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# Prevalence of Self-reported Allergic Diseases and IgE Levels: A 2010 KNHANES Analysis

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**Purpose:** The prevalence of allergic diseases is known to be associated with both demographic and environmental factors. Herein, we aimed to determine significant factors associated with the prevalence of allergic diseases and with total immunoglobulin E (tIgE) and specific immunoglobulin E (sIgE) levels in Korea. **Methods:** We analyzed unweighted data collected by the 2010 Korea National Health and Nutrition Examination Survey for 2,342 subjects who underwent serum tests for tIgE and sIgE to *Dermatophagoides farinae*, dog, and *Blattella germanica*, representing a sample of 16,003,645 citizens, by considering the sample weight and stratification. **Results:** The overall prevalence of self-reported allergic diseases was 37.6%. The prevalence rates of allergic rhinitis and atopic dermatitis decreased with age, whereas the asthma prevalence was not affected by the age of the subjects. When analyzed according to the type of allergic diseases, the prevalence of self-reported allergic disease was significantly associated with various factors (*e.g.* age, occupation, living in urban areas, and depression). The tIgE level decreased with age, but later increased. Elevation of tIgE was significantly associated with male sex, type of occupation, obesity, and smoking status. However, the risk factors for the increased sIgE levels to each allergen were quite different. Sensitization to *D. farinae* was more likely in young subjects, whereas the prevalence of sensitization to *B. germanica* was significantly higher in subjects with male sex, residing in a house (houses), and with glucose intolerance. Finally, young age and the smoking status were significantly associated with sensitization to dog. **Conclusions:** Various demographic and environmental factors were significantly associated with the prevalence of self-reported allergic diseases and the levels of tIgE and sIgE to *D. farinae*, *B. germanica*, and dog in Korea.

**Key Words:** Allergy; demographic factors; environment; immunoglobulin E

## INTRODUCTION

The pathogenesis of allergic diseases is multifactorial. Extensive evidence indicates that genetic susceptibility, as well as environmental and demographic factors, affects allergen sensitization and development of allergic diseases.[1-4] Exposure to allergens is crucially important in inducing sensitization and developing allergic diseases, and the environmental concentration of allergens is critical. For example, the prevalence of pollen sensitization and allergic diseases tends to be high for those living in an environment with high atmospheric concentration of pollen.[5,6] Demographic factors, including sex, age, and obesity, are significant contributing factors to the development of allergic diseases.[7-9] In addition, in recent studies, the vitamin D level was suggested as a significant factor associated with the risk of allergic diseases.[10] However, large-scale studies to detect significant factors related to the development of allergies are lacking, especially in Korea.

The Korea National Health and Nutrition Examination Survey (KNHANES) is a large-scale cross-sectional survey, conducted

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by the Korea Centers for Disease Control and Prevention (KCDC), which collects a significant amount of demographic and environmental data. The survey sample represents the entire non-institutionalized general population of South Korea.[11] In 2010, the survey included a questionnaire for allergic diseases and serologic tests for total immunoglobulin E (tIgE) and specific IgE (sIgE) to *Dermatophagoides farinae* (house dust mite), dog, and *Blattella germanica* (German cockroach). Thus, the KNHANES provides useful data to define and confirm significant factors associated with allergen sensitization and the prevalence of allergic diseases.

In this study, we aimed to define significant demographic and environmental factors associated with the tIgE and sIgE levels and the prevalence of allergic diseases using data from the fifth KNHANES, conducted in 2010.

## MATERIALS AND METHODS

### Study design and populations

This study analyzed the data from the fifth KNHANES, a national survey performed in 2010-2012. In the fifth KNHANES, all subjects were tested for tIgE. The survey used complex probability procedures to represent the entire Korean general population, including stratification and multiple stages of cluster selection using age, sex, location of residence, type of residence, education level, and other variables. In the present study, to obtain appropriate estimates, we followed the guidelines for reporting sample weight (sampling weights) and stratification designated by the KCDC; this information is available on the KNHANES website (http://knhanes.cdc.go.kr).

Among all subjects registered in 2010, a total of 2,342 subjects aged ≥10 years responded to the health survey and underwent serum IgE tests between January and December 2010. These subjects represented 16,003,645 citizens of Korea (about one-third of the total population of Korea) as obtained by complex sample analysis. In terms of the variables assessed, glucose tolerance status, body mass index (BMI), smoking history, and depression were assessed for 1,977 subjects aged ≥19 years, representing 13,762,677 citizens. The subjects' education level, marriage status, income level, and occupation were assessed for 1,577 subjects aged ≥30 years, representing 9,624,008 citizens.

All participants provided written informed consent prior to the survey. The KCDC Institutional Review Board approved the fifth KNHANES (#KCDC-2010-02CON-21-C).

### Interview items

Responses to all questionnaire items were obtained by face-to-face interviews. Allergic disease was defined as the presence of at least 1 self-reported allergic disease, including allergic rhinitis, atopic dermatitis, and bronchial asthma. Responses of "negative" for 1 or 2 allergic diseases in addition to missing responses for the remaining disease options were considered missing values. The presence of depression was assessed as previously described.[12-14] Each subject's residential district was classified as urban ("Dong" in Korea) or suburban/rural ("Eup/Myun"). The type of residence was classified as apartment or house. Income level was categorized into 4 quartiles: quartile 1, <$2,600/month; quartile 2, $2,600-$4,300/month; quartile 3, $4,300-$8,600/month; and quartile 4, >$8,600/month. Smoking history was classified as never-smoker, light smoker (<5 pack-years/entire life), or smoker (≥5 pack-years/entire life).

### Measurements

BMI is measured as body weight (to the nearest 0.1 kg) divided by the square of the body weight (nearest 0.1 cm), and expressed in unit of kg/m$^2$. Glucose tolerance was tested as previously described.[15] In brief, blood samples were obtained after ≥8 hours of fasting. Based on the fasting glucose levels, the glucose tolerance status was categorized as normal, impaired fasting glucose, or diabetes mellitus. The serum vitamin D level was categorized into 3 groups: quartile 1, <13.30 ng/mL; quartiles 2-3, 13.30-21.37 ng/mL; and quartile 4, ≥21.37 ng/mL. The 5th KNHANES included data on the tIgE and 3 types of sIgE. According to a previous Korean cohort study,[16] the selection of these 3 types of sIgE (*D. farinae*, *B. germanica*, and dog) does not lead to large discrepancies in revealing the atopy status in Korea. We used the ImmunoCAP® system (Thermo Scientific, Uppsala, Sweden) to measure the levels of tIgE and sIgE to *D. farinae*, *B. germanica*, and dog, following the manufacturer's instructions. Elevation of the tIgE level was defined as a tIgE level >100 kU/L. Positivity to sIgE was defined as an sIgE level >0.35 kU/L.

### Statistical analysis

For data analysis of the survey, which involved a complex sample, we used the KNHANES stratification variables and sampling weight (weights). The missing data were dealt with using complete case analysis. Because the distribution of serum IgE was log-normal, the tIgE levels were logarithmically transformed for statistical analysis. Differences in the geometric mean of tIgE were tested using *t* tests, and differences in the prevalence of allergic diseases were tested using $\chi^2$ tests. Univariate and multivariate logistic regression analyses were performed to identify factors associated with the prevalence of allergic diseases and positivity of sIgE to *D. farinae*, *B. germanica*, and dog. SPSS v. 18.0 (IBM Corp., Armonk, NY, USA) was used for all analyses, and *P* values <0.05 were considered statistically significant.

## RESULTS

### Univariate analysis of factors associated with the prevalence of any allergic disease

The overall prevalence of self-reported allergic diseases was

**Table 1.** Univariate analyses of factors associated with the total and specific immunoglobulin E levels and prevalence of any allergic diseases

| Characteristics | No. of participants | No. of represented population (%) | Allergic disease prevalence (%) | *P* value | tIgE (95% CI) (kU/L) | *P* value |
|---|---|---|---|---|---|---|
| Overall (No.) | 2,342 | 16,003,645 (100.0) | 37.6 | | 94.8 (87.9-102.3) | |
| Gender | | | | 0.858 | | <0.001 |
| Male | 1,159 | 8,925,094 (55.8) | 37.8 | | 130.5 (117.8-144.5) | |
| Female | 1,183 | 7,078,551 (44.2) | 37.3 | | 63.4 (58.0-69.3) | |
| Age (year) | | | | <0.001 | | 0.008 |
| 10-19 | 395 | 2,552,815 (16.0) | Not available‡ | | 104.1 (88.1-122.9) | |
| 20-29 | 370 | 3,826,822 (23.9) | 42.8 | | 90.3 (75.7-107.6) | |
| 30-39 | 393 | 2,776,446 (17.3) | 41.1 | | 84.9 (73.0-98.8) | |
| 40-49 | 393 | 3,011,436 (18.8) | 25.9 | | 81.2 (69.3-95.2) | |
| 50-59 | 400 | 2,394,115 (15.0) | 24.8 | | 114.6 (94.9-138.2) | |
| ≥60 | 391 | 1,442,012 (9.0) | 23.9 | | 114.6 (93.5-140.6) | |
| Residence district | | | | 0.039 | | 0.016 |
| Urban | 1,891 | 12,834,689 (80.2) | 39.1 | | 90.4 (83.2-98.2) | |
| Suburban/rural | 451 | 3,168,956 (19.8) | 31.3 | | 115.0 (96.3-137.2) | |
| Type of residence | | | | 0.719 | | 0.018 |
| House | 1,258 | 10,980,539 (68.6) | 37.2 | | 100.5 (91.2-110.7) | |
| Apartment | 1,084 | 5,023,107 (31.4) | 38.3 | | 83.6 (74.3-94.0) | |
| Education* | | | | 0.002 | | 0.244 |
| Below elementary school | 354 | 1,686,437 (17.7) | 28.0 | | 114.4 (91.8-142.5) | |
| Middle school | 197 | 1,181,370 (12.4) | 22.5 | | 87.7 (69.3-111.0) | |
| High school | 524 | 3,509,967 (36.9) | 25.5 | | 92.5 (79.7-107.4) | |
| Above university | 486 | 3,146,779 (33.0) | 37.9 | | 89.7 (78.9-102.0) | |
| Marriage* | | | | 0.050 | | 0.360 |
| Married | 1,480 | 8,801,817 (91.5) | 28.6 | | 93.2 (85.6-101.6) | |
| Unmarried | 96 | 819,421 (8.5) | 41.6 | | 108.0 (79.6-143.4) | |
| Income level* | | | | 0.268 | | 0.264 |
| 1 quartile | 411 | 2,727,269 (28.6) | 32.2 | | 109.7 (91.0-132.1) | |
| 2 quartile | 390 | 2,368,780 (24.9) | 24.9 | | 89.2 (76.6-103.9) | |
| 3 quartile | 379 | 2,230,668 (23.4) | 32.1 | | 84.4 (69.2-103.0) | |
| 4 quartile | 380 | 2,200,208 (23.1) | 28.8 | | 90.8 (77.4-106.4) | |
| Occupation* | | | | <0.001 | | <0.001 |
| Professional job | 199 | 1,353,626 (14.3) | 36.5 | | 83.9 (66.3-106.2) | |
| Office job | 147 | 911,227 (9.6) | 32.9 | | 77.5 (61.3-97.8) | |
| Service, sales job | 233 | 1,507,708 (15.9) | 20.4 | | 82.6 (66.7-102.2) | |
| Agriculture and fisheries job | 149 | 882,399 (9.3) | 14.1 | | 179.5 (138.6-232.5) | |
| Technician, engineer | 196 | 1,459,241 (15.4) | 35.5 | | 133.4 (107.7-165.1) | |
| Labor worker | 127 | 758,518 (8.0) | 33.1 | | 102.4 (71.3-147.2) | |
| Jobless | 503 | 2,596,925 (27.4) | 31.9 | | 73.3 (63.6-84.6) | |
| Glucose tolerance† | | | | 0.003 | | <0.001 |
| Normal | 1,432 | 10,249,174 (77.5) | 36.1 | | 85.2 (76.8-94.4) | |
| Impaired fasting glucose | 320 | 2,036,951 (15.4) | 25.3 | | 106.2 (88.4-127.7) | |
| Diabetes mellitus | 159 | 944,641 (7.1) | 23.4 | | 142.7 (113.5-179.5) | |
| BMI† ($kg/m^2$) | | | | 0.083 | | <0.001 |
| Low weight (<18.5) | 86 | 612,044 (4.5) | 42.0 | | 47.2 (35.0-63.7) | |
| Standard (18.5-25.0) | 1,248 | 8,718,890 (63.7) | 35.5 | | 84.5 (76.2-93.8) | |
| Obesity (>25.0) | 628 | 4,345,841 (31.8) | 29.5 | | 124.4 (108.5-142.5) | |

(Continued to the next page)

37.6% (Table 1). The prevalence rates of allergic rhinitis, atopic dermatitis, and asthma were 29.0%, 7.1%, and 4.1%, respectively (Table 2). The overall prevalence of allergic diseases was inversely correlated with age (Table 1). Although the prevalence rates of allergic rhinitis ($P<0.001$) and atopic dermatitis ($P<0.001$) significantly correlated with young age, no association between the prevalence of asthma and age was observed ($P=0.882$) (Table 2). The residence district, education level, occupation, glucose tolerance, depression, elevation of tIgE, sIgE to *D. farinae*, and sIgE to dog were also identified as significant factors associated with allergic diseases in the univariate analyses (Table 1).

**Table 1.** Continued

| Characteristics | No. of participants | No. of represented population (%) | Allergic disease prevalence (%) | *P* value | tIgE (95% CI) (kU/L) | *P* value |
|---|---|---|---|---|---|---|
| Smoking history† | | | | 0.226 | | <0.001 |
| Never smoker | 1,051 | 6,599,290 (48.2) | 34.0 | | 66.5 (60.6-72.9) | |
| Light smoker (<5 pack/whole life) | 68 | 585,990 (4.3) | 43.6 | | 103.8 (67.7-159.3) | |
| Smoker (≥5 pack/life) | 845 | 6,493,304 (47.5) | 32.4 | | 131.2 (114.4-150.4) | |
| Depression† | | | | 0.015 | | 0.001 |
| No | 1,688 | 11,885,162 (86.8) | 32.4 | | 99.0 (90.4-108.5) | |
| Yes | 279 | 1,807,876 (13.2) | 42.5 | | 64.3 (50.6-81.9) | |
| Serum vitamin D level | | | | 0.199 | | 0.018 |
| 1 quartile | 584 | 4,074,877 (25.5) | 40.4 | | 84.9 (74.7-96.5) | |
| 2, 3 quartile | 1,173 | 7,862,277 (49.1) | 38.3 | | 90.7 (81.7-100.7) | |
| 4 quartile | 585 | 4,066,492 (25.4) | 33.6 | | 115.6 (97.8-136.5) | |
| Elevation of tIgE (>100 kU/L) | | | | 0.002 | | - |
| Negative | 1,373 | 9,154,543 (57.2) | 33.7 | | 23.1 (32.3-36.0) | |
| Positive | 969 | 6,849,102 (42.8) | 42.8 | | 372.1 (347.4-398.6) | |
| Positivity to sIgE to *D. farinae* | | | | <0.001 | | - |
| Negative | 1,403 | 9,235,722 (57.7) | 32.4 | | 45.9 (42.7-49.5) | |
| Positive | 939 | 6,767,923 (42.3) | 44.6 | | 255.0 (229.1-283.7) | |
| Positivity to sIgE to *B. germanica* | | 12,562,395 (78.5) | | 0.387 | | - |
| Negative | 1,878 | 3,441,250 (21.5) | 36.9 | | 67.4 (62.6-72.5) | |
| Positive | 464 | | 39.9 | | 330.4 (291.4-374.7) | |
| Positivity to sIgE to dog§ | | | | 0.001 | | - |
| Negative | 2,198 | 14,824,206 (92.6) | 36.0 | | 82.7 (76.5-89.5) | |
| Positive | 144 | 1,179,439 (7.4) | 56.4 | | 527.8 (398.0-700.0) | |

tIgE, total immunoglobulin E; sIgE, specific immunoglobulin E; CI, confidence interval; BMI, body mass index.
*Subjects aged ≥30 years (n=1,577, representing 9,624,008 citizens); †Subjects aged ≥19 years (n=1,977, representing 13,762,677 citizens); ‡Data were missing for 60.3% of the participants; §Positivity to sIgE was defined as a level >0.35 kU/L.

**Table 2.** Univariate analyses of the prevalence rates of allergic rhinitis, atopic dermatitis, and asthma according to age and sex

| Characteristics | Prevalence of allergic rhinitis (%) | *P* value | Prevalence of atopic dermatitis (%) | *P* value | Prevalence of asthma (%) | *P* value |
|---|---|---|---|---|---|---|
| Overall | 29.0 | - | 7.1 | - | 4.1 | - |
| Gender | | 0.970 | | 0.366 | | 0.202 |
| Male | 29.0 | | 7.7 | | 4.7 | |
| Female | 29.1 | | 6.3 | | 3.2 | |
| Age (year) | | <0.001 | | <0.001 | | 0.882 |
| 10-19 | 36.8 | | 16.5 | | 6.1 | |
| 20-29 | 34.9 | | 11.7 | | 3.1 | |
| 30-39 | 34.8 | | 8.6 | | 4.6 | |
| 40-49 | 21.0 | | 3.8 | | 4.5 | |
| 50-59 | 20.4 | | 4.5 | | 3.9 | |
| ≥60 | 19.6 | | 1.5 | | 4.7 | |

### Univariate analyses of factors associated with the tIgE level

The geometric mean tIgE level was 94.8 kU/L (95% confidence interval [CI], 87.9-102.3). The mean tIgE level was significantly higher in men than in women. The tIgE level decreased with age, but later increased. The residence district, type of residence, occupation, glucose tolerance, BMI, smoking history, depression, and serum vitamin D level were significantly associated with the tIgE level in the univariate analyses (Table 1).

### Multivariate analyses for factors associated with self-reported allergic diseases

Multivariate analyses were conducted to assess the associations of the factors analyzed with each type of self-reported allergic disease (Table 2). Young age ($P$=0.013), the subjects' oc-

**Table 3.** Multivariate analyses of potential independent risk factors for allergic rhinitis, atopic dermatitis, and asthma in subjects aged ≥30 years

| Variables | Allergic rhinitis | | | Atopic dermatitis | | | Asthma | | |
|---|---|---|---|---|---|---|---|---|---|
| | OR | 95% CI | *P* value | OR | 95% CI | *P* value | OR | 95% CI | *P* value |
| Age (year) | | | 0.013 | | | 0.015 | | | 0.540 |
| 30-39 | Reference | - | | Reference | - | | Reference | - | |
| 40-49 | 0.592 | 0.404-0.868 | | 0.472 | 0.206-1.083 | | 0.996 | 0.412-2.410 | |
| 50-59 | 0.656 | 0.434-0.992 | | 0.608 | 0.281-1.314 | | 0.523 | 0.176-1.552 | |
| ≥60 | 0.561 | 0.352-0.894 | | 0.162 | 0.048-0.553 | | 0.637 | 0.266-1.522 | |
| Residence district | | | 0.713 | | | 0.989 | | | 0.555 |
| Urban | Reference | - | | Reference | - | | Reference | - | |
| Suburban/rural | 0.912 | 0.557-1.493 | | 1.006 | 0.413-2.453 | | 0.757 | 0.299-1.916 | |
| Education | | | 0.106 | | | 0.662 | | | 0.003 |
| Below elementary school | Reference | - | | Reference | - | | Reference | - | |
| Middle school | 0.743 | 0.405-1.365 | | 0.547 | 0.097-3.095 | | 0.873 | 0.303-2.518 | |
| High school | 0.746 | 0.437-1.275 | | 0.768 | 0.288-2.047 | | 0.127 | 0.041-0.392 | |
| Above university | 1.181 | 0.701-1.987 | | 1.155 | 0.411-3.243 | | 0.430 | 0.141-1.310 | |
| Occupation | | | 0.008 | | | 0.037 | | | 0.122 |
| Professional job in urban | Reference | - | | Reference | - | | Reference | - | |
| Office job | 1.219 | 0.695-2.139 | | 0.552 | 0.173-1.760 | | 0.537 | 0.126-2.292 | |
| Service, sales job | 0.680 | 0.396-1.168 | | 0.656 | 0.223-1.935 | | 0.579 | 0.168-1.999 | |
| Agriculture and fisheries job | 0.565 | 0.251-1.271 | | 0.108 | 0.016-0.746 | | 0.234 | 0.046-1.203 | |
| Technician, engineer | 1.498 | 0.863-2.598 | | 1.030 | 0.395-2.686 | | 0.842 | 0.280-2.533 | |
| Labor worker | 1.073 | 0.487-2.364 | | 1.700 | 0.367-7.867 | | 0.247 | 0.058-1.048 | |
| Jobless | 1.487 | 0.880-2.514 | | 0.425 | 0.139-1.299 | | 0.349 | 0.126-0.968 | |
| Glucose tolerance | | | 0.023 | | | 0.964 | | | 0.298 |
| Normal | Reference | - | | Reference | - | | Reference | - | |
| Impaired fasting glucose | 0.733 | 0.476-1.128 | | 1.100 | 0.514-2.355 | | 0.696 | 0.297-1.633 | |
| Diabetes mellitus | 0.463 | 0.259-0.830 | | 1.103 | 0.222-5.470 | | 1.999 | 0.666-5.999 | |
| Depression | | | 0.273 | | | 0.029 | | | 0.009 |
| No | Reference | - | | Reference | - | | Reference | - | |
| Yes | 1.247 | 0.839-1.852 | | 2.548 | 1.101-5.899 | | 2.691 | 1.280-5.655 | |
| Elevation of tIgE | | | 0.728 | | | 0.072 | | | 0.001 |
| Negative | Reference | - | | Reference | - | | Reference | - | |
| Positive | 0.934 | 0.633-1.377 | | 0.505 | 0.239-1.064 | | 0.264 | 0.123-0.567 | |
| Positivity to sIgE to *D. farinae* | | | 0.064 | | | 0.170 | | | 0.078 |
| Negative | Reference | - | | Reference | - | | Reference | - | |
| Positive | 0.697 | 0.475-1.021 | | 1.555 | 0.826-2.926 | | 1.943 | 0.927-4.073 | |
| Positivity to sIgE to dog | | | 0.007 | | | 0.729 | | | 0.001 |
| Negative | Reference | - | | Reference | - | | Reference | - | |
| Positive | 0.408 | 0.213-0.784 | | 0.801 | 0.227-2.825 | | 0.264 | 0.123-0.567 | |

OR, odds ratio; CI, confidence interval; tIgE, total immunoglobulin E; sIgE, specific immunoglobulin E.

cupation ($P$=0.008), glucose intolerance ($P$=0.023), and sensitization to dog ($P$=0.007) were found to be significant independent risk factors for allergic rhinitis. Young age ($P$=0.015), occupation ($P$=0.038), and depression ($P$=0.029) were significantly and independently associated with atopic dermatitis. Finally, a high education level ($P$=0.003), depression ($P$=0.009), elevation of tIgE ($P$=0.001), and sensitization to dog ($P$=0.001) were significantly and independently associated with asthma (Table 3).

### Risk factors for elevation of tIgE

Based on the results of the univariate analysis (Table 1), we conducted a multivariate analysis and found that sex, occupation, BMI, and smoking history were independent risk factors for elevation of tIgE in subjects aged ≥30 years. Specifically, male sex (odds ratio [OR] in women, 0.510; 95% CI, 0.329-0.790; $P$=0.003), occupations related to agriculture and fishery (OR, 2.728; 95% CI, 1.391-5.350; $P$=0.044), obesity (OR, 1.453; 95% CI, 1.061-1.989; $P$=0.010), and smokers (OR vs never-smokers, 1.693; 95% CI, 1.132-2.533; $P$=0.010) (Table 4) were independent risk factors for elevation of tIgE.

### Risk factors for sensitization to *D. farinae*

In the univariate analysis (Table 1), male sex, age, occupation, smoking history, BMI, and the vitamin D level were significant risk factors for sensitization to *D. farinae*. In the multivariate analysis, old age was found to be negatively associated with allergic diseases, when compared with those aged 30-39 years as the reference group (OR, 0.611 in those aged 40-49 years; OR, 0.785 in those aged 50-59 years; OR, 0.644 in those aged ≥60 years; $P$=0.036). Although the vitamin D level was significantly associated with sensitization to *D. farinae*, the effects on the sensitization were not consistent (OR, 0.731 for quartiles 2-3, $P$=0.030; OR, 1.072 for quartile 4) (Table 5).

### Risk factors for sensitization to *B. germanica*

In the univariate analysis, male sex, residential district, type of residence, occupation, glucose tolerance status, BMI, and smoking history were significant risk factors for sensitization to *B. germanica*. In the multivariate analysis, male sex was found to be a significant independent risk factor of sensitization to *B. germanica* (OR, 0.307 in women; 95% CI, 0.193-0.489; $P$<0.001), whereas subjects living in apartments had a reduced risk (OR, 0.682; 95% CI, 0.484-0.959; $P$=0.028). Further, glucose intolerance was identified as another significant risk factor for sensitization to *B. germanica* (OR, 1.413 in those with impaired fasting glucose; OR, 1.928 in those with diabetes mellitus; $P$=0.012) (Table 6).

### Risk factors for sensitization to dog

In the univariate analysis, male sex, age, and smoking status were significant risk factors for sensitization to dog. In the multivariate analysis, older age was found to be associated with a low risk for sensitization to dog ($P$=0.014), whereas smokers were associated with a high risk, as compared with never smokers (OR, 2.423; 95% CI, 1.416-4.145; $P$=0.004) (Table 7).

**Table 4.** Multivariate analysis for positive total immunoglobulin E in subjects aged ≥30 years (n=1,577, representing 9,624,008 citizens ≥30 years)

| Variables | OR | 95% CI | *P* value |
|---|---|---|---|
| Gender | | | 0.003 |
| Male | Reference | - | |
| Female | 0.510 | 0.329-0.790 | |
| Age (year) | | | 0.406 |
| 30-39 | Reference | - | |
| 40-49 | 0.765 | 0.522-1.122 | |
| 50-59 | 1.054 | 0.729-1.523 | |
| ≥60 | 0.949 | 0.598-1.508 | |
| Residence district | | | 0.821 |
| Urban | Reference | - | |
| Suburban/rural | 1.044 | 0.720-1.513 | |
| Type of residence | | | 0.379 |
| House | Reference | - | |
| Apartment | 0.879 | 0.658-1.174 | |
| Occupation | | | 0.044 |
| Professional job in urban area | Reference | - | |
| Office job | 0.954 | 0.536-1.700 | |
| Service, sales job | 1.300 | 0.766-2.206 | |
| Agriculture and fisheries job | 2.728 | 1.391-5.350 | |
| Technician, engineer | 1.840 | 1.075-3.150 | |
| Labor worker | 1.831 | 0.997-3.362 | |
| Jobless | 1.426 | 0.890-2.284 | |
| Glucose tolerance | | | 0.244 |
| Normal | Reference | - | |
| Impaired fasting glucose | 1.105 | 0.785-1.554 | |
| Diabetes mellitus | 1.414 | 0.943-2.120 | |
| BMI | | | 0.010 |
| Normal | Reference | - | |
| Low weight | 0.421 | 0.147-1.202 | |
| Obesity | | | 1.453 |
| Smoking history | | | 0.010 |
| Never smoker | Reference | - | |
| Light smoker | 2.469 | 1.076-5.662 | |
| Smoker | 1.693 | 1.132-2.533 | |
| Depression | | | 0.668 |
| No | Reference | - | |
| Yes | 1.091 | 0.730-1.632 | |
| Serum vitamin D level | | | 0.961 |
| 1 quartile | Reference | - | |
| 2, 3 quartile | 0.964 | 0.710-1.309 | |
| 4 quartile | 0.951 | 0.651-1.390 | |

Positive tIgE level was defined as tIgE levels >100 kU/L.
OR, odds ratio; CI, confidence interval; BMI, body mass index.


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**Table 5.** Univariate and multivariate analyses for positivity of specific immunoglobulin E to *D. farinae*

| Variables | Univariate analysis | | | Multivariate analysis* | | |
|---|---|---|---|---|---|---|
| | OR | 95% CI | *P* value | OR | 95% CI | *P* value |
| Sex | | | <0.001 | | | 0.141 |
| Male | 1.000 | - | | 1.000 | - | |
| Female | 0.535 | 0.437-0.654 | | 0.720 | 0.465-1.116 | |
| Age (year) | | | <0.001 | | | 0.036 |
| 10-19 | 1.000 | - | | - | - | |
| 20-29 | 1.169 | 0.814-1.679 | | - | - | |
| 30-39 | 0.779 | 0.562-1.079 | | 1.000 | - | |
| 40-49 | 0.529 | 0.372-0.751 | | 0.611 | 0.431-0.867 | |
| 50-59 | 0.685 | 0.469-1.001 | | 0.785 | 0.551-1.119 | |
| ≥60 | 0.591 | 0.391-0.892 | | 0.644 | 0.432-0.960 | |
| Occupation* | | | 0.003 | | | 0.104 |
| Professional job | 1.000 | - | | 1.000 | - | |
| Office job | 0.725 | 0.451-1.165 | | 0.618 | 0.373-1.025 | |
| Service, sales job | 0.655 | 0.413-1.038 | | 0.718 | 0.426-1.210 | |
| Agriculture and fisheries job | 1.666 | 0.996-2.785 | | 1.663 | 0.919-3.008 | |
| Technician, engineer | 1.075 | 0.713-1.621 | | 0.828 | 0.526-1.302 | |
| Labor worker | 0.836 | 0.498-1.404 | | 0.957 | 0.545-1.681 | |
| Jobless | 0.618 | 0.409-0.933 | | 0.788 | 0.484-1.282 | |
| BMI† | | | 0.016 | | | 0.056 |
| Normal | 1.000 | - | | 1.000 | - | |
| Low weight | 0.493 | 0.290-0.838 | | 0.377 | 0.154-0.921 | |
| Obesity | 1.182 | 0.926-1.509 | | 1.146 | 0.855-1.537 | |
| Smoking history† | | | <0.001 | | | 0.093 |
| Never smoker | 1.000 | - | | 1.000 | - | |
| Light smoker | 0.593 | 0.468-0.753 | | 1.102 | 0.460-2.643 | |
| Smoker | 0.594 | 0.315-1.120 | | 1.576 | 1.045-2.377 | |
| Serum vitamin D level | | | 0.029 | | | 0.030 |
| Low level (Q1) | 1.000 | - | | 1.000 | - | |
| Mod level (Q2-Q3) | 0.827 | 0.858-1.535 | | 0.731 | 0.524-1.020 | |
| High level (Q4) | 1.148 | 0.658-1.040 | | 1.072 | 0.692-1.662 | |

Positivity to sIgE was defined as sIgE levels >0.35 kU/L.
OR, odds ratio; CI, confidence interval; BMI, body mass index.
*Analysis included subjects aged ≥30 years (n=1,577, representing 9,624,008 citizens ≥30 years); †Analysis included subjects aged ≥19 years (n=1,977, representing 13,762,677 citizens ≥19 years).

## DISCUSSION

This large cross-sectional study aimed to identify demographic and environmental factors associated with the prevalence of allergic diseases and allergen sensitization in the non-institutionalized Korean general population. As a result, we found that allergic diseases and allergen sensitization were significantly associated with various demographic factors.

First, age was a significant risk factor for self-reported allergic diseases. Specifically, the prevalence of allergic rhinitis and atopic dermatitis decreased with increasing age, supporting the findings of previous studies.[17,18] Aging-related immunomodulation and immune tolerance induced by long-term exposure to allergens could be responsible for these associations.[19] In contrast, the asthma prevalence was not associated with age in this study. A previous large-scale cohort study also showed that age was not significantly associated with the prevalence of asthma.[20] However, some previous Korean cohort studies conversely showed that the prevalence of asthma increased with age.[21,22] Thus, further studies should be performed to confirm the association between the prevalence of asthma and age in Korea.

Second, occupation was a significant contributing factor for allergic diseases. The prevalence of at least 1 allergic disease for subjects in agriculture and fishery occupations (14.1%) or ser-

**Table 6.** Univariate and multivariate analyses for positivity of specific immunoglobulin E to *B. germanica*

| Variables | Univariate analysis | | | Multivariate analysis* | | |
|---|---|---|---|---|---|---|
| | OR | 95% CI | *P* value | OR | 95% CI | *P* value |
| Sex | | | <0.001 | | | <0.001 |
| Male | 1.000 | - | | 1.000 | - | |
| Female | 0.365 | 0.282-0.473 | | 0.307 | 0.193-0.489 | |
| Residence district | | | 0.040 | | | 0.230 |
| Urban | 1.000 | - | | 1.000 | - | |
| Suburban/rural | 1.458 | 1.017-2.090 | | 1.293 | 0.849-1.970 | |
| Type of residence | | | <0.001 | | | 0.028 |
| House | 1.000 | - | | 1.000 | - | |
| Apartment | 0.583 | 0.446-0.761 | | 0.682 | 0.484-0.959 | |
| Occupation* | | | <0.001 | | | 0.221 |
| Professional job | 1.000 | - | | 1.000 | - | |
| Office job | 1.340 | 0.758-2.369 | | 1.317 | 0.693-2.501 | |
| Service, sales job | 1.107 | 0.616-1.988 | | 1.359 | 0.701-2.635 | |
| Agriculture and fisheries job | 2.256 | 1.272-4.003 | | 1.761 | 0.902-3.437 | |
| Technician, engineer | 1.823 | 1.058-3.140 | | 1.341 | 0.720-2.469 | |
| Labor worker | 2.114 | 1.084-4.121 | | 2.500 | 1.219-5.127 | |
| Jobless | 0.843 | 0.512-1.389 | | 1.297 | 0.763-2.205 | |
| Glucose tolerance† | | | <0.001 | | | 0.012 |
| Normal | 1.000 | - | | 1.000 | - | |
| Impaired fasting glucose | 1.748 | 1.237-2.470 | | 1.413 | 0.958-2.084 | |
| Diabetes mellitus | 2.418 | 1.555-3.761 | | 1.928 | 1.182-3.147 | |
| BMI† | | | <0.001 | | | 0.225 |
| Normal | 1.000 | - | | 1.000 | - | |
| Low weight | 0.346 | 0.128-0.935 | | 0.274 | 0.055-1.363 | |
| Obesity | 1.611 | 1.224-2.122 | | 1.126 | 0.804-1.577 | |
| Smoking history† | | | <0.001 | | | 0.972 |
| Smoker | 1.000 | - | | 1.000 | - | |
| Light smoker | 0.869 | 0.413-1.828 | | 0.958 | 0.387-2.374 | |
| Never smoker | 0.496 | 0.364-0.676 | | 0.945 | 0.589-1.517 | |

Positivity to sIgE was defined as IgE levels >0.35 kU/L.
OR, odds ratio; CI, confidence interval; BMI, body mass index.
*Analysis included subjects aged ≥30 years (n=1,577, representing 9,624,008 citizens ≥30 years); †Analysis included subjects aged ≥19 years (n=1,977, representing 13,762,677 citizens ≥19 years).

vice and sales occupations (20.4%) was significantly lower than that for those in other occupations (31.9%-36.5%; data not shown). Especially, an occupation related to agriculture and fisheries was a protective factor for allergic rhinitis in the multivariate analysis, whereas it was an independent risk factor for the elevation of tIgE. Exposure to a farm environment has been considered protective against allergic diseases,[23-25] whereas exposure to chemical agents in some occupations, including among technicians and labor workers, is a risk factor for allergic diseases.[26] Thus, different occupational environments may affect the development of allergic disease.

Third, depression was significantly associated with allergic diseases, especially self-reported asthma (OR, 2.691; 95% CI, 1.280-5.655; $P$=0.009) and self-reported atopic dermatitis (OR, 2.549; 95% CI, 1.101-5.899; $P$=0.029). However, in contrast to the other factors described above, depression may not be a direct cause of allergic disease. The adverse effect of self-reported allergic disease on depression has already been well demonstrated in previous studies,[12-14] and it is likely that depression may be induced or aggravated by allergic diseases rather than being a cause.

Lastly, glucose intolerance was found to be a significant risk factor for allergic rhinitis, whereas a higher level of education was protective for self-reported asthma. Previous studies have reported a significant correlation between diabetes and allergic diseases.[15] However, evidence to confirm a significant causal re-

**Table 7.** Univariate and multivariate analyses for positivity of specific immunoglobulin E to dog

| Variables | Univariate analysis | | | Multivariate analysis* | | |
|---|---|---|---|---|---|---|
| | OR | 95% CI | *P* value | OR | 95% CI | *P* value |
| Sex | | | <0.001 | | | 0.249 |
| Male | 1.000 | - | | 1.000 | - | |
| Female | 0.407 | 0.278-0.596 | | 0.750 | 0.459-1.226 | |
| Age (year) | | | 0.013 | | | 0.014 |
| 10-19 | 1.000 | - | | 1.000 | - | |
| 20-29 | 1.038 | 0.563-1.912 | | 0.492 | 0.150-1.617 | |
| 30-39 | 0.575 | 0.316-1.045 | | 0.237 | 0.069-0.814 | |
| 40-49 | 0.373 | 0.184-0.757 | | 0.162 | 0.043-0.610 | |
| 50-59 | 0.644 | 0.335-1.236 | | 0.271 | 0.076-0.971 | |
| ≥60 | 0.411 | 0.200-0.846 | | 0.186 | 0.050-0.685 | |
| Smoking history* | | | 0.001 | | | 0.004 |
| Never smoker | 1.000 | - | | 1.000 | - | |
| Light smoker | 0.491 | 0.157-1.533 | | 1.024 | 0.293-3.576 | |
| Smoker | 0.385 | 0.234-0.636 | | 2.423 | 1.416-4.145 | |

Positivity to sIgE was defined as sIgE levels >0.35 kU/L.
OR, odds ratio; CI, confidence interval.
*Analysis included subjects aged ≥19 years (n=1,977, representing 13,762,677 citizens ≥19 years).

lationship between these conditions is still lacking. Similarly, while data regarding the effects of education level on self-reported asthma have been accumulated, the evidence is still insufficient.[27,28]

Interestingly, in the present study, we observed significant gaps between the tIgE level and the prevalence of allergic disease. Male sex, obesity, and smoking were identified as significant risk factors for tIgE. The higher frequency of elevated tIgE in men supports the findings of previous studies.[29,30] This result may be secondary to the correlations of alcohol consumption and/or parasitic infections with IgE, as heavy alcoholics and asymptomatic parasite-infected subjects are frequently observed in Korea, especially among men.[31-33] Although the data are not shown, the positivity rate of tIgE increased with increasing alcohol consumption amount in this study (37.1%, 50.5%, and 70.5% for subjects with ≤1, 2-3, and ≥4 events of alcohol consumption/week, respectively $P<0.001$). However, male sex was still a significant risk factor for positivity of tIgE even after adjusting for the alcohol consumption amount in the multivariate analysis, indicating that male sex is an independent risk factor for positivity of tIgE regardless of alcohol consumption. The effects of obesity[34,35] and smoking[36,37] on the tIgE level are also widely accepted, based on sufficient evidence. Of note, recent studies have revealed that the sIgE/tIgE ratio is more accurate than sIgE alone in predicting outcomes in food allergy, suggesting a protective effect of tIgE against allergic symptoms.[38] However, this topic remains controversial, with varying opinions,[39,40] and some studies have suggested that the serum tIgE level is positively correlated with allergic disease.[41-43]

The factors associated with positivity of sIgE differed according to the type of allergen. Male sex and house residence were significant factors associated with positivity of sIgE to *B. germanica*. These factors are associated with household hygiene and have been previously reported as significant factors for sensitization to *B. germanica*. In addition, smoking was significantly associated with positivity of sIgE to dog; this result is also supported by other studies.[44,45]

Some of the associated factors identified in the present study are modifiable, and exposure or avoidance of these factors may help prevent allergen sensitization and development of allergic diseases. For example, early exposure to a farm-like environment may help prevent allergic diseases. Hygiene-related factors, including residing in an apartment, and glucose intolerance should be improved to avoid sensitization to cockroaches. In addition, avoidance of smoking and obesity may help prevent the development of allergic diseases.

The major strength of this study is that the data were obtained from a well-designed national program with complex, multistage probability sample extraction, and that we used complex sample analysis, resulting in the representation of 16,003,645 citizens, which is one-third of the total population of Korea. Although the KNHANES provides specific guidelines to ensure appropriate estimates and results due to the inherent nature of a multiple complex survey design, almost all research articles published on the basis of the data from the KNHANES used standard statistical analyses.[46] We followed the KNHANES guidelines concerning the statistical analysis; this provided valuable information that can be generalized to the entire Kore-

an general population.

However, an important limitation of the present study is its cross-sectional design; because it was not a longitudinal study, the temporal relationship of the associated factors could not be evaluated. For example, we could not determine if smoking was a significant risk factor for allergic diseases or if subjects with allergic disease were at risk for smoking. Another limitation of this study is that the data in the multivariate analysis were assessed only for subjects who were older than 30 years. This was because we considered that the assessment of the subjects' education level, marriage status, income level, and occupation at that age was reliable. Third, most parameters, including allergic disease, occupation, and income level, were obtained using a self-reported survey. The prevalence of physician-diagnosed allergic disease may differ from that of self-reported allergic disease. Similarly, self-reported occupation and income level may be affected by the respondent's judgment. Moreover, the residence district and occupation may also be affected by various parameters. For example, people who moved to a rural area recently after living in an urban area or who had a recent change in occupation might result in confusion. Lastly, although we could not conduct further analysis due to limited provided information, dividing the subjects into those with allergic asthma and non-allergic asthma might provide interesting results, as the pathogeneses and treatments differ between these entities.[47]

In conclusion, demographic and environmental risk factors associated with the tIgE and sIgE levels, as well as with self-reported allergic diseases, differ according to the type of allergens and allergic diseases. The results of the present study suggest that appropriate management of numerous modifiable factors might help prevent allergen sensitization and development of allergic diseases. Further studies are warranted to confirm our findings and identify any causal relationships.

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