settled dust and in air samples in selected primary schools in Namyangju and Chuncheon city, Korea and compare them with a similar school study from Uppsala, Sweden. The second aim was to compare reported symptoms of asthma and allergy among pupils in these schools by use of a questionnaire. Furthermore, correlations between pet-keeping at home and allergen levels in the Korean classrooms were investigated.

Materials and methods

Study design

When these studies were performed, both Korea and Sweden had a 6-year primary school system and the children start at the age of 7. In year 2004, the school administrators in 12 primary schools in urban parts of Guri, in urban and rural parts of both Namyangju and Chuncheon city in Korea were contacted and agreed to participate. All pupils in fourth grade (9–11 years) were included in the study. For comparison, data from a previous school study performed in Uppsala, Sweden was used (Kim et al., 2005). In that study, all pupils in eight primary schools (1–6th form) in Knivsta municipality, a suburb of Uppsala, were included. For comparison with the Korean study, only pupils aged 9–11 years were included from the Swedish study.

Questionnaire data

The questionnaire contained one set of questions asking about asthma, which included the doctor's diagnosed asthma, current asthma medication, or asthma attacks during the last 12 months. Current asthma was defined as either having 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). Another set of questions asked about airway symptoms related to asthma during the last 12 months, without using the phrase 'asthma.' These symptoms included: (1) wheezing or whistling in the chest, (2) at least one daytime attack of shortness of breath during exercise or while resting, and (3) at least one night-time awakening with attacks of breathlessness or tightness in the chest (Norbäck et al., 1999). Finally there were questions about history of atopy, including allergy to pollen and furry pets. This questionnaire has been used in several school investigations (Kim et al., 2005; Smedje and Norbäck, 2001a).

Hygienic measurements

Pupils of this age spend most of their time in a home-classroom in both Korea and Sweden. Samples were collected during November–December in both countries. All classes were included for the questionnaire study in both countries, but we arbitrarily selected three home-classrooms from each school (Korea, $n = 34$; Sweden, $n = 23$) to represent different parts of the buildings. The only exception was one school in Sweden and two schools in Korea, which only had two classrooms and both were included.

The school buildings were inspected and details on constructions, materials, type of ventilation system, cleaning routines, amount of open shelves and textiles, and number of pupils were noted. The room volume (m^3), shelf factor (m/m^3), textile factor (m^2/m^3), and population density were calculated in each classroom. The shelf factor is defined as the length of open shelves divided by the room volume and textile factor as the surface area of fabrics divided by the room volume (Skov et al., 1990). Population density was calculated by dividing number of pupils with classroom volume. Temperature, relative air humidity, and concentration of carbon dioxide (CO_2) were measured in each classroom during normal activities with closed windows and doors and compared with outdoors. These factors were measured over time (45–60 min) with Q-Trak™ IAQ Monitor (TSI Incorporated, St Paul, MN, USA), by logging average values over 1 min. The instruments were regularly calibrated by Comfort Control, the Swedish service laboratory for TSI equipment. The average concentration for each school was calculated and used in the statistical models.

Allergen measurements

Settled dust was collected from desks, chairs, and floors with a vacuum cleaner (effect 400 W) provided with a special dust collector and an ALK-filter (ALK Abello, Copenhagen, Denmark). Each classroom was divided into two halves and one sample was collected from the corridor-side and one from the window-side. Vacuum cleaning was performed for 4 min per sample equally divided between floor and desks/chairs (Smedje et al., 1997). The filters were sealed with a lid and stored in plastic bags at $-20^\circ C$ until extraction. The same sampling procedure and instruments were used in both countries.

In Korea, airborne samples were collected during 6–9 days by placing two Petri dishes in each classroom (1–1.5 m height) with base and lid facing upward on horizontal surfaces on the corridor side (Karlsson et al., 2002). Petri dishes were closed and stored at room temperature until extraction. This method was not available in our laboratory when the Swedish study was performed.

Analysis of allergen levels

The total amount of dust in each sample was weighed and 100 mg was extracted in 2 ml of phosphate-buffered saline containing 0.05% Tween 20 (PBS-T) for 2 h at room temperature with rotation. Samples were centrifuged at 4500 rpm (3500g) for 10 min followed by another at 10 000 rpm (7000g) for 10 min. Supernatants were stored at -20°C until analysis.

The base and lid of the Petri dish were extracted with 3 ml PBS-T containing 1% BSA. The buffer was mixed for 1 h at room temperature on the base, and then transferred to the lid, and continued for another hour. Evaporation was minimized by keeping the Petri dishes closed during the rotation. The extract was centrifuged at 10 000 rpm for 10 min. Supernatants were stored at -20°C until analysis.

Allergen levels were determined using two-site sandwich ELISA for cat (Fel d 1), dog (Can f 1), cockroach (Bla g 1), dust-mites (Der f 1 and Der p 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 immunoglobulins was from Dakocytomation (Norden AB, Stockholm, Sweden). Allergen concentrations were expressed as ng/g dust, except for horse allergen which was expressed as Unit/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 on the standard was performed with the micro-BCA method (Pierce, Rockford, IL, USA) using BSA as standard. Samples with intra-assay coefficient of variance $> 10\%$ were re-assayed. The detection limit in the settled dust sample was 200 ng/g dust for cat, dog, and dust-mite allergens, and 200 U/g dust for horse allergen.

Airborne cat allergen samples were analyzed using a commercial signal amplification kit (AmpakTM, Dakocytomation) basically following the manufacturer's recommendations (Karlsson et al., 2002). The standard curve range was 2.5–160 pg Fel d 1/ml. Detection limit for airborne allergens were 0.005 ng/ml for Fel d 1 and 0.39 ng/ml for Can f 1 in solutions. Airborne allergen levels were expressed as ng/m²/day calculated on a total surface of 0.024 m² of the Petri dish. This corresponds to a detection limit of 0.10 ng/m²/day for Fel d 1 and 7.86 ng/m²/day for Can f 1.

Statistical analysis

Difference in prevalence was analyzed by chi-square test. Difference in indoor climate condition and aller-

gen levels between Korea and Sweden were analyzed by Mann–Whitney test. Correlation between pet keeping at home and allergen levels in classrooms were performed by Kendall's Tau-beta rank correlation test. Allergen levels below the detection limit were assigned a value of half the detection limit for statistical calculations. Associations between the allergen levels and asthma and atopic sensitization were evaluated by multiple logistic regression analysis, adjusting for age and gender. All statistical calculations were performed with Statistical Package for Social Sciences (SPSS) for Windows, version 12.0.1, using two-tailed tests and a 5% level of significance.

Results

Questionnaire survey

In Korea, 2453 pupils in 65 classes received a questionnaire, of which 2365 (96%) completed it. There were 51% boys and the mean age was 9.9 years (s.d. = 1.51, range 9–11 years). In Sweden, the response rate was 68% (448 pupils) with a mean age of 10.0 years (s.d. = 0.79, range 9–11 years), of which 49% were boys. Korean pupils reported more daytime breathlessness, nocturnal breathlessness, and at least one airway symptom than Swedish pupils. However, Swedish pupils reported more atopic sensitization than Korean pupils. Boys in Korea reported more asthma and atopic sensitization and girls reported more dog allergy (Table 1). The gender difference in relation to reported symptoms among Swedish pupils was similar to that in Korea (Kim et al., 2005).

School environment

In Korea, the mean age of the school buildings was 11 years (range 2–34 years). None of the schools had a mechanical ventilation system. All schools were made of concrete with openable windows and had daily cleaning of floors and desks 1–6 times/week performed by the pupils who go to school 6 days/week. Floors were made of wood, unpainted concrete, or polyvinyl chloride (PVC) and only one had laminated floor.

In Sweden, the mean age of the buildings was 46 years (range 1–103 years). Mechanical ventilation, with supply and exhaust air systems and without air humidification were found in seven schools (88%), while only one had natural ventilation. Most of the classrooms had daily floor cleaning and the desks were wiped 1–5 times/week by cleaning-staff. Floors were made of linoleum or PVC.

The mean temperature in the classroom was 21°C in both countries. Indoor relative humidity, concentration of CO₂ and population density were higher in Korea than Sweden. However, open shelves and textiles were more common in the Swedish classrooms.

Table 1 Reported current airway symptoms, asthma and atopic sensitization among pupils (9–11 years) in Korea and Sweden

	Both populations			In Korea		
	Korea (%) (n = 2365)	Sweden (%) (n = 448)	OR (95% CI)	Boys (%) (n = 1204)	Girls (%) (n = 1150)	OR (95% CI)
Questions on current airway symptoms						
Wheeze or whistling in the chest	8.0	7.0	1.17 (0.79–1.73)	8.5	7.5	1.15 (0.85–1.55)
Daytime attacks of breathlessness	41.2	4.8	14.01 (8.97–21.88)***	42.6	39.7	1.13 (0.96–1.33)
Nocturnal attacks of breathlessness	5.4	1.8	3.11 (1.51–6.41)**	6.4	4.5	1.43 (0.99–2.06)
At least one airway symptom ^a	43.9	9.1	7.84 (5.61–10.95)***	45.3	42.5	1.12 (0.95–1.32)
Questions on asthma						
Ever had asthma	11.8	8.1	1.52 (1.06–2.19)*	13.1	10.5	1.29 (1.00–1.67)*
Ever had doctor's diagnosed asthma	5.4	7.6	0.69 (0.47–1.03)	6.5	4.3	1.55 (1.07–2.24)*
Current asthma medication	4.0	4.7	0.83 (0.51–1.36)	4.5	3.4	1.34 (0.88–2.05)
Current asthma attacks	3.1	3.6	0.86 (0.49–1.51)	4.0	2.0	2.05 (1.24–3.39)**
Current asthma ^b	5.7	5.2	1.10 (0.69–1.75)	6.9	4.5	1.60 (1.12–2.29)**
Questions on atopic sensitization						
Cat allergy	2.6	7.0	0.35 (0.23–0.55)***	2.7	2.5	1.06 (0.63–1.76)
Dog allergy	4.9	5.8	0.83 (0.53–1.28)	4.5	5.3	0.84 (0.58–1.22)
Pollen allergy	4.0	9.4	0.40 (0.27–0.58)***	4.2	3.8	1.09 (0.72–1.65)
Pollen or furry pet allergy	8.8	12.3	0.69 (0.50–0.94)*	8.7	9.0	0.97 (0.73–1.29)

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

^aWheeze or whistling in the chest, daytime attacks of breathlessness or nocturnal attacks of breathlessness during the last 12 months.

^bCurrent asthma medication or asthma attacks during the last 12 months.

Mean outdoor temperature and relative humidity was 8.3°C and 56% in Korea and 5.0°C and 82% in Sweden. The mean outdoor CO₂ was 463 ppm in Korea and 368 ppm in Sweden (Table 2).

Reports on pet-keepings at home

In Korea, 19.9% of pupils had at least one pet at home, whereas in Sweden it was 58.8%. Figure 1 shows that the most common pet in Korea was dog (14.0%), whereas in Sweden it was cat (25.9%). Only 0.8% reported cat-keeping in Korea. In addition, only one pupil (0.04%) had contact with a horse from home in Korea and two (0.45%) in Sweden. In Figure 1, fowls include chicken, duck, and bird.

Allergen levels in dust samples

In Korea, the highest level was to dog allergen. Cat allergen was found in only 3 of 68 dust samples (4%),

dog allergen was found in most samples (88%), and only one (1%) of the samples contained horse allergen. House dust-mite, Der f 1 was detected in 42 samples (62%), while Der p 1 was found in only one sample (1%). All Swedish classrooms had cat allergen and most had dog and horse allergens above 1000 ng/g dust. None of the Swedish samples contained Der f 1 or Der p 1. Cockroach allergen (Bla g 1) was not detected in the samples from either country. To reflect better the total allergen amount in a classroom, the allergen concentrations were multiplied with total dust weight/filter. However, similar differences were seen for allergen amounts between Korea and Sweden (Table 3).

Airborne allergen levels measured only in Korean classrooms

There were totally 33 airborne allergen samples as one went missing. Fel d 1 was detected in 91% and Can f 1 in 61% of all air samples. The Geometric Mean values

Table 2 Indoor factors in classrooms in Korea and in Sweden

	Korea			Sweden			P-value
	n	M (s.d.)	Min–Max	n	M (s.d.)	Min–Max	
Room temperature (°C)	34	21.7 (2.41)	17.9–28.1	23	21.4 (0.6)	20.2–22.5	0.987
Relative air humidity (%)	34	41.1 (8.1)	27.6–62.0	23	31 (8)	20–46	<0.001
Carbon dioxide (ppm)	34	2417 (839.3)	907–4113	23	761 (196)	400–1170	<0.001
Shelf factor ^a	34	0.052 (0.032)	0.006–0.135	23	0.104 (0.063)	0–0.218	0.001
Textile factor ^b	34	0.021 (0.029)	0–0.113	23	0.074 (0.083)	0.012–0.362	<0.001
Population density ^c	34	0.212 (0.014)	0.140–0.267	23	0.112 (0.046)	0.022–0.207	<0.001

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

^aShelves/room volume.

^bTextiles/room volume.

^cNumber of students/room volume.

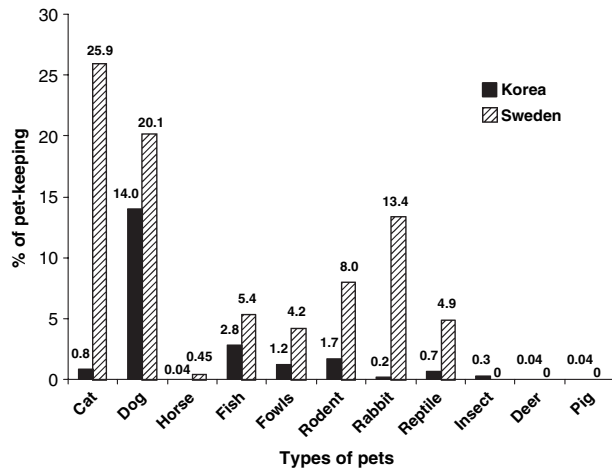


Fig. 1 Reports of pet-keeping from questionnaire in Korea and Sweden

for Fel d 1 was 0.88 ng/m²/day (range 0.08–10.31) and for Can f 1 was 20.91 ng/m²/day (range 5.90–197.0). Median (IQR) was 0.70 ng/m²/day (0.44–2.13) for Fel d 1 and 19.35 (7.86–38.71) ng/m²/day for Can f 1, respectively. Detailed airborne allergen levels in Korean schools are presented in Table 4.

Correlation between pet-keeping and allergen concentration in classrooms

There was a significant correlation between air allergen level of cat/dog in classrooms and number of pupils having cat/dog at home. For the detailed analysis, we divided the classrooms into two groups as follows: 24 classrooms had no cat owner and 10 classrooms had one or two cat owners. Those classrooms with one or two cat owners had higher allergen levels than those

Table 4 Indoor allergen levels in settled dust and air in Korean schools

School	Cat		Dog	
	Dust ^a	Air ^b	Dust ^a	Air ^b
1	<200	0.85	1010	28.5
2	<200	3.21	1680	77.2
3	200	6.68	900	116.7
4	<200	2.50	370	7.9
5	<200	1.33	1620	41.4
6	350	3.29	1540	46.0
7	<200	0.77	1010	25.6
8	<200	0.37	730	14.3
9	<200	1.79	300	12.6
10	<200	0.48	1040	61.2
11	<200	1.75	520	14.3
12	<200	0.50	<200	7.9

^aConcentration expressed as ng/g dust.

^bConcentration expressed as ng/m²/day.

without cat (Mann–Whitney test, $P = 0.005$). However, we could not analyze for the significant difference between one cat owner and two cat owners as there was only one classroom which had two pupils with cat at home. For dog keeping, the classrooms were classified into two groups. Eighteen classrooms had 1–5 pupils having dog and 16 classrooms had 6–11 pupils having dog. There were significantly higher levels of dog allergen in the air in classrooms with more dog owners (Mann–Whitney test, $P = 0.028$) (Figure 2). We also found a correlation between the number of dog owners in the classes and the dog allergen levels in dust samples (Tau-beta = 0.27; $P = 0.030$) (data not shown). Furthermore, Figure 3 shows that there was a correlation between levels of Can f 1 in air and dust samples (Tau-beta = 0.50; $P < 0.001$). Fel d 1 levels in air and dust samples were also statistically correlated (Tau-beta = 0.31; $P = 0.032$).

Table 3 Allergen levels from settled dust samples in 34 classrooms in Korea and in 23 classrooms in Sweden

	Korea			Sweden			P-value
	<i>n</i> ^a	Median (IQR)	Min–Max	<i>n</i> ^a	Median (IQR)	Min–Max	
Total dust (g/sample)	68	0.853 (0.61–1.23)	0.227–2.802	46	0.794 (0.57–1.16)	0.235–2.652	0.544
Allergen concentration							
Fel d 1 (ng/g dust)	68	<200	<200–1360	46	1300 (890–2250)	290–4700	<0.001
Can f 1 (ng/g dust)	68	670 (380–1120)	<200–4685	46	1650 (800–2250)	<200–6200	<0.001
Equ cx (U/g dust)	68	<200	<200–620	46	1250 (720–2700)	<200–31,000	<0.001
Der p 1 (ng/g dust)	68	<200	<200–290	46	<200	<200	0.41
Der f 1 (ng/g dust)	68	250 (<200–400)	<200–850	46	<200	<200	<0.001
Bla g 1 (ng/g dust)	68	<200	<200	46	<200	<200	n.s.
Allergen amount							
Fel d 1 (ng/filter)	68	92 (<80–132)	<80–510	46	982 (660–1825)	197–8009	<0.001
Can f 1 (ng/filter)	68	580 (303–902)	89–2805	46	986 (638–1846)	85–6002	<0.001
Equ cx (U/filter)	68	<80	<80–651	46	930 (457–2380)	<80–3008	<0.001
Der p 1 (ng/filter)	68	<80	<80–280	46	<80	<80–265	0.46
Der f 1 (ng/filter)	68	170 (106–368)	<80–1708	46	<80	<80–265	<0.001
Bla g 1 (ng/filter)	68	<80	<80–280	46	<80	<80–265	n.s.

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

^aTwo samples/classroom.

Discussion

This study demonstrates that there were different types of ventilation and different patterns of allergens in Korean and Swedish schools. There were some different patterns of symptoms among pupils. Moreover, there was also a correlation between air allergen levels in classrooms and number of pupils keeping pets at home. To our knowledge, this is the first study on school environment in Korea.

The schools in both countries were arbitrarily selected irrespective of symptom prevalence or type of school environment and the same symptom questionnaire was used. The response rate was high in both countries. In Korea, it was 96% and in Sweden 68%. We have no information about non-responders, but the proportion of girls was around 50% in both countries indicating no gender selection. Mean age was similar that is 9.9 years in Korea and 10.0 years in Sweden. Assuming that non-symptomatic subjects were less prone to participate, the lower participating rate in Sweden could slightly increase the prevalence of symptoms in Sweden when compared with Korea. However, the prevalence of any respiratory symptom was lower in Sweden. The environmental measurements were performed during the same season (winter) using the same equipment and laboratory for both countries. The previous ISAAC study has demonstrated that school children of this age can answer a symptom questionnaire about asthma and respiratory symptoms in a reliable way. In Hong Kong, the ISAAC written and video questionnaire (AVQ 3.0) have been compared and they were both similarly good to predict respiratory symptoms and bronchial hyper-reactivity (Lai et al., 1997). A similar validation study was published from Europe (Braun-Fahrlander et al., 1997). Thus, both data from questionnaire and environment inspection should be comparable from a methodological point of view.

Boys reported more asthma and atopic sensitization than girls in both countries, which is in agreement with earlier studies (Forsberg et al., 1997; Kim et al., 2005;

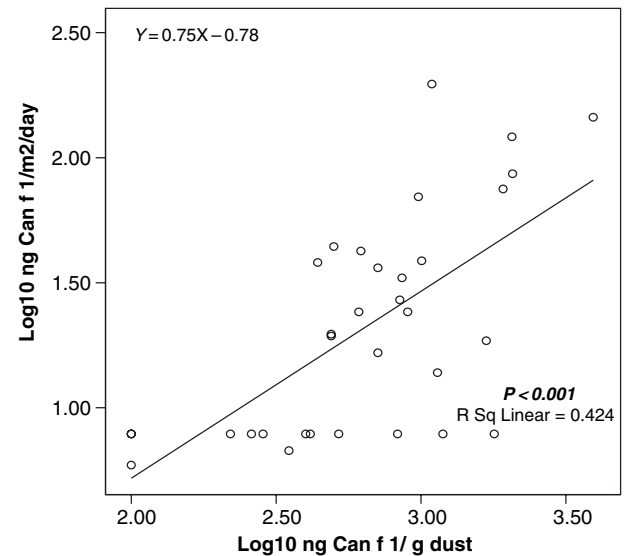


Fig. 3 Association between Can f 1 allergen levels in dust and air samples

Morgan and Martinez, 1992; Rönmark et al., 1998). Asthma and respiratory symptoms, particularly daytime breathlessness, were more common among Korean pupils than Swedish, while reports on cat and pollen allergy were less common. Breathlessness is commonly regarded as a combination with wheeze in ISAAC questionnaire but no questions on only breathlessness without wheeze. High prevalence of daytime breathlessness has been reported in some previous studies (Mi et al., 2006; Zhao et al., 2006) and one of them has suggested relation with school environment (Mi et al., 2006). As we did not perform clinical testing, we cannot clearly explain the finding but it could be a symptom of bronchial hyper-responsiveness (BHR). There is a lack of a population-based study on BHR in Korea.

We found that 11.8% reported ever had asthma, which is higher than in previous Korean studies. Previous studies in school children reported 4.2% of asthma in 1995, 5.3% of asthma in 2000, and 9.1% in 2000 in a larger Korean study (Ahn et al., 2005; Hong

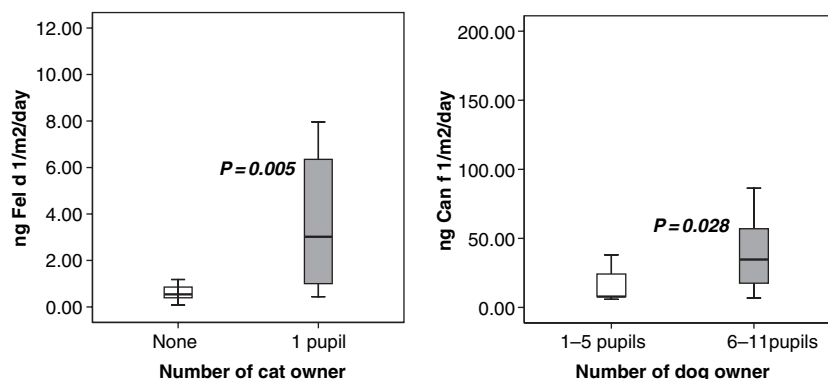


Fig. 2 Association between number of pupils with pet-keeping and airborne allergen levels at school

et al., 2004; Kim et al., 1997). We found that the prevalence of wheeze (8.0%) was similar to other Korean studies: 8.2% in 1997, 9.3% in 2000, and 5.7 in the larger study from 2000 (Ahn et al., 2005; Hong et al., 2004; Kim et al., 1997).

We found that 2.6%, 4.9% and 4.0% of children reported cat, dog, and pollen allergy, respectively. The prevalence of pollen allergy was similar to another Korean study reporting 3.4% allergy to grass pollen mixture, 2.2% to tree pollen mixture, 4.4% to mugwort pollen, and 2.8% to ragweed pollen, which was verified by skin prick test (Kim et al., 1997). The same study reported 20.4% cat allergy, which is much higher than in our study. Therefore, there could be some under-reporting of cat allergy, in our study. We found no available population data about dog allergy in Korea. One study in children with respiratory allergy showed that 89.1% and 24.0% had cat and dog allergy, respectively (Kim et al., 2002) indicating that dog allergy can be a health risk in Korea.

Current pet keeping, particularly cats and other small furry animals, was more common in Sweden. We could not find any previous data of pet-keeping in Korea and possible selection effects when sensitized children who got rid of their pet should be further investigated. The prevalence of pet-keeping among the Swedish pupils was similar to a previous study from middle Sweden, where 34% had a cat and 25% had a dog (Smedje and Norbäck, 2001a). We could not find any data on furry pet allergen levels in Korean dwellings or schools. The house dust-mite *D. farinae* is the most common and *D. pteronyssinus* is less in Korean homes (Nam et al., 2004; Park et al., 2002; Ree et al., 1997). We found almost exclusively Der f 1 allergen in the school dust and 62% of the classrooms had detectable but rather low levels. Moreover, we found associations between levels of house dust-mite and reported wheeze and atopic sensitization. As house dust-mite allergy is the most common allergy in Korean children (30.9% allergy to Der p 1 and 27.5% to Der f 1) (Kim et al., 1997), sensitized children may react to even low levels at school.

Cat, dog, and horse allergen levels were generally lower in Korean than Swedish schools (Kim et al., 2005). This is logical as pet keeping is less common and there are few textile materials and fittings which may serve as a reservoir of deposited allergens (Smedje and Norbäck, 2001b). Cat allergen in settled dust was found in only two schools, totally three classrooms. Moreover, there was only one pupil who had contact with a horse at home and horse allergen was detected only in that pupil's classroom. The main source of allergens in classrooms is track in of allergens by, e.g. clothes and hair from pupils' homes (Patchett et al., 1997; Perzanowski et al., 1999; Smedje and Norbäck, 2001a).

Despite the low furry pet allergen levels in settled dust, we could detect cat and dog allergens in the air in most Korean classrooms. Interestingly, we found a correlation between cat/dog allergen levels in the air in the classroom and the number of pupils keeping cat/dog at home. Thus, airborne allergen sampling may be a more relevant measurement of allergen exposure in schools. A correlation was found between allergen levels in air and in dust samples for both cat and dog allergen. Our study indicates that airborne allergen measurement by the Petri dish method is relevant, easy to use and convenient for epidemiological studies and can detect low levels of allergen. An association between the proportion of cat keepers ($\leq 10\%$ vs. $\geq 20\%$) and Fel d 1 levels in air measured by the Petri dish method has previously been reported in a study in Swedish schools (Karlsson et al., 2002).

In conclusion, our results indicate that the pattern of asthma and allergic diseases and allergen exposure in the schools differ between the two countries. Dog allergen was the dominating allergen in Korean schools, while Swedish schools had high levels of cat, dog, and horse allergen. Since cat, dog and house dust mite allergen contamination was common in Korean schools it may contribute to allergic sensitisation among Korean pupils. Measurement of airborne allergen levels seems to be of importance to more correctly monitor pet allergen exposure in classrooms.

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