



# The relationships among birth season, sunlight exposure during infancy, and allergic disease

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**Purpose:** The recent increase in the prevalence of allergic diseases is hypothetically attributed to immune dysregulation in turn caused by a reduction in exposure to sunlight. We explored relationships between birth season, sunlight exposure, exercise duration, and an allergic disease.

**Methods:** We performed a questionnaire-based survey on allergic diseases among elementary school students. Birth time was categorized according to the season (summer and winter).

**Results:** The prevalence of atopic dermatitis (AD) "symptoms ever" was higher in the children born in winter than in those born in summer (adjusted odds ratio [aOR], 1.24; 95% confidence interval [CI], 1.03–1.49;  $P=0.024$ ). Birth in winter was associated with an increase in the "symptoms in the past 12 months" prevalence of food allergy (FA) (aOR, 1.56; 95% CI, 1.09–2.24;  $P=0.015$ ). The lifetime prevalence of allergic diseases except FA was higher in the children whose parents considered their sunlight exposure prior to 24 months of age as inadequate than those who considered their exposure as adequate ("diagnosis ever" asthma: aOR, 1.4; 95% CI, 1.17–1.67;  $P<0.001$ ; allergic rhinitis [AR]: aOR, 1.4; 95% CI, 1.17–1.67;  $P<0.001$ ; AD: aOR, 1.26; 95% CI, 1.06–1.51;  $P=0.01$ ). Neither recent sunlight exposure nor exercise duration was associated with the prevalence of an allergic disease.

**Conclusion:** Birth in winter may be associated with development of AD and FA. Inadequate sunlight exposure before the age of 24 months might possibly increase the risks of development of asthma, AR, and AD.

**Key words:** Asthma, Dermatitis atopic, Food hypersensitivity, Rhinitis allergic, Sunlight

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## Introduction

The prevalence of asthma and allergic diseases, including allergic rhinitis (AR), atopic dermatitis (AD), and food allergy (FA), continues to increase worldwide and occurs more frequently in younger age groups<sup>1,2</sup>. Therefore, the cost of managing and preventing allergic diseases is also rising worldwide.

Numerous factors are known to be associated with the development of allergic diseases, including age, obesity, lifestyle, and environmental status, among others<sup>3,4</sup>. Among such factors, there is growing recognition of the influence of sunlight exposure and vitamin D. Since its immunomodulatory effect was first confirmed, vitamin D has emerged as a variable of interest in the pathogenesis of allergic diseases; accordingly, there is also interest in sunlight exposure because of its association with the generation of vitamin D. Several studies have shown that vitamin D has an effect on the pathogenesis of allergic diseases<sup>5,6</sup>. Season of birth has also been suggested as a possible risk factor for allergic diseases, particularly FA<sup>7,8</sup>. Recent report reported that FA was more common in children born in Boston, during the autumn and winter seasons, suggesting that seasonal fluctuations in sunlight, and perhaps also vitamin D levels, may be involved in the pathogenesis of FA<sup>7</sup>.

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Recent reports have shown that vitamin D deficiency is very common in Korea<sup>9)</sup>, particularly in young adults<sup>10)</sup>. The increased prevalence of vitamin D deficiency may in turn be associated with the increased prevalence of allergic diseases in Korea.

Synthesis in the skin represents the major natural source of vitamin D; such dermal synthesis is dependent on sun exposure. Therefore, it may be hypothesized that the level of sun exposure determines the level of vitamin D in the human body.

The aim of this study was to investigate associations between birth season, sunlight exposure adequacy during infancy, level of recent exercise, and allergic disease prevalence. We conducted a survey on allergic diseases among elementary school students using the International Study of Asthma and Allergies in Childhood (ISAAC) written questionnaire, together with an additional questionnaire concerning sunlight exposure during infancy and level of recent exercise.

## Materials and methods

### 1. Subjects

We obtained 2012 data from the Atopy and Asthma-Friendly School Program of Bucheon, Korea, which included students from seven elementary schools (n=3,400). We targeted elementary school students aged 6 to 13 years.

### 2. Data collection

Questionnaires were administered to the parents or caregivers of the children. A Korean version of the ISAAC questionnaire was used, the characteristics of which have been reported in detail elsewhere. Asthma prevalence was determined by lifetime and current (past 12 months) wheezing episodes. We also recorded whether asthma had been diagnosed by a doctor and whether asthma treatment had occurred in the past 12 months; similar questions were also applied to AD, AR, and FA. Demographic information (age, sex, weight, and height, type of delivery, use of antibiotics before the age of 12 months, duration of breast feeding, parental history of allergic diseases), birth season, and level of recent exercise were also assessed. Birth season was divided into 2 seasons (summer, April to September; winter, October to March). There was a question on sunlight exposure adequacy (e.g., "Do you think your child had enough sunlight exposure before the age of 24 months?"). Other questions included: "With the exception of school physical education classes, what was your child's average duration of outdoor sunlight exposure per week in winter during recent years?" and "With the exception of school physical education classes, what was your child's average duration of sunlight exposure per week in spring, summer, and autumn during recent years?" The response options were "less than 1 hour," "1 to 2 hours," "2 to 3 hours," and "more

than 3 hours." Level of exercise was assessed by the following question: "Aside from school physical education classes, on how many days per week did your child exercise or play to the extent that they broke a sweat or experienced shortness of breath?" The response options were "0 day," "1 to 2 days," "3 to 4 days," and "more than 5 days."

The survey was conducted from May 2012 to June 2012. This study was approved by Institutional Review Board of Soonchunhyang University, College of Medicine, Bucheon (approval number: 2015-08-006).

### 3. Statistical analysis

The demographic characteristics of all subjects were presented as frequency and proportion (%) for categorical variables and as mean±standard deviation for continuous variables. Univariate logistic regression analysis was performed to examine associations between several parameters and the presence of symptoms, diagnosis, and treatment of allergic disease; odds ratios (ORs) were also calculated for these parameters. Furthermore, multivariate logistic regression was conducted to adjust for the effects of sex, age, and body mass index, type of delivery, use of antibiotics before the age of 12 months, breast feeding more than 3 months, parental history of allergic diseases and several parameters; ORs were adjusted for these variables and 95% confidence intervals (CIs) were calculated. The prevalence of each allergic disease was described using 95% CIs computed by Wilson method. A two-tailed *P* value of <0.05 was taken to indicate statistical significance. All analyses were performed using the SPSS ver. 14.0 (SPSS Inc., Chicago, IL, USA).

## Results

### 1. General characteristics

This study recruited a total of 3,400 children from 7 elementary schools. The response rate was 98.4% (n=3,344). The mean age of the respondents was 8.79±1.84 years. There were 1,703 boys and 1,641 girls (male:female ratio=50.93:49.07). The age, sex, type of delivery, use of antibiotics before the age of 12 months, breast feeding more than 3 months, parental history of allergic diseases, and several parameters of the 2 groups (children who born in summer vs. winter) are shown in Table 1.

### 2. Prevalence of allergic diseases

Table 2 shows the prevalence of asthma, AR, AD, and FA. The lifetime prevalence of asthma symptoms was 12.92% (95% CI, 11.82–14.10). The 12-month prevalence of asthma symptoms was 5.83% (95% CI, 5.09–6.68), and the lifetime prevalence of asthma diagnosis was 7.89% (95% CI, 7.03–8.86). The prevalence of asthma treatment in the past 12 months was 2.75% (95% CI,

**Table 1.** Demographic characteristics of the subjects

Variable	Born in summer (n=1,642)	Born in winter (n=1,702)	Total (n=3,344)	P value
Sex				0.593
Male	828 (50.43)	875 (51.41)	1,703 (50.93)	
Female	814 (49.57)	827 (48.59)	1,641 (49.07)	
Age (yr)	8.75±1.87	8.84±1.8	8.79±1.84	0.15
Height (cm)	135.55±12.6	135.22±12.73	135.39±12.67	0.631
Body weight (kg)	32.32±9.52	32.36±10.87	32.34±10.23	0.766
Body mass index (kg/m <sup>2</sup> )	17.29±2.77	17.46±4.48	17.38±3.74	0.487
Type of delivery				0.106
NSVD	933 (56.82)	1,015 (59.64)	1,948 (58.25)	
C-section	709 (43.18)	687 (40.36)	1,396 (41.75)	
Use of antibiotics before the age of 12 months	1,219 (74.24)	1,261 (74.09)	2,480 (74.16)	0.953
No	423 (25.76)	441 (25.91)	864 (25.84)	
Yes				
Breast feeding more than 3 months				0.220
No	734 (44.7)	724 (42.54)	1458 (43.6)	
Yes	908 (55.3)	978 (57.46)	1,886 (56.4)	
Parental history of allergic diseases				
Asthma	44 (2.68)	50 (2.94)	94 (2.81)	0.729
Allergic rhinitis	499 (30.39)	505 (29.67)	1,004 (30.02)	0.678
Atopic dermatitis	95 (5.79)	114 (6.7)	209 (6.25)	0.309
Food allergy	72 (4.38)	78 (4.58)	150 (4.49)	0.847

Values are presented as number (%) or mean±standard deviation. NSVD, normal spontaneous vaginal delivery.

**Table 2.** Prevalence of allergic diseases of the subjects

Allergic disease	Category	No. (%)	95% CI*
Asthma	Symptom, ever	432 (12.92)	11.82–14.10
	Symptom, recent 1 yr	195 (5.83)	5.09–6.68
	Diagnosis, ever	264 (7.89)	7.03–8.86
	Treatment, recent 1 yr	92 (2.75)	2.25–3.36
Allergic rhinitis	Symptom, ever	1466 (43.84)	42.17–45.53
	Symptom, recent 1 yr	1309 (39.14)	37.5–40.81
	Diagnosis, ever	1176 (35.17)	33.57–36.80
	Treatment, recent 1 yr	876 (26.20)	24.73–27.71
Allergic rhinitis	Symptom, ever	735 (21.98)	20.61–23.41
	Symptom, recent 1 yr	443 (13.25)	12.14–14.44
	Diagnosis, ever	987 (29.52)	27.99–31.08
	Treatment, recent 1 yr	411 (12.29)	11.22–13.45
Food allergy	Symptom, ever	501 (14.98)	13.81–16.23
	Symptom, recent 1 yr	156 (4.67)	4.00–5.43
	Diagnosis, ever	182 (5.44)	4.72–6.26
	Treatment, recent 1 yr	63 (1.88)	1.48–2.40

CI, confidence interval; AR, allergic rhinitis; AD, atopic dermatitis; FA, food allergy.

\*95% Confidence interval (CI) of prevalence was computed by Wilson's binomial method.

2.25–3.36).

The lifetime prevalence of AR symptoms was 43.84% (95% CI, 42.17–45.53). The 12-month prevalence of AR was 39.14% (95% CI, 37.50–40.81), and the lifetime prevalence of AR diagnosis was 35.17% (95% CI, 33.57–36.80). The prevalence of AR treatment in the past 12 months was 26.20% (95% CI, 24.73–27.71).

The lifetime prevalence of AD symptoms was 21.98% (95% CI, 20.61–23.41). The 12-month prevalence of AD was 13.25% (95% CI, 12.14–14.44), and the lifetime prevalence of AD diagnosis was 29.52% (95% CI, 27.99–31.08). The prevalence of AD treatment in the past 12 months was 12.29% (95% CI, 11.22–13.45).

The lifetime prevalence of FA symptoms was 14.98% (95% CI, 13.81–16.23). The 12-month prevalence of FA was 4.67% (95% CI, 4.00–5.43), and the lifetime prevalence of FA diagnosis was 5.44% (95% CI, 4.72–6.26). The prevalence of FA treatment in the past 12 months was 1.88% (95% CI, 1.48–2.40).

### 3. Risk factors for allergic diseases

#### 1) Prevalence of allergic diseases according to birth season

The prevalence of AD “symptoms, ever” was higher in children born in winter than in summer (adjusted OR [aOR], 1.24; 95% CI, 1.03–1.49; *P*=0.024); AD “symptoms in the past 12 months,” “treatment during the past 12 months,” and “diagnosis, ever”

were not significantly associated with birth season. FA “symptoms in the past 12 months” was observed in 5.52% (95% CI, 4.53–6.71) of children born in winter and in 3.78% (95% CI, 2.96–4.81) of those born in summer. In adjusted analyses, the prevalence was 1.56 folds higher (95% CI, 1.09–2.24;  $P=0.016$ ) among those born in winter. However, winter birth was not associated with an increased prevalence of “FA diagnosis, ever” or “FA treatment during the past 12 months.” There were no significant associations between birth season and asthma or AR among all of the respondents (Table 3).

2) Prevalence of allergic diseases according to sunlight exposure

(1) Sunlight exposure before the age of 24 months

We investigated whether parents or caregivers believed that their child had received sufficient sunlight exposure before the age of 24 months; the prevalence of asthma “diagnosis, ever” and “symptom, ever,” were higher in children whose parents answered “no” than in children whose parents answered “yes” (“diagnosis, ever”: aOR, 1.54; 95% CI, 1.15–2.06;  $P=0.004$ ; “symptom, ever”: aOR, 1.3; 95% CI, 1.02–1.65;  $P=0.031$ ). However, there was no relationship between sunlight exposure before 24 months of age and asthma “symptoms in the past 12 months,” and “treatment during the past 12 months” (Table 4).

Insufficient sunlight exposure before 24 months of age was associated with a higher prevalence of AR “symptoms, ever,” and “diagnosis, ever.” In adjusted analyses, the OR for AR “symptoms, ever” was 1.25 folds higher (95% CI, 1.05–1.48;

$P=0.011$ ) in children whose parents answered “no.” Similarly, for AR “diagnosis, ever,” the OR was 1.4 folds higher (95% CI, 1.17–1.67;  $P<0.001$ ) in children whose parents answered “no.” No association was found between AR “symptoms in the past 12 months” “treatment during the past 12 months” and sunlight exposure before 24 months of age (Table 4).

Insufficient sunlight exposure before 24 months of age was associated with a higher prevalence of AD “symptoms, ever” (aOR, 1.3; 95% CI, 1.07–1.57;  $P=0.008$ ). AD “diagnosis, ever” was also more common in children whose parents answered “no” than in children whose parents answered “yes” (aOR, 1.26; 95% CI, 1.06–1.51;  $P=0.01$ ). There was no relationship between AD “symptoms in the past 12 months” “treatment during the past 12 months” and sunlight exposure before 24 months of age (Table 4).

There were also no group differences in FA “symptoms, ever,” “symptoms in the past 12 months,” “diagnosis, ever,” or “treatment in the past 12 months” (Table 4).

(2) Recent sunlight exposure

Unlike sunlight exposure before 24 months of age, there were no associations between the level of recent outdoor sunlight exposure and the prevalence of any allergic disease (i.e., asthma, AD, AR, and FA) (Tables 5, 6).

3) Recent exercise

We also evaluated whether the level of recent exercise was associated with recent allergic symptoms or treatment for allergic diseases using the following question: “Aside from school physical education classes, on how many days per week did your

**Table 3.** Relationship between the birth season and prevalence of allergic diseases

Birth season	Symptom, ever		Symptom, recent 1 yr		Diagnosis, ever		Treatment, recent 1 yr	
	aOR <sup>†</sup> (95% CI)	P value	aOR <sup>†</sup> (95% CI)	P value	aOR <sup>†</sup> (95% CI)	P value	aOR <sup>†</sup> (95% CI)	P value
Asthma*	0.82 (0.65–1.03)	0.094	1.01 (0.66–1.55)	0.960	0.83 (0.63–1.10)	0.200	0.83 (0.53–1.30)	0.418
Allergic rhinitis*	1.02 (0.87–1.20)	0.820	1.40 (0.96–2.05)	0.079	1.15 (0.97–1.36)	0.105	1.17 (0.98–1.41)	0.084
Atopic dermatitis*	1.24 (1.03–1.49)	0.024	1.24 (0.88–1.75)	0.223	1.14 (0.96–1.35)	0.125	1.01 (0.81–1.28)	0.900
Food allergy*	1.01 (0.81–1.25)	0.943	1.56 (1.09–2.24)	0.016	1.02 (0.73–1.42)	0.900	1.02 (0.58–1.78)	0.954

Parent’s allergic disease includes asthma, allergic rhinitis, atopic dermatitis, and food allergy.

aOR, adjusted odds ratio; CI, confidence interval; Summer, April to September; Winter, October to March.

\*Born in winter (reference: summer). <sup>†</sup>Odds ratios are calculated with adjustment by sex, age, body mass index, type of delivery, use of antibiotics before the age of 12 months, duration of breast feeding, and parental history of allergic diseases.

**Table 4.** Relationship between adequacy of sun exposure before the age of 24 months and prevalence of allergic diseases

Sunlight exposure before 24 months of age	Symptom, ever		Symptom, recent 1 yr		Diagnosis, ever		Treatment, recent 1 yr	
	aOR <sup>†</sup> (95% CI)	P value	aOR <sup>†</sup> (95% CI)	P value	aOR <sup>†</sup> (95% CI)	P value	aOR <sup>†</sup> (95% CI)	P value
Asthma*	1.30 (1.02–1.65)	0.031	0.74 (0.47–1.15)	0.179	1.54 (1.15–2.06)	0.004	1.06 (0.66–1.70)	0.815
Allergic rhinitis*	1.25 (1.05–1.48)	0.011	1.35 (0.90–2.01)	0.148	1.40 (1.17–1.67)	<0.001	1.20 (0.99–1.46)	0.060
Atopic dermatitis*	1.30 (1.07–1.57)	0.008	0.85 (0.59–1.21)	0.359	1.26 (1.06–1.51)	0.010	1.26 (0.99–1.60)	0.059
Food allergy*	1.00 (0.8–1.26)	0.971	1.08 (0.74–1.57)	0.686	0.77 (0.54–1.11)	0.16	0.88 (0.49–1.60)	0.678

Parent’s allergic disease includes asthma, allergic rhinitis, atopic dermatitis, and food allergy.

aOR, adjusted odds ratio; CI, confidence interval.

\*Insufficient (reference: sufficient). <sup>†</sup>Odds ratios are calculated with adjustment by sex, age, body mass index, type of delivery, use of antibiotics before the age of 12 months, duration of breast feeding, and parental history of allergic diseases.

**Table 5.** Relationship between the duration of sun exposure in winter and prevalence of allergic diseases

Duration of sunlight exposure per week	Symptom, ever		Symptom, recent 1 yr		Diagnosis, ever		Treatment, recent 1 yr	
	aOR <sup>†</sup> (95% CI)	P value	aOR <sup>†</sup> (95% CI)	P value	aOR <sup>†</sup> (95% CI)	P value	aOR <sup>†</sup> (95% CI)	P value
Asthma*	1.31 (0.96–1.77)	0.084	1.22 (0.67–2.23)	0.511	1.01 (0.70–1.46)	0.963	1.20 (0.67–2.16)	0.533
Allergic rhinitis*	1.12 (0.91–1.39)	0.279	1.35 (0.90–2.01)	0.776	0.93 (0.75–1.16)	0.528	0.95 (0.75–1.21)	0.688
Atopic dermatitis*	1.24 (0.97–1.58)	0.081	0.96 (0.61–1.49)	0.846	0.97 (0.78–1.21)	0.771	0.97 (0.72–1.31)	0.842
Food allergy*	1.19 (0.91–1.58)	0.209	1.30 (0.82–2.06)	0.258	1.14 (0.74–1.78)	0.553	1.65 (0.77–3.55)	0.199

Parent’s allergic disease includes asthma, allergic rhinitis, atopic dermatitis, and food allergy.

Winter, December to February; aOR, adjusted odds ratio; CI, confidence interval.

\* <2 hours (reference: ≥2 hours). <sup>†</sup>Odds ratios are calculated with adjustment by sex, age, body mass index, type of delivery, use of antibiotics before the age of 12 months, duration of breast feeding, and parental history of allergic diseases.

**Table 6.** Relationship between the duration of sun exposure in recent spring, summer, and autumn and prevalence of allergic diseases

Duration of sunlight exposure per week	Symptom, ever		Symptom, recent 1 yr		Diagnosis, ever		Treatment, recent 1 yr	
	aOR <sup>†</sup> (95% CI)	P value	aOR <sup>†</sup> (95% CI)	P value	aOR <sup>†</sup> (95% CI)	P value	aOR <sup>†</sup> (95% CI)	P value
Asthma*	0.85 (0.65–1.11)	0.223	0.82 (0.48–1.4)	0.476	0.82 (0.59–1.15)	0.259	0.79 (0.47–1.34)	0.380
Allergic rhinitis*	0.9 (0.75–1.1)	0.304	0.86 (0.55–1.36)	0.527	1.05 (0.86–1.29)	0.616	1.18 (0.95–1.47)	0.128
Atopic dermatitis*	0.86 (0.69–1.07)	0.174	1.19 (0.8–1.76)	0.392	0.97 (0.79–1.18)	0.762	1.06 (0.81–1.4)	0.661
Food allergy*	0.84 (0.66–1.08)	0.176	0.7 (0.46–1.06)	0.090	1.23 (0.83–1.83)	0.304	1.01 (0.53–1.93)	0.980

Parent’s allergic disease includes asthma, allergic rhinitis, atopic dermatitis, and food allergy.

Autumn, March to November; aOR, adjusted odds ratio; CI, confidence interval.

\* <2 hours (reference: ≥2 hours). <sup>†</sup>Odds ratios are calculated with adjustment by sex, age, body mass index, type of delivery, use of antibiotics before the age of 12 months, duration of breast feeding, and parental history of allergic diseases.

child exercise or play to the extent that they broke a sweat or experienced shortness of breath”? There was no association between the level of recent exercise and allergic disease prevalence, including that with respect to “diagnosis in the past 12 months” and “treatment in the past 12 months” (data not shown).

## Discussion

We hypothesized that there may be an association between the perinatal vitamin D status and the development of allergic diseases. Therefore, we examined the relationships among birth season, degree of sunlight exposure during infancy, and allergic disease prevalence in elementary school children.

We found that being born in winter was associated with an increased prevalence of lifetime AD symptoms and recent FA symptoms. Insufficient sunlight exposure during infancy was associated with an increased likelihood of developing all of the allergic diseases investigated except FA.

In addition to its effect on calcium homeostasis, vitamin D has major effects on innate and adaptive immunity, such that the influence of vitamin D on allergic diseases represents an area of significant interest. Although results are equivocal, a considerable body of evidence suggests that vitamin D has an important impact on the progression of allergic diseases<sup>11</sup>.

Following confirmation of the immunomodulatory effects of vitamin D and formulation of the hypothesis that vitamin D may

be associated with allergic disease prevalence, numerous studies pertaining to the relationship between vitamin D and allergic diseases have been conducted.

The prevalence of vitamin D deficiency continues to increase<sup>12</sup> and is particularly severe during winter months, in which ultraviolet B rays are reduced<sup>13</sup>. All ultraviolet radiation reaching the earth’s surface is markedly reduced in both autumn and winter<sup>13</sup>. Due to the reduced sun exposure associated with a Western life style and an increase in the number of people who spend the majority of their time indoors, vitamin deficiency is now common in Korea<sup>10</sup>. Insufficient vitamin D has been reported in 47.3% of males and 64.5% of females: the prevalence rate of vitamin D deficits is highest in those aged 20 to 29 years (65.0% of males and 79.9% of females)<sup>10</sup>. Vitamin D synthesis rates change periodically according to season; synthesis is at its highest during the summer and lowest during the winter<sup>14</sup>. Therefore, we assessed the correlation between birth season and allergic disease prevalence. Vitamin D levels in newborns are directly related to the mother’s condition<sup>15</sup>. Vitamin D passes to the fetus through the placenta; 25-hydroxy-vitamin D concentrations in umbilical cord blood at the time of delivery range from 68% to 108% of maternal levels<sup>15</sup>. Therefore, assessing the effects of birth season on allergic disease prevalence is important. The climate of Korea has recently changed to reflect subtropical conditions, with relatively short spring and autumn seasons. Therefore, for analysis purposes, we divided birth season into 2 categories: winter and summer.



Several studies have demonstrated associations of birth season with FA and allergen sensitization prevalence, particularly with respect to food and pollen<sup>8,16-18</sup>. Although the underlying mechanism remains to be clearly established, seasonal differences in ultraviolet B exposure, and perhaps also vitamin D levels, may be involved in the development of allergic diseases<sup>7,18</sup>.

In our study, the lifetime prevalence of AD symptoms and the previous 12-month prevalence of FA symptoms in children born in winter were higher than those in children born in summer. The odds of lifetime AD were 1.24 folds higher (95% CI, 1.03–1.49;  $P=0.024$ ) in children born in winter than summer. One study assessed the relationships among month of birth, sensitization, and manifestations of atopy in children followed from birth to 12 to 15 years of age: the prevalence rates of atopic disease and IgE antibodies to food and animal dander at 9 months were higher in children born in the autumn and winter seasons, (i.e., September to February) than in those born in spring and summer (egg, 20% vs. 6%; milk, 10% vs. 2%)<sup>19</sup>. In the present study, the prevalence of 12-month FA was 1.56 folds higher (95% CI, 1.09–2.24;  $P=0.016$ ) among children born in winter. Previous study showed that food allergies were more common in children born in Boston, during the autumn and winter seasons; those <5 years of age who were born in autumn or winter had a 53% higher likelihood of FA than controls<sup>7</sup>. In another study, autumn birth was associated with an increased risk of FA; this risk was greatest among those most likely to experience seasonal variations in vitamin D during infancy (Caucasians) and in those at risk of skin barrier dysfunction (i.e., subjects with a history of eczema)<sup>18</sup>.

Unlike AD and FA, there were no associations of the prevalence of asthma and AR with birth season in the present study. A few previous studies also found no association between season of birth and subsequent asthma and AR<sup>20,21</sup>. One study hypothesized that early exposure to respiratory viral infections, which are more prevalent during the winter months, and/or to aeroallergens (which also vary according to season) may sensitize children and increase the risk of developing wheezing, asthma, or AR<sup>20</sup>. However, they did not find relationships between season of birth and diagnosis of asthma. In a birth cohort study cord blood 25(OH)-vitamin D deficiency was associated with increased risk of recurrent troublesome lung symptoms till age 7 years, but showed no association with respiratory infection, asthma, or rhinitis<sup>21</sup>. In contrast, there are previous studies showing that birth of month are closely correlated with the presence of asthma or AR<sup>8,22</sup>.

We also examined whether sun exposure, during infancy and in recent years, was related to the prevalence of allergic diseases. The lifetime prevalence rates of asthma, AR, and AD diagnosis and symptoms were higher among children whose parents answered that their children had insufficient sun exposure before the age of 24 months. As expected, sun exposure during infancy was not related to the prevalence of asthma, AR, and AD symptoms

in the past 12 months. Early life represents an important period with respect to both allergic diseases and the development of the immune system. Therefore, we suggest that sun exposure and vitamin D status during infancy may have an impact on the likelihood of developing allergic diseases. According to our results, low sun exposure during infancy probably increases the risk of allergic diseases. In contrast with other allergic diseases, we did not find any association between winter birth and the presence of FA in school children. Because several studies showed that winter birth could be a risk factor for FA<sup>7,18</sup>, and vitamin D is considered as the factor that mediates the association between birth season and allergic diseases, we expected that insufficient sun exposure during infancy would exert a same influence on the presence of FA. There is no possible explanation for this because of lack of study. Numerous studies have shown that vitamin D deficiency is associated with an increased incidence of allergic diseases<sup>23,24</sup>. However, to the best of our knowledge, no previous study has assessed the association between sun exposure during infancy and the prevalence of allergic diseases.

In the questions asking the duration of recent sun exposure per week, those who answered “1 to 2 hours,” and “2 to 3 hours” are in the majority. The number of people who answered “less than 1 hour,” and “more than 3 hours” was small. So the data were analyzed after dividing the answers into two, “less than 2 hours,” and “more than 2 hours.” In contrast to sun exposure during infancy, we observed no relationship between the level of recent outdoor sun exposure and the prevalence of any allergic diseases (for all prevalence categories). This suggests that the level of recent sun exposure may not be associated with allergic diseases. However, other reports suggest that the recent vitamin D status is associated with allergen sensitization<sup>3,25,26</sup>. In one study, vitamin D deficiency in children and adolescents was reportedly associated with an increased prevalence of allergen sensitization<sup>24</sup>.

Although exercise can trigger bronchial hyper-responsiveness, outdoor play in children is likely to play a role in prophylaxis against persistent wheezing. Decreased physical activity may have played a major role in the recent increase in asthma prevalence and severity<sup>27</sup>. A recent study demonstrated that aerobic training reduced bronchial hyper-responsiveness and serum pro-inflammatory cytokines and improved quality of life and asthma exacerbation in patient with moderate or severe asthma<sup>28</sup>. Therefore, we hypothesized that physical exercise would be associated with decreased prevalence rates for recent asthma treatment and diagnosis. However, the level of recent outdoor exercise was not related to the prevalence of allergic diseases, including asthma, and also showed no association with the likelihood of recent asthma treatment or diagnosis.

This study had several important limitations, the first of which concerns the data collection method. We used a ques-

tionnaire-based, cross-sectional design with no physical examinations performed by doctors. Therefore, the allergic disease prevalence rates may be overestimated, particularly with respect to symptoms; for example, food intolerance is frequently misclassified as a hypersensitivity reaction. Second, we asked parents or caregivers whether their child had experienced sufficient sunlight exposure before 24 months of age, and they answered the question only from past memory. We did not clearly define an exact amount of sunlight exposure. Therefore, these data can be highly subjective and may also be affected by recall bias. Third, we could not directly examine the relationship between vitamin D status and allergic disease prevalence because serum vitamin D levels were not recorded. Finally, there is a lack of research on the effect factor for amount of sun exposure and vitamin D status such as clothes and vitamin D supplements. Despite these limitations, our results are meaningful for the following reasons: (1) a relatively large number of children were surveyed; and (2) response bias is unlikely given the high response rate (98.4%).

In conclusion, being born during winter months may be associated with the prevalence of AD and FA symptoms. Furthermore, it appears possible that a low level of sunlight exposure before the age of 24 months may increase the risk of asthma, AR, and AD in elementary school children. To confirm the effect of sun exposure during infancy on the development of allergic diseases, further prospective investigations that measure serum vitamin D levels are required.

## Conflict of interest

No potential conflict of interest relevant to this article was reported.

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