INTRODUCTION

Skin prick testing (SPT) is the standard method to assess IgE-mediated sensitization to inhalant allergens (1). It is a rapid, reproducible and accurate way of identifying the causative allergen of an IgE-mediated allergy (1). Allergic sensitization is a well-known important risk factor for asthma in adults and children (2). Early identification of those specific environmental allergens in children may assist in medical and environmental interventions in disease management (3). Sensitization to more than one indoor allergen is also common in atopic children and puts young adults at high risk of bronchial hyperresponsiveness (4).

Although previous studies have reported the sensitization rates of in Korea (5-12), those studies generally have been conducted on patients who have visited hospitals with suspected allergic symptoms. The studies of allergic sensitization in a general population sample of children have been performed in localized areas such as Seoul, Jeongeup, and Jeju (6, 7, 13). Although the...
The nonparticipating schools were substituted with “replacement schools” to meet the predetermined sample size. For the second stage of sampling, three classes were selected randomly within each sample school and all children in the sample classes were asked to take part in this survey. Parents were asked to complete questionnaires describing basic demographic information, including age, sex, region, urbanization, and monthly income of the family. We defined metropolitan areas as Seoul and 6 metropolitan cities, urban areas as cities, and rural areas as non-city areas (“gun”). Average monthly income level was classified into four categories: ≤ 1,990,000; 2,000,000-3,990,000; 4,000,000-5,990,000; and ≥ 6,000,000 Korean won.

Extracts and reagents
The following 18 inhalant allergens were selected for the standard SPT panel: Der p, Der f, Tyrophagus putrescentiae (Tyr p), cockroach, cat, dog, alder, birch, oak, Japanese cedar (Lofarma, Milan, Italy), orchard grass, bermuda grass, timothy, mugwort, ragweed, Japanese hop, Alternaria, and Aspergillus fumigatus. Histamine was used as a positive control and normal saline as a negative control. Unless otherwise stated, the allergens were provided by Allergopharma, Reinbek, Germany.

Skin prick tests
Testing solutions were stored at 2°C to 8°C when not in use. SPT was performed on the volar aspects of the forearms. A testing grid was fixed on the volar forearm surface of the student, and the orientation of the grid marked on the patient’s arm. Numbers and dots were recorded 2 cm apart on volar forearms. A small drop of each testing solution was then placed next to the dot and the allergens applied in the same order for each test. For each allergen, a new 25 gauge needle was used that was then pressed against the skin in the center of the allergen drop without causing bleeding. After one minute, any excess solution was blotted with a tissue to avoid cross-contamination. After 15 min, wheal and flare reactions were determined by marking both reactions and copying the marks on a form via an adhesive tape.

The largest and perpendicular diameter of the wheal for each of the allergens was measured, and the following value was calculated: (largest + perpendicular diameter)/2. A test was regarded positive if the value calculated was ≥ 3 mm and controls showed adequate reactions. Patients were excluded if they had a negative histamine control.

Statistical analysis
SAS version 9.1, a statistical software package that takes into account the complex sample design features, was used for statistical analyses. Because the participants for this survey were selected using a stratified two-stage cluster sampling design, we constructed the sampling weights for this study to take into account differential selection probabilities, non-response and post-stratification. The chi-squared test using the SURVEYFREQ pro-
procedure of SAS version 9.1 was applied to estimating the differences of positive SPT by age and gender and to estimating the tests for trend for the area of residence. A $P < 0.05$ was considered to be significant.

**Ethics statement**
This study was approved by the institutional review board (IRB) at Dankook University in Cheonan (IRB approval number: DKUH IRB 2010-09-0260). Written informed consent was confirmed by the IRB and obtained from all parents prior to participation in this study.

**RESULTS**

**Study population**
A total of 7,829 valid data sets were analyzed. The demographic and geographical characteristics of the study population are demonstrated in Table 1. The study sample included 2,002 (52.1%) boys and 1,838 (47.9%) girls in elementary school and 2,066 (51.8%) boys and 1,923 (48.2%) girls in middle school. Residential areas during the study period were 1,096 (14.0%) rural, 3,465 (44.3%) urban, and 3,268 (41.7%) metropolitan, respectively.

**Sensitization to aeroallergens by demographic characteristics**
Of 7,829 analyzed subjects, 3,753 (47.9%) were sensitized to at least one of the aeroallergens, and the prevalence increased in...

**Table 1. Demographic characteristics of study population**

| Characteristics          | 6 to 7 yr | 12 to 13 yr |
|--------------------------|-----------|-------------|
| Total number of participants | 3,840     | 3,989       |
| Gender (M/F)             | 2,002/1,838 | 2,066/1,923 |
| Urbanization              |           |             |
| Urban                    | 1,600 (41.7) | 1,668 (41.8) |
| Suburban                 | 1,598 (41.6) | 1,867 (46.8) |
| Rural                    | 642 (16.7)   | 454 (11.4)   |
| Monthly income (Korean won) |         |             |
| ≤ 1,990,000              | 563 (15.1) | 562 (14.6)  |
| 2,000,000-3,990,000      | 1,879 (50.3) | 1,619 (42.0) |
| 4,000,000-5,990,000      | 929 (24.9)  | 1,110 (28.8) |
| ≥ 6,000,000              | 363 (9.7)   | 564 (14.6)  |
| Residence                |           |             |
| Seoul                    | 650 (16.9)  | 679 (17.0)  |
| Incheon, Gyeonggi-do    | 1,220 (31.8) | 1,242 (31.1) |
| Daejeon, Chungcheongnam-do, Chungcheongbuk-do | 411 (10.7) | 427 (10.7) |
| Jeollabuk-do             | 158 (4.1)   | 188 (4.7)   |
| Gwangju, Jeollanam-do   | 260 (6.8)   | 268 (6.8)   |
| Daegu, Gyeongsangbuk-do | 270 (7.0)   | 446 (11.2)  |
| Busan, Ulsan, Gyeongsangnam-do | 708 (18.4) | 598 (15.0)  |
| Gangwon-do              | 109 (2.8)   | 96 (2.4)    |
| Jeju-do                 | 54 (1.4)    | 45 (1.1)    |

Fig. 1. Prevalence of positive skin prick tests to various aeroallergens is shown.
children at 12 to 13 yr of age compared to those at 6 to 7 yr of age. The prevalence was 41.1% in subjects aged 6 to 7 yr, while it was 55.0% in those aged 12 to 13 yr. In addition, middle school students were more sensitized to all Aeroallergens than elementary school students.

Overall, HDM was the most prevalent allergen causing positive SPT (Fig. 1). Sensitization to Der f was found to be the most prevalent in children aged 6 to 7 yr (32.4%), followed by Der p (32.1%), Tyr p (4.5%), Japanese hop (4.4%), and oak (3.9%). In the age group of 12 to 13 yr, Der p yielded the highest prevalence (42.7%), followed by Der f (21.9%), Tyr p (9.1%), Japanese hop (8.0%), and cat (7.7%) (Fig. 1).

Boys were more likely to be sensitized to any allergen as compared to girls in all age groups (Table 2). In particular, significant gender differences were noted in Der p, Der f, Tyr p, cockroach, birch, oak, Japanese cedar, Japanese hop, and Aspergillus in subjects aged 6 to 7 yr and in all Aeroallergens except Japanese cedar in those aged 12 to 13 yr.

In the 6 to 7 yr age group, the sensitization to at least one of the 18 allergens was lower in rural areas compared to the metropolitan or urban areas, although there was no significant difference (P = 0.052) (Table 3). In this age group, sensitization to Der f was significantly lower in rural areas compared to the metropolitan or urban areas, and sensitization to dog was higher in the metropolitan area than others (P = 0.031 and 0.011, respectively). In the 12 to 13 yr age group, sensitization to at least one of the 18 allergens was also the lowest in rural areas (P = 0.019) (Table 3). In this age group, sensitization to Der p, Der f, Tyr p, cat, and dog was highest in metropolitan areas (P = 0.046, 0.026, 0.006, < 0.001, and 0.041, respectively), but sensitization to Aspergillus was highest in rural areas (P = 0.019). There was no difference in sensitization to pollen by the urbanization in both age groups.

The prevalence of sensitization to at least one of the 18 allergens in the 6 to 7 yr age group was not associated with economic status, which was classified by monthly income (P = 0.082) (Table 4). In the 12 to 13 yr age group, however, the higher sensitization rate of at least one of the 18 allergens was associated with the highest income group (P = 0.002) (Table 4). The middle

| Table 2. Difference of sensitization rates to Aeroallergens by age and gender |
|-----------------|-----------------|-----------------|-----------------|
| Allergen        | 6 to 7 yr (n = 3,840) | 12 to 13 yr (n = 3,989) | P value |
| boys (%) girls (%) | boys (%) girls (%) |                      |
| Any**           | 45.1 36.6 < 0.001 | 59.7 49.9 < 0.001 |          |
| Der f           | 35.5 28.4 < 0.001 | 46.0 39.2 < 0.001 |          |
| Der p           | 35.6 29.0 < 0.001 | 45.5 38.0 < 0.001 |          |
| Tyr p           | 5.3 3.6 0.016 | 10.3 7.7 0.007 |          |
| Cockroach       | 2.4 1.2 0.006 | 7.5 3.8 < 0.001 |          |
| Cat             | 2.5 1.9 0.286 | 9.4 5.9 < 0.001 |          |
| Dog             | 3.2 2.3 0.114 | 6.5 3.7 < 0.001 |          |
| Elder           | 3.1 2.5 0.293 | 7.9 5.5 0.009 |          |
| Birch           | 4.6 2.3 < 0.001 | 7.3 4.3 < 0.001 |          |
| Oak             | 4.8 2.9 0.004 | 9.5 5.4 < 0.001 |          |
| Japanese cedar  | 0.3 0.1 0.032 | 0.7 0.4 0.236 |          |
| Orchard grass   | 1.4 1.2 0.630 | 4.7 2.1 < 0.001 |          |
| Bermuda grass   | 1.3 1.2 0.742 | 3.1 1.5 0.003 |          |
| Timothy         | 1.2 1.0 0.565 | 3.7 1.2 < 0.001 |          |
| Mugwort         | 3.1 1.9 0.053 | 7.9 3.9 < 0.001 |          |
| Ragweed         | 1.4 0.7 0.055 | 3.7 1.9 0.002 |          |
| Japanese hop    | 5.2 3.6 0.027 | 10.1 5.8 < 0.001 |          |
| Alternaria      | 4.1 3.2 0.213 | 9.5 5.4 < 0.001 |          |
| A. fumigatus    | 0.6 0.2 0.049 | 2.0 1.2 0.038 |          |

*At least one of the 18 allergens.

| Table 3. Difference of sensitization rates to Aeroallergens by urbanization |
|-----------------|-----------------|-----------------|-----------------|
| Allergen        | 6 to 7 yr | 12 to 13 yr | P value |
| Metropolitan (%) Urban (%) Rural (%) | Metropolitan (%) Urban (%) Rural (%) |          |
| Any**           | 41.6 42.4 36.3 | 57.2 54.3 49.8 | 0.019 |
| Der f           | 33.1 32.8 28.0 | 45.0 41.5 39.2 | 0.046 |
| Der p           | 33.4 33.4 27.4 | 44.2 40.9 37.4 | 0.026 |
| Tyr p           | 4.0 5.1 4.3 | 10.9 7.6 8.4 | 0.006 |
| Cockroach       | 1.7 2.1 1.4 | 6.7 5.2 4.4 | 0.090 |
| Cat             | 2.7 2.1 1.2 | 9.9 6.1 6.7 | < 0.001 |
| Dog             | 3.8 2.1 2.1 | 6.7 6.8 6.5 | 0.989 |
| Elder           | 3.4 2.6 1.9 | 6.7 6.8 6.5 |          |
| Birch           | 3.4 4.1 2.2 | 6.5 5.6 4.6 | 0.317 |
| Oak             | 3.9 4.2 3.2 | 7.8 7.6 6.3 | 0.614 |
| Japanese cedar  | 0.2 0.3 0.1 | 0.4 0.6 0.11 | 0.123 |
| Orchard grass   | 1.2 1.6 1.1 | 2.9 3.6 4.5 | 0.249 |
| Bermuda grass   | 1.1 1.6 0.8 | 5.3 6.3 7.2 | 0.306 |
| Timothy         | 0.9 1.3 1.0 | 2.4 2.2 4.1 | 0.100 |
| Mugwort         | 2.3 2.6 2.8 | 5.3 6.3 7.2 | 0.306 |
| Ragweed         | 0.7 1.3 1.2 | 2.4 3.0 3.4 | 0.505 |
| Japanese hop    | 4.2 4.5 4.7 | 7.5 8.9 6.1 | 0.131 |
| Alternaria      | 3.3 3.9 4.0 | 6.6 8.5 7.1 | 0.119 |
| A. fumigatus    | 0.5 0.5 0.3 | 1.8 1.1 3.0 | 0.019 |

*At least one of the 18 allergens.
class with a monthly income of 4,000,000-5,990,000 Korean won showed the second-highest sensitization rate in this age group. The prevalence of sensitization to Der p and Der f classified by monthly income was significantly high in the middle class group that had a monthly income of 4,000,000-5,990,000 Korean won in elementary school (P = 0.042 and 0.037, respectively) and middle school children (P = 0.001 and < 0.001, respectively). The group with a monthly income of 4,000,000-5,990,000 Korean won showed the highest prevalence of oak sensitization in elementary school children (P = 0.039) and dog sensitization in middle school children (P = 0.041). However, a higher prevalence of cockroach sensitization was associated with the lowest income group in elementary and middle schoolchildren (P = 0.045 and 0.008, respectively).

**Sensitization to aeroallergens by geographical locations**

In elementary schoolchildren, sensitization to Tyr p was the most prominent in Gangwon-do (18.4%, P < 0.001), with dog sensitization (6.2%, P = 0.009). The highest rate of sensitization to cockroach was also seen in Jeju-do (7.7%, P < 0.001). Sensitization to Alder was the highest in Busan/Ulsan/Gyeongsangnam-do (4.5%, P = 0.049). Daegu/Gyeongsangbuk-do also showed the highest sensitization rate for oak and ragweed (7.6% and 2.9%, P = 0.017 and 0.043, respectively), and Daejeon/Chungcheongnam-do/Chungcheongbuk-do for Japanese hop (7.3%, P = 0.003). In addition, *Alternaria* sensitization was the most prevalent in Jeollabuk-do (7.8%, P = 0.015) (Fig. 2).

In middle schoolchildren, Tyr p was the most prominent in Jeju-do (14.9%, P = 0.014), with cockroach sensitization (18.5%, P = 0.002). The highest rate of sensitization to cat was also seen in Seoul (11.4%, P < 0.001). Oak showed the highest SPT positivity in Daegu/Gyeongsangbuk-do (11.0%, P = 0.003), with Japanese hop and *Alternaria* (12.3% and 10.4%, P < 0.001 and < 0.001, respectively). Sensitizations to bermuda grass and mugwort were the highest in Daejeon/Chungcheongnam-do/Chungcheongbuk-do (3.9% and 8.5%, P = 0.013 and 0.002, respectively). In addition, Incheon/Gyeonggi-do showed the highest sensitization rate for ragweed (4.6%, P < 0.001).

**DISCUSSION**

This is the first nationwide, population-based study that evaluated sensitization to aeroallergens in Korean schoolchildren. These results are in accordance with worldwide reports that allergic sensitization has become a common condition. In our study, the prevalence of aeroallergen sensitization in elementary schoolchildren was 41.1%, while the prevalence in middle schoolchildren was 55.0%. The prevalence shows a similar level to results in other countries from 39% to 58%, although the dominating allergen is different in various geographic areas (16-18). In addition, our rates are similar to those found in other studies of sensitization in general schoolchildren in some restricted areas of Korea (6, 7). However, it is difficult to compare with the other Korean studies (5, 9, 12, 19), because most subjects in earlier studies were composed of referred patients for evaluation of possible atopic illnesses, not the general public. Furthermore, the results of the present study demonstrated that epidemiologically relevant allergens were different in each geographic area. The reason for this difference remains to be explained, but it has been suggested that the influence of environmental dif-

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**Table 4. Difference of sensitization rates to aeroallergens by monthly income**

| Allergen   | Low* (%)* | Middle† (%)* | High‡ (%)* | Very high§ (%)* | P value | Low* (%)* | Middle† (%)* | High‡ (%)* | Very high§ (%)* | P value |
|------------|-----------|---------------|------------|----------------|---------|-----------|---------------|------------|----------------|---------|
| Any        | 37.3      | 41.0          | 44.4       | 38.6           | 0.082   | 53.8      | 51.8          | 59.0       | 59.6           | 0.002   |
| Der p      | 27.9      | 32.5          | 35.3       | 29.2           | 0.042   | 42.9      | 38.0          | 48.3       | 46.3           | < 0.001 |
| Der f      | 30.0      | 32.2          | 36.1       | 27.9           | 0.037   | 41.8      | 38.3          | 46.6       | 44.4           | < 0.001 |
| Tyr p      | 4.3       | 4.4           | 4.4        | 5.0            | 0.965   | 9.5       | 8.0           | 10.6       | 9.2            | 0.174   |
| Cockroach  | 3.4       | 1.6           | 1.6        | 1.4            | 0.045   | 9.3       | 5.2           | 5.0        | 5.5            | 0.008   |
| Cat        | 2.2       | 2.4           | 2.5        | 1.0            | 0.475   | 7.6       | 7.3           | 7.8        | 10.1           | 0.298   |
| Dog        | 3.2       | 2.9           | 2.8        | 2.0            | 0.766   | 6.2       | 4.0           | 6.5        | 5.2            | 0.041   |
| Alder      | 1.9       | 2.8           | 2.8        | 3.4            | 0.592   | 7.5       | 6.5           | 7.3        | 6.5            | 0.852   |
| Birch      | 2.0       | 3.2           | 4.9        | 3.7            | 0.074   | 6.4       | 5.4           | 6.4        | 6.3            | 0.752   |
| Oak        | 2.7       | 3.4           | 5.4        | 4.7            | 0.039   | 7.4       | 7.9           | 7.7        | 7.3            | 0.975   |
| Japanese cedar | 0.1       | 0.2           | 0.4        | 0.1            | 0.181   | 0.8       | 0.6           | 0.6        | 0.3            | 0.805   |
| Orchard grass     | 0.6       | 1.3           | 1.3        | 2.2            | 0.267   | 4.0       | 3.3           | 3.8        | 2.9            | 0.713   |
| Bermuda grass     | 0.8       | 1.4           | 1.1        | 1.8            | 0.584   | 2.8       | 2.3           | 2.7        | 1.7            | 0.637   |
| Timothy      | 0.6       | 1.1           | 0.9        | 1.9            | 0.298   | 2.7       | 2.4           | 2.8        | 2.4            | 0.894   |
| Mugwort      | 1.7       | 2.9           | 1.9        | 3.3            | 0.216   | 5.8       | 5.6           | 7.4        | 4.2            | 0.112   |
| Ragweed      | 0.9       | 1.1           | 0.6        | 1.8            | 0.387   | 2.5       | 2.6           | 3.1        | 2.9            | 0.809   |
| Japanese hop | 2.5       | 4.5           | 4.9        | 5.7            | 0.134   | 5.6       | 8.0           | 9.6        | 7.7            | 0.093   |
| Alternaria   | 2.4       | 3.6           | 4.4        | 3.9            | 0.401   | 7.7       | 7.5           | 7.8        | 7.1            | 0.976   |
| A. fumigatus | 0.7       | 0.2           | 0.7        | 0.6            | 0.213   | 2.0       | 1.6           | 1.7        | 1.3            | 0.854   |

*≤ 1,990,000 Korean won; †2,000,000-3,990,000 Korean won; ‡4,000,000-5,990,000 Korean won; §≥ 6,000,000 Korean won; ‖At least one of the 18 allergens.
ferences such as pollen distribution, temperature, and humidity plays an important role.

*Der p* and *Der f* were the most prevalent allergens in all age groups, and were evenly distributed throughout each region. Those results are consistent with other data reported in Korea (6, 12, 19). Some studies in China and Turkey have reported that HDM was the most common allergen (18, 20), while those in Estonia and Europe have pointed to grasses and cockroach as dominating allergens (1, 14, 21).

Tyr *p*, which is known to be a storage mite, was the dominating sensitizer in Gangwon and Jeju-do. Storage mites that were usually found in rural areas or warehouses, have prevailed in previous studies that mainly involved farmers, but those studies were reported to have clinical significance for allergies in city dwellers (5, 22, 23). There is also the possibility of cross-reactivity between *Dermatophagoides* and *Tyrophagus* (24). Sensitization rates to dogs or cats were lower than those in other countries (1, 25), indicating that levels of pet exposure were low in Korea. It is inferred that environmental control could have an impact on allergic sensitization, because positive correlations were reported between the community prevalence of cat and the prevalence of sensitization to cats (26). Sensitization to each pollen revealed obvious differences according to local areas in this study. In particular, Japanese cedar sensitization was the most prevalent in Jeju-do, as in other reports (6, 11, 13). It has been well known that Jeju-do has plenty of Japanese cedar on mandarin orange farms to protect against the wind (6).

Oh et al. (9) reported that sensitization rates for outdoor airborne pollens have increased in Korean children with suspected allergic diseases. They also presented an increase in pollen count including ragweed in a nationwide pollen counting survey (9). Although characteristics of those subjects are different

![Fig. 2. Sensitization rates to aeroallergens by geographical location are demonstrated.](http://jkms.org)
from ours, it would be interesting to note whether this trend might be observed in the general population. It might be helpful for identification of the trend in pollen sensitization to study the population using the same allergen panel and analyze the association between sensitization rate and pollen count over the next few years.

It was noteworthy that, in our study, boys had higher rates of aeroallergen sensitization than girls, supporting the earlier studies that reported in which males have more atopy compared to females (3, 6), although the reason for that is not entirely understood. In addition, children in metropolitan or urban areas showed higher prevalence of sensitization to aeroallergens than in rural areas. This finding corresponds with the results of a recent study, which reported that the sensitization rate was higher in Seoul than in Jeongeup (7). This might be either because urban environmental irritants promote the development of allergic sensitization or because rural environmental factors have the protective role, which is compatible with hygiene hypothesis (27). An increased sensitization rate was also observed in the highest income group. The reason for this difference does not exclude the possibility that people living in metropolitan or urban areas have higher incomes than those in rural areas (28). The higher prevalence of cockroach sensitization was associated with the lowest income group. There is a controversy as to whether cockroach sensitization is associated with economic state (29, 30). However, it is presumed that hygiene practices in homes or local community might affect the cockroach sensitization.

In conclusion, the prevalence of sensitization to aeroallergen in a population study of Korea is 41.1% in 6-7 yr olds and 55.0% in 12-13 yr olds. Sensitization rates were different according to urbanization, monthly income state, and geographic locations. The most common allergens are HDM, but relevant allergens are different according to regional location. These data would be compared with the lowest income group. There is a controversy as to whether cockroach sensitization is associated with economic state (29, 30). However, it is presumed that hygiene practices in homes or local community might affect the cockroach sensitization.

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AUTHOR SUMMARY

Sensitization to Aeroallergens in Korean Children: A Population-based Study in 2010

Jihyun Kim, Myung-Il Hahm, So-Yeon Lee, Woo Kyung Kim, Yoomi Chae, Yong Mean Park, Man Yong Han, Kee-Jae Lee, Ho-Jang Kwon, Jin-A Jung, Su Young Kim and Kangmo Ahn

This study shows that house dust mite is the most prevalent allergen in the pediatric population in Korea, and the higher sensitization rate is shown in metropolitan areas and the higher income group.