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Sensitization rates of airborne pollen and mold in children

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Purpose: Aeroallergens are important causative factors of allergic diseases. Previous studies on aeroallergen sensitization rates investigated patients groups that had visited pediatric allergy clinics. In contrast, we investigated sensitization rates in a general population group of elementary school to teenage students in Incheon, Jeju, and Ulsan.

Methods: After obtaining parental consent, skin-prick tests were performed on 5,094 students between March and June 2010. Elementary school students were tested for 18 common aeroallergens, whereas middle and high school students were tested for 25 allergens. The 25 allergens included *Dermatophagoides pteronyssinus, Dermatophagoides farinae*, pollen (birch, alder, oak, Japanese cedar, pine, willow, elm, maple, Bermuda grass, timothy grass, rye grass, orchard grass, meadow grass, vernal grass, mugwort, Japanese hop, fat hen, ragweed, and plantain), and mold (*Penicillatum, Aspergillus, Cladosporium, and Alternaria*).

Results: The sensitization rates in descending order were 25.79% (*D. pteronyssinus*), 18.66% (*D. farinae*), 6.20% (mugwort), and 4.07% (willow) in Incheon; 33.35% (*D. pteronyssinus*), 24.78% (*D. farinae*), 15.36% (Japanese cedar), and 7.33% (*Alternaria*) in Jeju; and 32.79% (*D. pteronyssinus*), 30.27% (*D. farinae*), 10.13% (alder), and 8.68% (birch) in Ulsan. The dust mite allergen showed the highest sensitization rate among the 3 regions. The sensitization rate of tree pollen was the highest in Ulsan, whereas that of Alternaria was the highest in Jeju. The ragweed sensitization rates were 0.99% in Incheon, 1.07% in Jeju, and 0.81% in Ulsan.

Conclusion: The differences in sensitization rates were because of different regional environmental conditions and distinct surrounding biological species. Hence, subsequent nationwide studies are required.

Key words: Allergens, Sensitization, Child

Introduction

The prevalence of allergic diseases such as asthma, allergic rhinitis, and atopic dermatitis have increased rapidly worldwide during the past 30 years[1,2]. In Korea, this increase is because of improvements in

environmental hygiene, environmental pollution augmentation, and the westernized form of residential environments[3-5]. To systemically manage the increasing prevalence of allergic diseases, data regarding precipitating factors is required.

In Korea, skin tests revealed that the highest positive rate was for house dust mite antigen in patients with respiratory and allergic diseases, with rates ranging from 69 to 93%[6-10]. As such, house dust mite antigens play a major role in allergic diseases, yet studies on pollen antigens have been insufficient[11,12]. However, since pollens such as ragweed allergen and mold are recently emerging as the cause of allergic diseases in children, the number of patients suffering from seasonal allergic rhinitis and allergic conjunctivitis is increasing[13-16]. Increased pollen has been shown in domestic environments, and studies have revealed a significant association between pollen concentration and the occurrence of allergic diseases in children[17]. Air pollen is closely related to weather, especially temperature, and recent reports have indicated that changes of pollen and allergenicity are related to global warming[18].

Therefore, further data on air pollen and mold is required. Previous domestic reports on the sensitization rates to pollen and mold have mostly investigated patients who had visited allergy centers, and studies based on the general population are rare. In this study, we investigated the sensitization rates of aeroallergens in a general population group of children and adolescents living in the cities of Incheon, Jeju, and Ulsan.

Materials and methods

1. Subjects

The subjects of this study were 5,094 school age children and adolescents living in Incheon, Jeju, and Ulsan. Schools were randomly selected and included 19 schools in Incheon Metropolitan City (8 elementary schools, 5 middle schools, and 6 high schools), 13 schools in Jeju Special Self-Governing Province (6 elementary schools, 3 middle schools, and 4 high schools), and 8 schools in Ulsan Metropolitan City (4 elementary schools, 2 middle schools, and 2 high schools). Skin prick tests (SPTs) were performed using aeroallergens after obtaining parental consent between March and June in 2010.

2. Allergens used in SPTs

Elementary school students were tested for 21 common aeroallergens, whereas middle and high school students were tested for 28 allergens (Table 1). The 25 allergens included the positive control (1% histamine), negative control (normal saline), *Dermatophagoides pteronyssinus*, *Dermatophagoides farinae*, pollen (*Cryptomeria* [Japanese cedar], *Pinus* [pine], Salix [willow], Acer [maple], *Betula* [birch], *Quercus* [oak], *Alnus* [alder], *Ulmus* [elm], *Ambrosia* [ragweed], *Artemisia* [mugwort], *Humulus* [Japanese hop], *Chenopodiaceae* [fat hen], *Plantago* [plantain], *Cynodon* [Bermuda grass], *Phleum* [timothy grass], *Lolium* [rye grass], *Dactylis* [orchard grass], *Poa* [meadow grass], *Anthoxanthum* [vernal grass]), and mold (*Penicillatum*, *Aspergillus*, *Cladosporium*, and *Alternaria*). The 18 allergens used on elementary school students were the same as the above with the exception of *Ulmus*, *Chenopodiaceae*, *Plantago*, *Lolium*, *Dactylis*, *Poa*, and *Anthoxanthum*.

The positive and negative controls and all allergens except *Chenopodiaceae* were manufactured by Allerpha International (Seoul, Korea).

Table 1. Skin Prick Test Allergen

	Elementary school	Middle & high school
Control		
Saline	O	O
Histamine	O	O
Dust mite		
Dermatophagoides pteronyssinus	O	O
Dermatophagoides farinae	O	O
Pollen-tree		
Cryptomeria (Japanese cedar)	O	O
Pinus (pine)	O	O
Salix (willow)	O	O
Acer (maple)	O	O
Betula (birch)	O	O
Quercus (oak)	O	O
Alnus (alder)	O	O
Ulmus (elm)	-	O
Pollen-herb (weed)		
Ambrosia (ragweed)	O	O
Artemisia (mugwort)	O	O
Humulus (Japanese hop)	O	O
Chenopodiaceae (fat hen)	-	O
Plantago (plantain)	-	O
Pollen-poaceae (grass)		
Cynodon (bermuda grass)	O	O
Phleum (timothy grass)	O	O
Lolium (rye grass)	-	O
Dactylis (orchard grass)	-	O
Poa (meadow grass)	-	O
Anthoxanthum (vernal grass)	-	O
Mold		
Alternaria	O	O
Cladosporium	O	O
Aspergillus	O	O
Penicillatum	O	O

The reagents for *Chenopodiaceae* were manufactured by Shin Kwang New Drugs Company (Seoul, Korea).

In this report, the pollen name is indicated by the scientific name according to the internationally accepted notation of the International Code of Botanical Nomenclature, and the English name is written in parentheses to facilitate comprehension of the scientific name. Generic names that were difficult to classify morphologically are written as family names.

3. SPTs

SPT was performed as follows. We sterilized forearms of students with an alcohol swab and introduced the reagent at constant 2.5 cm intervals. The cutting edge of the lancet was held flush with the skin, and pricks were administered with consistent intensity and depth. After 15 minutes, results were read according to wheal and flare size. A wheal more than 3 mm in diameter and larger, produced by positive control (1% histamine) was considered a positive result. For middle and high school students, SPTs were carried out with 14 types of allergens on each arm. For elementary school students, 10 allergens were pricked on 1 arm and the remaining allergens on the other arm. To exclude errors related to the time of day of the examination, all examinations were performed in the morning by trained inspectors.

4. Statistical analysis

All statistical analyses were performed using SAS ver. 9.1.3 (SAS Institute Inc., Cary, NC, USA). The chi-sqare test was used for comparison of discontinuous variables. A P value of <0.05 (Bofferoni corrected P=0.0167) was considered statistically significant.

Results

1. Demographic characteristics

A total of 5,094 students (2,478 females and 2,616 males) were tested for SPT reactivity. The population included 2,320 students in Incheon (1,116 females and 1,204 males), 1,549 students in Jeju (785 females and 764 males), and 1,225 students in Ulsan (577 females and 648 males) by region and 2,290 elementary school students (3rd to 5th grade, 9 to 11 years old), 1,344 middle school students (1st to 2nd grade, 13 to 14 years old), and 1,460 high school students (1st grade, 16 years old) by age (Table 2).

2. Comparison of sensitization rate between the 3 regions SPT results in elementary school students

The sensitization rate of *Cryptomeria* was highest in Jeju (11.18%) compared to the other regions (P=0.0003). Differences in the sensitization rates of *Cryptomeria* were observed between Incheon and Jeju and between Ulsan and Jeju, but no difference was observed between Incheon and Ulsan (P=0.8016). *Pinus* antigen was positive in 2.53% participants in Ulsan, which was significantly higher than that in the other regions. The sensitization rates of *Betula*, *Quercus*, and *Alnus* allergens were significantly higher in Ulsan, whereas the sensitization rate of *Ambrosia* allergen was not markedly different between the 3 areas. Sensitization rate of *Alternaria* allergen was significantly higher in Jeju compared to the other areas. *D. pteronyssinus* positivity was 20.82% in Incheon, which was lower than that in other regions, while *D. farinae* positivity was 26.79% in Ulsan, which was significantly higher than that in other areas (Table 3).

3. SPT results in middle school students

The sensitization rate of *Cryptomeria* was significantly higher in Jeju (16.76%) than in Incheon (P<0.0001) and Ulsan (P<0.0001), and was higher in middle school students than in elementary students (11.18%) in Jeju. Sensitization rate of Salix allergen was not statistically different between areas in elementary school students but was 6.28% in middle school students in Incheon, which was significantly higher than that in middle school students from other regions. *Betula* and *Quercus* allergens were lower in Jeju than in the other regions. *Phleum* showed a low positivity in Ulsan (0.50%). The sensitization rate of *Lolium* was different among the 3 regions: 1.93% in Incheon, 4.60% in Jeju, and 0.00% in Ulsan. The sensitization rate of *Alternaria* was significantly different only between Jeju and Ulsan (P=0.0335). The sensitization rates of both allergens of *D. pteronyssinus* and *D. farinae* were lower in Incheon compared to the other 2 regions (Table 4).

4. SPT results in high school students

The sensitization rate of *Cryptomeria* was significantly higher in Jeju (21.59%) than in Incheon and Ulsan. The sensitization rate of *Pinus* was significantly different in Ulsan (5.10%) compared with the other 2 areas. The sensitization rates of *Betula* and *Quercus* were

Table 2. Participating Students by Region (Incheon, Jeju, and Ulsan)

Region	Elementary school	Middle school	High school	Total
Incheon (n=2,320)				
Male	523	288	393	1,204
Female	494	325	297	1,116
Jeju (n=1,549)				
Male	310	266	188	764
Female	307	277	201	785
Ulsan (n=1,225)				
Male	316	92	240	648
Female	340	96	141	577
Total (n=5,094)	2,290	1,344	1,460	5,490

Table 3. Sensitization Rates in Elementary School Students

Allergen	Sensitization rate (%)			*P* value		
	Incheon	Jeju	Ulsan	Incheon/Jeju	Incheon/Ulsan	Ulsan/Jeju
House dust mite						
Dermatophagoides pteronyssinus	20.82	28.69	28.57	0.0003	0.0003	0.9634
Dermatophagoides farinae	17.30	22.04	26.79	0.0180	<0.0001	0.0480
Pollen-tree						
Cryptomeria (Japanese cedar)	1.17	11.18	1.04	<0.0001	0.8016	<0.0001
Pinus (pine)	0.39	0.97	2.53	0.1429	<0.0001	0.0349
Salix (willow)	2.25	1.13	2.23	0.1030	0.9825	0.1285
Acer (maple)	1.08	1.30	2.23	0.6849	0.0580	0.2050
Betula (birch)	0.88	1.46	8.04	0.2757	<0.0001	<0.0001
Quercus (oak)	0.98	1.30	5.65	0.5480	<0.0001	<0.0001
Alnus (alder)	1.17	0.49	8.04	0.1570	<0.0001	<0.0001
Pollen-herb (weed)						
Ambrosia (ragweed)	1.08	0.65	1.19	0.3789	0.8256	0.3113
Artemisia (mugwort)	4.40	2.11	2.53	0.0149	0.0449	0.6150
Humulus (Japanese hop)	2.54	2.76	2.08	0.7930	0.5432	0.4315
Pollen-poaceae (grass)						
Cynodon (bermuda grass)	0.68	1.78	1.49	0.0386	0.1042	0.6763
Phleum (timothy grass)	0.68	2.11	2.23	0.0110	0.0059	0.8776
Mold						
Alternaria	1.47	6.65	2.08	<0.0001	0.3379	<0.0001
Cladosporium	0.39	0.32	0.60	0.8280	0.5484	0.4750
Aspergillus	0.78	0.65	0.74	0.7582	0.9302	0.8366
Penicillatum	0.59	0.49	0.30	0.7900	0.3960	0.5863

11.48% and 7.14%, respectively, in Ulsan, which were higher than those in the other 2 regions. The positivity of *Lolium*, *Dactylis*, *Poa*, and *Anthoxanthum* was highest in Jeju. The sensitization of *Alternaria* allergen was highest in Jeju and similar in both elementary and middle school students. A statistical difference was observed in *D. pteronyssinus* allergen sensitization between Incheon and Jeju, and *D. farinae* allergen in all 3 regions. The sensitization rate of *Dermatophagoides* spp., which was the highest among all allergens, was similar among elementary and middle school students and was highest in high school students (Table 5).

5. Comparison of sensitization rates according to region

The overall sensitization rates of allergen according to 3 areas were shown on Figs. 1, 2. The sensitization rate of *Cryptomeria* was significantly higher in Jeju (15.36%) than in the other 2 regions, whereas the *Pinus* allergen sensitization rate was significantly higher in Ulsan. Sensitization rates of *Betula* and *Quercus* allergen were both highest in Ulsan. The sensitization rates of *Artemisia* and *Humulus* allergens were highest in Incheon. The sensitization rates of *Phleum*, *Lolium*, *Dactylis*, *Poa*, *Anthoxanthum*, and *Alternaria* were highest in Jeju. The sensitization rate of *D. pteronyssinus* allergen, which was the highest in all 3 regions, was highest in Jeju and lowest in Incheon, similar to that of the *D. farinae* allergen. Excluding *D.* spp., the 2 highest allergen sensitization rates by region were for *Artemisia* (6.20%) and Salix (4.07%) in Incheon, *Cryptomeria* (15.36%) and *Alternaria* (7.33%) in Jeju, and *Alnus* (10.13%) and *Betula* (8.68%) in Ulsan.

Discussion

Pollen and mold are important allergens, and higher proportions of allergic diseases are now related to pollen and mold[11]. Sensitization rate studies of pollen and mold are insufficient because of the lower allergenicities of pollen and mold compared to the house dust mite. Therefore, we investigated the sensitization rates of pollen and mold in a general population group of school age children. The aeroallergens that showed high sensitization rates differed between regions and sensitization to these aeroallergens tended to increase with age.

Cryptomeria, which was first imported in Jeju for use in forest windbreaks and is mostly cultivated in the Seogwipo region, is an important allergen in Jeju. Excluding *D.* spp., the sensitization rate of *Cryptomeria* was highest in Jeju. According to data published

Table 4. Sensitization Rates in Middle School Students

Allergen	Sensitization rate (%)			*P* value		
	Incheon	Jeju	Ulsan	Incheon/Jeju	Incheon/Ulsan	Ulsan/Jeju
House dust mite						
Dermatophagoides pteronyssinus	27.38	34.62	35.32	0.0075	0.0314	0.8586
Dermatophagoides farinae	18.04	25.78	30.85	0.0014	0.0001	0.1679
Pollen-tree						
Cryptomeria (Japanese cedar)	1.45	16.76	1.49	<0.0001	0.9645	<.0001
Pinus (pine)	1.29	0.74	1.99	0.3527	0.4709	0.1410
Salix (willow)	6.28	1.47	1.00	<0.0001	0.0028	0.6149
Acer (maple)	2.90	1.66	1.49	0.1605	0.2722	0.8740
Betula (birch)	4.19	1.84	6.97	0.0211	0.1116	0.0004
Quercus (oak)	2.74	1.10	3.48	0.0459	0.5855	0.0280
Alnus (alder)	3.86	0.74	9.45	0.0005	0.0020	<0.0001
Ulmus (elm)	0.48	1.47	0.00	0.0815	0.3235	0.0836
Pollen-herb (weed)						
Ambrosia (ragweed)	0.97	1.10	0.00	0.8151	0.1619	0.1346
Artemisia (mugwort)	7.89	2.21	2.49	<0.0001	0.0072	0.8220
Humulus (Japanese hop)	6.12	1.29	1.49	<0.0001	0.0088	0.8306
Chenopodiaceae (fat hen)	0.64	0.37	0.00	0.5121	0.2540	0.3889
Plantago (plantain)	1.45	1.29	0.50	0.8149	0.2847	0.3526
Pollen-poaceae (grass)						
Cynodon (bermuda grass)	0.81	1.29	0.50	0.4148	0.6561	0.3526
Phleum (timothy grass)	2.90	3.87	0.50	0.3595	0.0490	0.0160
Lolium (rye grass)	1.93	4.60	0.00	0.0095	0.0471	0.0020
Dactylis (orchard grass)	1.45	4.42	0.00	0.0023	0.0861	0.0024
Poa (meadow grass)	1.77	4.42	0.00	0.0083	0.0575	0.0024
Anthoxanthum (vernal grass)	1.45	1.84	0.00	0.5982	0.0861	0.0527
Mold						
Alternaria	5.31	6.45	2.49	0.4115	0.0972	0.0335
Cladosporium	0.81	0.00	0.00	0.0361	0.2019	-
Aspergillus	1.77	0.55	0.00	0.0570	0.0575	0.2910
Penicillatum	0.97	0.74	1.00	0.6721	0.9711	0.7264

in 2010, the sensitization rate of *Cryptomeria* was 9.7% in 1998 and 18.2% in 2008 in students in Jeju. Thus, this sensitization has increased within 10 years and has also increased with age[17]. The positivity of *Cryptomeria* in Jeju in our study is similar to that reported in previous studies. In addition, the tendency of the sensitization rates of *Cryptomeria* to increase with increasing age is similar to previous reports. However, a limitation of our study is that we did not show temporal changes in our subjects because this requires a repetitive SPT in the same subjects.

Betula, *Quercus*, and *Alnus* positivity was highest in Ulsan. These pollens belong to the *Betula*ceae family and are high in allergenicity. These temperate plants are mostly distributed in Korea, especially in the southern area[14]. The highest positivity in Ulsan reflects the high exposure rate of this allergen in the area, which is located in southern Korea. Tree pollen was a main allergen with significant importance in patients living in areas of high exposure who showed strong positivity to pollen in the SPT.

In our study, for elementary school students going on to middle school in Incheon and Jeju the sensitivity increased along with the age, but in Ulsan the subjects showed a pattern of decreasing sensitivity on tree pollens excluding *Alnus*. In all three regions, the antigens were tested with device from the same medical corporation, and there were no denaturalization in antigens to note of. Our research is a cross-sectional study, and while it is possible to perceive a generalized trend according to age group, there is a limitation in comparing sensitivity among age groups, which is why we are in need of a longitudinal study in the future.

In Jeju, the sensitization rate of grass pollen other than *Cynodon*

Table 5. Sensitization Rates in High School Students

Allergen	Sensitization rate (%)			*P* value		
	Incheon	Jeju	Ulsan	Incheon/Jeju	Incheon/Ulsan	Ulsan/Jeju
House dust mite						
Dermatophagoides pteronyssinus	32.56	40.62	37.24	0.0079	0.1186	0.3393
Dermatophagoides farinae	21.56	28.79	35.46	0.0077	<0.0001	0.0461
Pollen-tree						
Cryptomeria (Japanese cedar)	1.01	21.59	0.51	<0.0001	0.3811	<0.0001
Pinus (pine)	1.01	1.54	5.10	0.4438	<0.0001	0.0056
Salix (willow)	4.92	0.77	1.28	0.0003	0.0020	0.4840
Acer (maple)	2.75	1.80	2.04	0.3281	0.4722	0.8059
Betula (birch)	2.32	1.54	11.48	0.3879	<0.0001	<0.0001
Quercus (oak)	2.32	0.77	7.14	0.0639	0.0001	<0.0001
Alnus (alder)	3.47	0.00	14.29	0.0002	<0.0001	<0.0001
Ulmus (elm)	0.29	1.03	0.51	0.1168	0.5649	0.4070
Pollen-herb (weed)						
Ambrosia (ragweed)	0.87	1.80	1.02	0.1779	0.8014	0.3556
Artemisia (mugwort)	7.53	2.83	3.32	0.0016	0.0051	0.6924
Humulus (Japanese hop)	3.33	2.57	1.79	0.4873	0.1371	0.4522
Chenopodiaceae (fat hen)	0.58	0.77	0.77	0.7053	0.7129	0.9925
Plantago (plantain)	0.87	1.54	1.28	0.3103	0.5207	0.7516
Pollen-poaceae (grass)						
Cynodon (bermuda grass)	1.30	0.77	1.53	0.4240	0.7575	0.3201
Phleum (timothy grass)	2.46	3.60	1.28	0.2819	0.1841	0.0351
Lolium (rye grass)	1.88	6.17	1.28	0.0002	0.4536	0.0003
Dactylis (orchard grass)	0.87	3.86	1.28	0.0006	0.5207	0.0224
Poa (meadow grass)	0.72	3.60	1.02	0.0006	0.6051	0.0163
Anthoxanthum (vernal grass)	1.01	3.60	0.77	0.0031	0.6821	0.0067
Mold						
Alternaria	3.18	9.51	2.81	<0.0001	0.7282	<0.0001
Cladosporium	0.43	0.26	0.51	0.6456	0.8592	0.5675
Aspergillus	1.01	0.26	0.26	0.1643	0.1616	0.9957
Penicillatum	0.87	1.54	0.26	0.3103	0.2262	0.0563

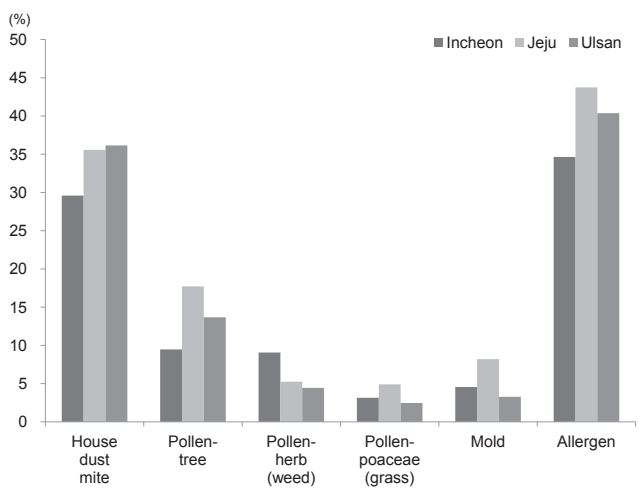

Fig. 1. Sensitization rates of allergen according to region.

was high. The sensitization rate of 4.91% in our study was not significantly different from the sensitization rate of 3.3% reported in previous studies[17]. Grass pollen is scattered from the end of April to November, with strong allergenicity during this period. Because grass is cultivated in areas that people inhabit, the prevalence rate of pollenosis to grass pollen is high[19]. In particular, the positivity of grass pollen is high in Jeju because of the warm and humid climate.

The pollen of *Pinus* is scattered from spring to summer, and although the amount of pollen is high in Korea, the allergenicity is reported to be low[19]. However, the positivity reached levels of up to 3.08% in the students in our study.

Ambrosia, a representative weed that causes pollenosis in autumn, emerged as an important pollen allergen when trade with foreign countries became active in the 1970s[19]. The distribution of ragweed is

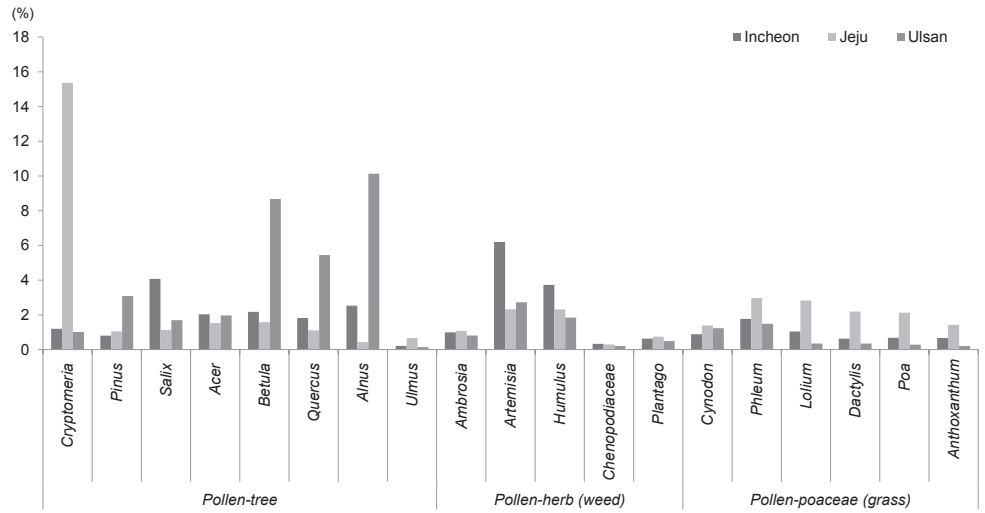

Fig. 2. Sensitization rates of pollen according to region. *Cryptomeria*, Japanese cedar; *Pinus*, pine; *Salix*, willow; *Acer*, maple; *Betula*, birch; *Quercus*, oak; *Alnus*, alder; *Ulmus*, elm; *Ambrosia*, ragweed; *Artemisia*, mugwort; *Humulus*, Japanese hop; *Chenopodiaceae*, fat hen; *Plantago*, plantain; *Cynodon*, bermuda grass; *Phleum*, timothy grass; *Lolium*, rye grass; *Dactylis*, orchard grass; *Poa*, meadow grass; *Anthoxanthum*, vernal grass.

now increasing rapidly all over the country. The positivity of ragweed was 7.1% in a study conducted in 2003 that analyzed patients who had visited allergy clinics in Seoul, Gwangju, Busan, and Daegu[15]. This study showed that the positivity of ragweed has been increasing every year in pediatric patients due to the hazardous environment created by increases in ragweed propagation, traffic growth, apartment buildings, and air pollution. However, the sensitization rate of ragweed was approximately 1% in the general population in the 3 regions, and there was no significant difference between regions in our study. This difference between studies suggests that allergens like ragweed show high positivity in patients with allergic disease and low positivity in the general population.

Although inhaled mold can cause respiratory symptoms in patients who are sensitized to it, diagnosis of mold allergy is difficult because the relationship between this allergy and clinical symptoms is unclear, and cross reactivity may occur with other allergens[20]. In a previous domestic study, the positivity of *Alternaria* and of other molds was 10 % and 2 to 4%, respectively, in children with atopy[20]. In our study, the sensitization rate of *Alternaria* was highest among the 4 species of mold tested. This rate was especially high in Jeju because *Alternaria* grows mainly in regions of high humidity (-2 to 25%).

D. spp., the most important allergen in pediatric allergic diseases, differs in type and density according to region. According to domestic literature, the most common kind of house dust mite in Korea is *D. farinae*[21]. Previous studies indicated that the *D.* spp. sensitization rates reach up to 70% in pediatric patients with allergic diseases, while sensitization rates were around 20 to 30% in the general pediatric population[21,22]. Although *D. farinae* is known to be dominant, our study revealed a lower positivity of *D. farinae* compared to *D. pteronyssinus* by SPTs conducted under the same conditions. To clarify this difference, allergy skin test data from other regions is required.

Our study was conducted between March and June. There was a previous study investigating the sensitization rates of aeroallergens in elementary and middle school students during October and November[23]. The sensitization rate of tree pollen in Ulsan of our study was higher than that of the previous study, and grass pollen showed similar sensitization rates of less than 1 percent difference. Ragweed, a weed pollen which is prevalent in the atmosphere from July to December, also showed similar sensitization rates of less than 1 percent difference. There are limitations of this study that it was conducted during a specific season. However, comparison of sensitization rates with a study conducted during a different season revealed that there were no seasonal differences in sensitization rates of pollen allergens except tree pollen.

Because allergen exposure rates differ depending on regional climate and environment, sensitization rates were characterized according to these differences in our study. Further studies in other cities are required for obtaining nationwide data. In addition, the correlation between allergic diseases and pollen or mold as a causative allergen may be determined by further research on the prevalence rate of allergic diseases in other areas. We anticipate that subsequent studies and nationwide research based on these data will enable the development of preventive measures to promote national health.

In conclusion, the sensitization rates of pollen were 15 to 20%, and the sensitization rates of mold were 3 to 8%. The sensitization rates including *D. pteronyssinus* and *D. farinae* were 34 to 44%.

Difference in exposure rates to allergens with increasing age result

in difference in sensitization rates. These differences in sensitization rates are due to different regional living environmental conditions and distinct surrounding biologic species. It may be useful to manage allergic diseases by continuous investigation related to this study on a national scale and systematical observation of the regional differences and chronological changes of living environments.

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