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Prevalence of allergic diseases among Korean adolescents during the COVID-19 pandemic: comparison with pre-COVID-19 11-year trends

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Abstract. – OBJECTIVE: During the coronavirus disease 2019 (COVID-19) pandemic, emergency department utilization and hospitalization rates for allergic diseases declined and the severity of allergies among admitted patients was low. This study aimed to determine the prevalence of allergic diseases among adolescents and the changes in trend during the COVID-19 pandemic compared with those during the preceding 11 years.

SUBJECTS AND METHODS: We analyzed data from the nationwide web-based self-report Korea Youth Risk Behavior Survey. From 2009 to 2020, adolescents aged 13-18 years participated in the survey. The survey period was divided into pre-pandemic Periods I (2009-2011), II (2012-2014), III (2015-2017), and IV (2018-2019) and the pandemic period (Period V, 2020). The current prevalence of asthma, allergic rhinitis, atopic dermatitis, allergic morbidity (having at least one of the three conditions) and changes in the prevalence before and during the COVID-19 pandemic were analyzed.

RESULTS: Data of 787,043 participants were analyzed after weighting the study population (mean age, 15.1 years; males, 52.3%). The prevalence of asthma, allergic rhinitis, atopic dermatitis, and allergic morbidity was 2.1%, 18.4%, 6.8%, and 23.6%, respectively. The prevalence of allergic morbidity increased between Periods I and IV but declined significantly from Periods IV to V. From Periods I to IV, the prevalence of asthma decreased, the prevalence of allergic rhinitis increased, and the prevalence of atopic dermatitis remained unchanged. During Period V, the prevalence of all three conditions decreased.

CONCLUSIONS: It is necessary to update management measures and develop relevant policies in response to the altered prevalence of allergic diseases since the outbreak of COVID-19.

Key Words:
COVID-19, Asthma, Allergic rhinitis, Atopic dermatitis, Allergic morbidity, Adolescent, Disease prevalence, KYRBS.

Introduction

Asthma and other allergic diseases are among the most common chronic conditions in adolescence worldwide[1,2]. Adolescents undergo dramatic physical growth and changes in hormonal composition and secretion during puberty. During this period, adolescents engage in more activities, start drinking and smoking, and display poor medication adherence. The regulation and exacerbation of allergic diseases among adolescents are influenced by complex interactions among such diverse factors[3,4]. Large-scale epidemiological studies[5] have reported that the prevalence of allergic diseases differs between adolescence and childhood.

The coronavirus disease 2019 (COVID-19) pandemic has drastically transformed the behavioral traits of people throughout society. People enhanced their personal hygiene levels, wore face masks, and practiced social distancing[6]. Furthermore, particulate matter and air pollution were reduced[7]. In compliance with government policies, adolescents followed an alternate schedule for online classes and cut back on all activities outside their homes and social gatherings[6]. Furthermore, emergency department utilization and hospitalization rates for allergic diseases declined, and the severity of allergic diseases decreased[8,9]. However, there is a paucity of large-scale studies[10]

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that examined whether the prevalence of allergic diseases actually decreased during the pandemic. Moreover, none of the previous studies[11] have compared the changes in allergic disease prevalence trend during the pandemic with changes in the pre-pandemic long-term trend.

Therefore, this study aimed to investigate whether the prevalence of allergic diseases among adolescents declined during the pandemic and to compare the change in this prevalence trend during the pandemic with changes in the trend during the 11 years preceding the pandemic. This study utilized the nationally representative Korea Youth Risk Behavior Survey (KYRBS) data.

Subjects and Methods

Study Population

We used data from the KYRBS[11], which was supervised by the Korea Disease Control and Prevention Agency (KDCA) and Ministry of Education, to establish and evaluate government policies. The data (including information on smoking, drinking, physical activity, and allergic diseases) were used to investigate the health behavior of a nationally representative sample of adolescents in 15 areas. The KYRBS selected the study population by applying two-step stratification in the order of school and class, with details specified on the official website of the KDCA (http://www.kdca.go.kr/yhs/). The participants completed a web-based survey in computer laboratories at their respective schools. These data were gathered voluntarily, with a response rate of over 95%. The reliability and validity of the KYRBS were verified[12]. We used data for a 12-year period from 2009 to 2020. All adolescents (age, 12-18 years: middle to high school) were included. Participants with missing data were excluded from the study. The KYRBS is a government-approved statistical survey (approval number 117058), and its results and raw data are disclosed online. In this study, we performed secondary analysis of the data. The study protocol was exempted from review by the Institutional Review Board of Seoul National University/Seoul National University Hospital (No. 2108-137-1246).

Variable Definitions

Current asthma, allergic rhinitis, and atopic dermatitis were defined as having been diagnosed with the respective condition by a physician in the past 12 months. Individuals with at least one of the three conditions (asthma, allergic rhinitis, and/or atopic dermatitis) were considered to have allergic morbidity. Body mass index (BMI) was calculated from the self-reported height and weight of the participant and classified as follows: underweight (<5th percentile), normal (5th-84th percentile), overweight (85th-94th percentile), and obesity (≥95th percentile). The areas of residence were classified as large cities or rural areas (including small- and medium-sized cities)[5]. Smoking was defined as having smoked a cigarette at least once within the last 30 days. Alcohol consumption was assessed based on a 30-day drinking frequency (0, 1-5, 6-30 days/month). Physical activity was determined based on the number of days per week in which an individual engaged in ≥60 min of physical activity for increased heart rate or dyspnea (≤1, 2-4, and 5-7 days). Parents' educational levels were determined based on the highest educational level of either parent (high school or lower, college or higher, and unknown)[11]. Economic status and school performance were classified as high, middle-high, middle, middle-low, or low. Sleep satisfaction was indicated by the responses "very sufficient" and "sufficient" to the question on whether the sleep duration in the preceding 7 days was sufficient for fatigue relief[11]. Parents' educational levels, economic status, and school performance were self-reported.

Statistical Analysis

We used data from the KYRBS from 2009 to 2020 to calculate the prevalence of allergic disorders, including allergic morbidity, asthma, allergic rhinitis, and atopic dermatitis, stratified by sex, BMI group, and residence area. Baseline covariates were considered for the following factors: age, sex, BMI group, residence area, smoking, alcohol consumption, highest educational level of parents, economic level, and school performance.

The pre-COVID-19 period was set in consideration of the KYRBS cycle of 2 or 3 consecutive years to stabilize the prevalence. Consequently, Period I was defined as the period from 2009 to 2011; Period II, 2012-2014; Period III, 2015-2017; and Period IV, 2018-2019. Considering that the first COVID-19 case in South Korea was reported on January 20, 2020, Period V in 2020 was defined as the COVID-19 pandemic period.

We performed several analyses using weighted complex sampling analysis with binary and linear logistic regression models and Fisher's exact tests. These analyses are presented as weighted odds ratios (ORs) with 95% confidence intervals (CIs) or

weighted β-coefficients with 95% CIs. βbc and βac were defined as β-coefficients between Periods I and IV and IV and V, respectively. Trend difference was analyzed as βdiff (βac-βbc). All analyses were performed using the SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Statistical significance was defined as a two-sided *p*-value of <0.05.

Our next endpoint was whether the COVID-19 pandemic affected the trends in the prevalence of allergic disorders. We tested whether trends in the prevalence of asthma, allergic rhinitis, and atopic dermatitis changed during the COVID-19 pandemic compared with that before the pandemic. The estimated β (95% CI) was calculated using linear regression or its related difference, and the KYRBS cycle was analyzed as a continuous variable. The estimated OR (95% CI) was calculated using binomial regression, and the KYRBS cycles (Period IV *vs.* Period V) were analyzed as categorical variables.

Results

From 810,766 participants, 23,723 with missing data were excluded. Thus, 787,043 participants were included in the analysis. There were 216,682 participants in Period I, 212,542 in Period II, 190,201 in Period III, 114,084 in Period IV, and 53,534 participants in Period V (the COVID-19 pandemic; Figure 1).

Supplementary Table I in the Online Repository presents the demographic characteristics of the total and weighted samples. The weighted mean age was 15.1 years. The weighted male sex proportion was 52.3%, and 55.1% of the participants lived in a rural area.

Table I shows participants' characteristics stratified by the type of allergic disease. The prevalence of asthma, allergic rhinitis, and atopic dermatitis was 2.1%, 18.4%, and 6.8%, respectively. The prevalence of allergic morbidity was 23.1%. The mean age of the allergic morbidity group was 15.1 years, and 50.2% were male. Compared with the no allergy group, this group showed a significantly higher economic status (high, 8.7% *vs.* 8.2%; middle-high, 27.7% *vs.* 25.7%) and school performance (high, 13.7% *vs.* 11.4%; middle-high, 26.4% *vs.* 24.2%). The mean age of the asthma group was 14.8 years, and there were more males (61.5%) than females. Of the participants with asthma, 11.8% and 6.4% were overweight and had obesity, respectively. These proportions were higher than the 9.8% and 4.9%, respectively, in

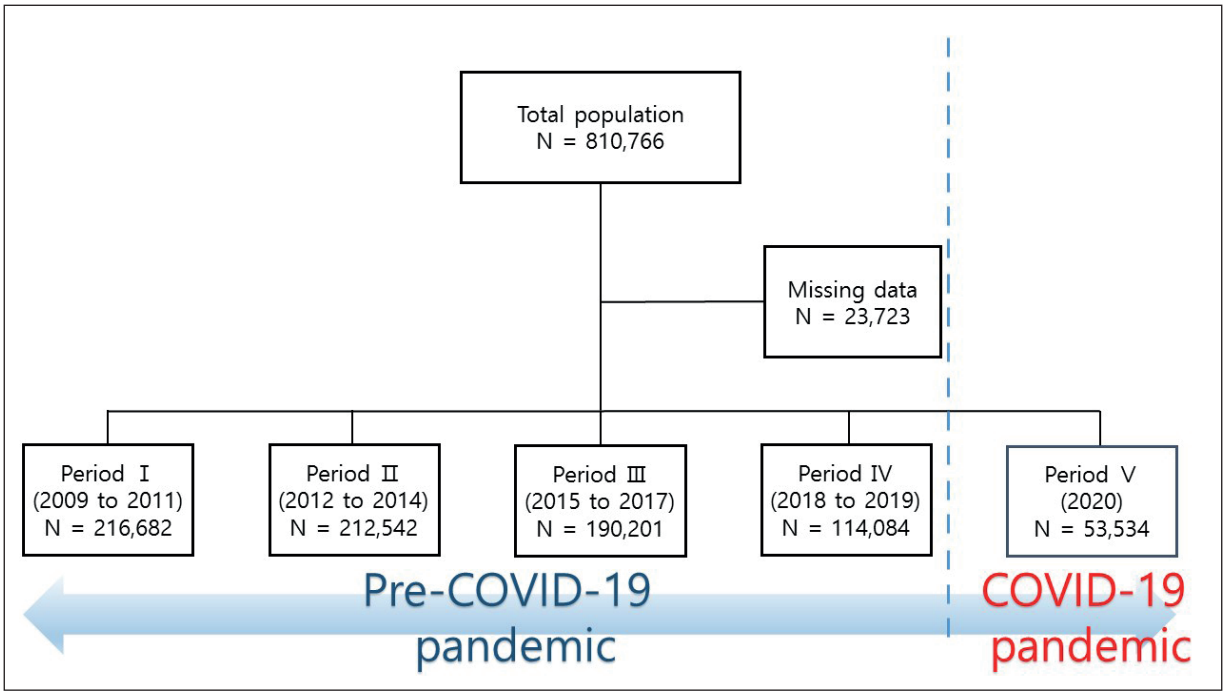

Figure 1. Schematic diagram showing classification of particiants by period. The survey period was divided into pre-COVID-19 Periods I (2009-2011), II (2012-2014), III (2015-2017), and IV (2018-2019) and Period V (2020) representing the COVID-19 pandemic period.

Table I. Demographic and clinical characteristics of participating adolescents in the KYRBS stratified by disease (N = 787,043).

Characteristic	Non-allergic disease	Allergic morbidity†	Allergic diseases		
			Asthma	Allergic rhinitis	Atopic dermatitis
Number, n (%)	605,088 (76.9)	181,955 (23.1)	16,822 (2.1)	140,635 (17.9)	53,587 (6.8)
Overall prevalence, weighted % (95% CI)	76.4 (76.3 to 76.5)	23.6 (23.5 to 23.7)	2.1 (2.1 to 2.2)	18.4 (18.3 to 18.5)	6.8 (6.8 to 6.9)
Age, years, weighted mean (95% CI)	15.1 (15.0 to 15.1)	15.05 (15.04 to 15.07)	14.82 (14.78 to 14.85)	15.17 (15.15 to 15.19)	15.09 (15.07 to 15.11)
Sex, male, weighted % (95% CI)	53.0 (52.2 to 53.8)	50.2 (49.4 to 51.1)	61.5 (60.4 to 62.6)	51.1 (50.2 to 52.0)	44.3 (43.4 to 45.3)
BMI, kg/m^2, weighted % (95% CI)					
Underweight (below 5th percentile)	5.0 (4.9 to 5.0)	4.3 (4.2 to 4.4)	4.8 (4.5 to 5.1)	4.3 (4.2 to 4.4)	4.1 (3.9 to 4.3)
Normal (5th–85th percentile)	80.3 (80.2 to 80.5)	80.1 (79.8 to 80.3)	77.0 (76.3 to 77.7)	80.4 (80.1 to 80.7)	79.1 (78.7 to 79.6)
Overweight (85th–95th percentile)	9.8 (9.7 to 9.9)	10.5 (10.3 to 10.6)	11.8 (11.3 to 12.4)	10.3 (10.1 to 10.5)	11.2 (10.9 to 11.5)
Obese (above 95th percentile)	4.9 (4.8 to 5.0)	5.2 (5.0 to 5.3)	6.4 (6.0 to 6.8)	5.0 (4.9 to 5.1)	5.5 (5.3 to 5.8)
Region of residence, weighted % (95% CI)					
Rural	55.0 (54.6 to 55.4)	55.5 (55.0 to 56.0)	57.2 (56.2 to 58.2)	55.3 (54.7 to 55.8)	55.8 (55.2 to 56.5)
Urban	45.0 (44.6 to 45.4)	44.5 (44.0 to 45.0)	42.8 (41.8 to 43.8)	44.7 (44.2 to 45.3)	44.2 (43.5 to 44.8)
Smoking, weighted % (95% CI)	8.7 (8.6 to 8.9)	9.3 (9.1 to 9.6)	14.1 (13.4 to 14.7)	9.2 (8.9 to 9.4)	9.4 (9.1 to 9.8)
Alcohol consumption, weighted % (95% CI)					
0 days/month	83.3 (83.1 to 83.4)	81.4 (81.2 to 81.7)	78.6 (77.9 to 79.4)	81.5 (81.2 to 81.8)	81.2 (80.8 to 81.6)
1–5 days/month	13.0 (12.8 to 13.1)	14.4 (14.2 to 14.6)	14.9 (14.3 to 15.6)	14.4 (14.2 to 14.7)	14.3 (13.9 to 14.6)
6–30 days/month	3.8 (3.7 to 3.9)	4.2 (4.1 to 4.3)	6.5 (6.0 to 6.9)	4.1 (3.9 to 4.2)	4.5 (4.3 to 4.7)
Physical activity, weighted % (95% CI)					
≤1 days per week	55.1 (54.8 to 55.4)	53.6 (53.2 to 53.9)	48.8 (47.9 to 49.7)	53.0 (52.7 to 53.4)	55.8 (55.2 to 56.3)
2–4 days per week	32.4 (32.2 to 32.6)	33.7 (33.4 to 34.0)	36.0 (35.2 to 36.9)	34.0 (33.7 to 34.3)	32.2 (31.7 to 32.6)
5–7 days per week	12.5 (12.4 to 12.7)	12.8 (12.6 to 13.0)	15.2 (14.5 to 15.8)	12.9 (12.7 to 13.2)	12.1 (11.8 to 12.4)
Highest educational level of parents, weighted % (95% CI)					
High school or lower	27.5 (27.2 to 27.7)	26.2 (25.9 to 26.6)	26.6 (25.7 to 27.4)	25.4 (25.1 to 25.8)	27.8 (27.3 to 28.3)
College or higher	48.7 (48.4 to 49.0)	55.7 (55.3 to 56.1)	52.2 (51.2 to 53.1)	57.4 (56.9 to 57.8)	52.5 (51.9 to 53.1)
Unknown	23.8 (23.6 to 24.0)	18.1 (17.8 to 18.3)	21.3 (20.6 to 22.0)	17.2 (16.9 to 17.4)	19.7 (19.3 to 20.1)
Economic level, weighted % (95% CI)					
High	8.2 (8.0 to 8.3)	8.7 (8.5 to 8.9)	11.1 (10.6 to 11.7)	9.0 (8.8 to 9.2)	8.1 (7.8 to 8.4)
Middle-high	25.7 (25.5 to 25.8)	27.7 (27.5 to 28.0)	26.4 (25.6 to 27.1)	28.6 (28.3 to 28.9)	25.1 (24.6 to 25.5)
Middle	47.9 (47.7 to 48.1)	45.3 (45.0 to 45.6)	42.1 (41.3 to 43.0)	44.9 (44.6 to 45.3)	46.3 (45.8 to 46.8)
Middle-low	14.5 (14.4 to 14.7)	14.4 (14.2 to 14.6)	14.4 (13.8 to 15.1)	13.8 (13.6 to 14.1)	16.0 (15.6 to 16.4)
Low	3.8 (3.7 to 3.8)	3.8 (3.7 to 4.0)	5.9 (5.5 to 6.3)	3.6 (3.5 to 3.7)	4.6 (4.4 to 4.8)
School performance, weighted % (95% CI)					
High	11.4 (11.3 to 11.5)	13.7 (13.5 to 13.9)	12.5 (11.9 to 13.0)	14.5 (14.2 to 14.7)	11.8 (11.5 to 12.1)
Middle-high	24.2 (24.1 to 24.4)	26.4 (26.2 to 26.7)	23.6 (22.9 to 24.4)	27.3 (27.0 to 27.5)	24.5 (24.1 to 24.9)
Middle	28.5 (28.4 to 28.7)	27.4 (27.1 to 27.6)	26.1 (25.4 to 26.9)	27.4 (27.0 to 27.5)	27.3 (26.8 to 27.7)
Middle-low	24.6 (24.4 to 24.7)	22.5 (22.3 to 22.7)	24.1 (23.3 to 24.9)	21.6 (21.3 to 21.9)	24.7 (24.3 to 25.2)
Low	11.3 (11.2 to 11.4)	10.0 (9.9 to 10.2)	13.7 (13.1 to 14.3)	9.3 (9.1 to 9.5)	11.7 (11.4 to 12.0)

BMI, body mass index; KYRBS, Korea Youth Risk Behavior Web-based Survey; SD, standard deviation. † Allergic morbidity was defined as having one or more of the following conditions: asthma, allergic rhinitis, and/or atopic dermatitis. Continuous and categorical variables were analyzed using the design-based Wilcoxon rank-sum test and chi-square test, respectively.

the no allergy group. Furthermore, the proportion of participants living in rural areas and those who were smokers was significantly higher in the asthma group than in the no allergy group (rural residency, 57.2% *vs.* 55.0%; smoking, 14.1% *vs.* 8.7%). The degree of physical activity was also higher in the asthma group than in the no allergy group (2-4 days per week, 36.0% *vs.* 32.4%; 5-7 days per week, 15.2% *vs.* 12.5%). The mean age of participants in the allergic rhinitis group was 15.2 years, and 51.1% were male. The allergic rhinitis group showed higher school performance than the no allergy group (high, 14.5% *vs.* 11.4%; middle-high, 27.3% *vs.* 24.2%). The mean age of participants in the atopic dermatitis group was 15.1 years, and 44.3% were male, showing a higher proportion of females. The prevalence of being overweight and of obesity was higher in the atopic dermatitis group than in the no allergy group (overweight, 11.2% *vs.* 9.8%; obesity, 5.5% *vs.* 4.9%).

Changes in the prevalence of allergic morbidity, asthma, allergic rhinitis, and atopic dermatitis from 2009 to 2020 are shown in Figure 2 and Tables II-V. The slope for the prevalence of allergic morbidity was positive between Periods I and IV, showing a gradual increase, and negative between Periods IV and V, showing a decline in prevalence (Table II). There was a negative change in the slope (β_{diff} = −0.086; 95% CI, −0.096 to −0.076) from periods before the pandemic to during the pandemic, showing a significant reduction in prevalence. The prevalence was significantly lower during Period V than during Period IV. This trend was consistent regardless of sex, obesity status, and area of residence (Table II).

The prevalence of asthma declined between Periods I and IV, as shown by a negative slope (Table III). In the subgroup analysis, there was a significant declining trend in prevalence among the male participants; however, the trend was similar but not significant among female participants. The slope between Periods IV and V was significantly negative, and the prevalence of asthma was significantly lower than that between Periods I and IV (β_{diff} = −0.097; 95% CI, −0.123 to −0.071). The declining trend in prevalence during this period was consistent regardless of sex, obesity status, and area of residence. The prevalence significantly decreased, by 49%, between Periods IV and V (Table III).

The slope for the prevalence of allergic rhinitis was positive between Periods I and IV, showing an increase. The slope was greater among female participants than among male participants, and the 95%

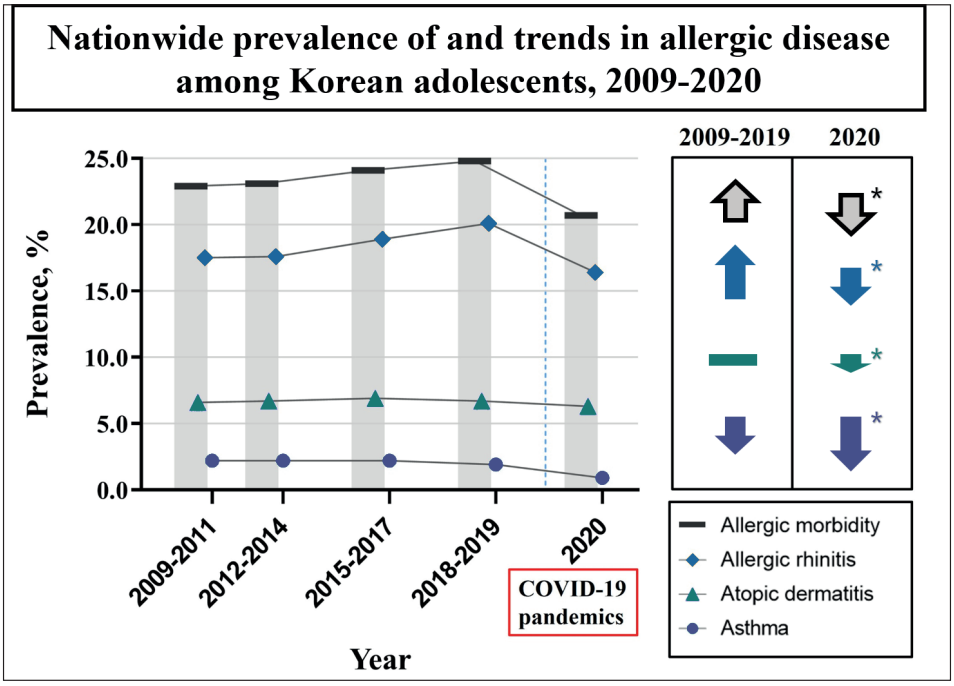

Figure 2. Nationwide trends and prevalence of allergic diseases among Korean adolescents from 2009 to 2020. Prevalence trends are illustrated using arrows that indicate an increase, no change, or a decrease. The size of the arrow is expressed according to the absolute value of β (<0.3, ≥0.3 to <0.6, and ≥0.6). * Significant trend difference.

Table II. Allergic morbidity weighted prevalence and trend in the Korean general adolescent population using the KYRBS from 2009 to 2020.

	Trends in current allergic morbidity†								Odds for prevalence of current allergic morbidity† before and after entering the COVID-19 pandemic, OR (95% CI)[b]
	Pre-COVID-19 pandemic era				COVID-19 pandemic	Trend before entering the COVID-19 pandemic, β_{bc} (95% CI) [a]	Trend after entering the COVID-19 pandemic, β_{ac} (95% CI) [a]	Trend difference, β_{diff} (95% CI)	
	Period I‡	Period II‡	Period III‡	Period IV‡	Period V‡	Period I‡ to IV‡	Period IV‡ to V‡	β_{ac} - β_{bc}	Period IV‡ to V‡
Current allergic morbidity†, weighted% (95% CI)									
Overall	23.2 (22.9-23.5)	23.3 (23.1-23.5)	24.3 (24.1-24.6)	25.1 (24.8-25.4)	21.2 (20.7-21.6)	**0.039 (0.031 to 0.047)**	**-0.047 (-0.054 to -0.041)**	**-0.086 (-0.096 to -0.076)**	**0.802 (0.777-0.828)**
Sex									
Male	22.7 (22.4-23.1)	22.4 (22.1-22.7)	23.3 (22.9-23.6)	23.4 (22.9-23.8)	20.0 (19.4-20.4)	**0.016 (0.005 to 0.027)**	**-0.042 (-0.052 to -0.033)**	**-0.058 (-0.073 to -0.043)**	**0.821 (0.784-0.859)**
Female	23.7 (23.3-24.1)	24.3 (24.0-24.7)	25.5 (25.2-25.9)	27.0 (26.5-27.4)	22.4 (21.9-23.0)	**0.062 (0.051 to 0.073)**	**-0.052 (-0.061 to -0.044)**	**-0.114 (-0.128 to -0.100)**	**0.783 (0.752-0.816)**
BMI									
Normal or less	23.0 (22.7-23.3)	23.1 (22.9-23.4)	24.1 (23.8-24.4)	24.9 (24.6-25.3)	20.9 (20.4-21.4)	**0.035 (0.030 to 0.046)**	**-0.049 (-0.056 to -0.041)**	**-0.084 (-0.095 to -0.073)**	**0.794 (0.767-0.823)**
Overweight or obese	24.6 (24.0-25.2)	24.3 (23.7-24.9)	25.5 (24.9-26.0)	25.8 (25.1-26.4)	22.3 (21.4-23.2)	**0.029 (0.012 to 0.046)**	**-0.043 (-0.056 to -0.029)**	**-0.072 (-0.094 to -0.050)**	**0.826 (0.777-0.879)**
Region of residence									
Rural	23.6 (23.2-24.0)	23.3 (22.9-23.6)	24.5 (24.2-24.9)	25.2 (24.8-25.7)	20.9 (20.3-21.6)	**0.035 (0.024 to 0.046)**	**-0.052 (-0.061 to -0.043)**	**-0.087 (-0.101 to -0.073)**	**0.784 (0.749-0.820)**
Urban	22.7 (22.4-23.1)	23.3 (23.0-23.7)	24.1 (23.7-24.5)	24.9 (24.4-25.3)	21.5 (20.9-22.2)	**0.043 (0.032 to 0.053)**	**-0.040 (-0.050 to -0.031)**	**-0.083 (-0.097 to -0.069)**	**0.827 (0.791-0.866)**

BMI, body mass index; CI, confidence interval; KYRBS, Korea Youth Risk Behavior Web-based Survey; OR, odds ratio. †Allergic morbidity was defined as having one or more of the following diseases: asthma, allergic rhinitis, and/or atopic dermatitis. ‡We defined Period I as 2009–2011; Period II, 2012–2014; Period III, 2015–2017; Period IV, 2018–2019; and Period V, 2020. [a]The estimated β (95% CI) was derived using linear regression, and this analysis included the KYRBS cycle (Period I, II, III, IV, V) as a continuous variable. [b]The estimated OR (95% CI) was calculated using binomial regression, and this analysis included the KYRBS cycle (Period IV and V) as a categorical variable. Numbers in bold indicate a significant difference ($p < 0.05$).

Table III. Asthma weighted prevalence and trend in the Korean general adolescent population using the KYRBS from 2009 to 2020.

	Trends in current asthma								Odds for prevalence of current asthma before and after entering the COVID-19 pandemic, OR (95% CI)[b]
	Pre-COVID-19 pandemic era				COVID-19 pandemic	Trend before entering the COVID-19 pandemic, β_{bc} (95% CI) [a]	Trend after entering the COVID-19 pandemic, β_{ac} (95% CI) [a]	Trend difference, β_{diff} (95% CI)	
	Period I†	Period II†	Period III†	Period IV†	Period V†	Period I† to IV†	Period IV† to V†	β_{ac} - β_{bc}	Period IV† to V†
Current asthma, weighted % (95% CI)									
Overall	2.2 (2.2-2.3)	2.3 (2.2-2.4)	2.2 (2.2-2.3)	2.0 (1.9-2.1)	1.0 (0.9-1.1)	**-0.031 (-0.051 to -0.011)**	**-0.128 (-0.145 to -0.111)**	**-0.097 (-0.123 to -0.071)**	**0.510 (0.458-0.566)**
Sex									
Male	2.6 (2.5-2.7)	2.7 (2.6-2.8)	2.6 (2.5-2.8)	2.3 (2.1-2.4)	1.1 (1.0-1.3)	**-0.036 (-0.061 to -0.010)**	**-0.132 (-0.155 to -0.109)**	**-0.096 (-0.130 to -0.062)**	**0.497 (0.431-0.573)**
Female	1.8 (1.7-1.9)	1.8 (1.7-1.9)	1.8 (1.7-1.9)	1.7 (1.6-1.8)	0.9 (0.8-1.0)	-0.021 (-0.051 to 0.010)	**-0.122 (-0.149 to -0.096)**	**-0.101 (-0.141 to -0.061)**	**0.528 (0.451-0.618)**
BMI									
Normal or less	2.2 (2.1-2.2)	2.2 (2.1-2.3)	2.1 (2.1-2.2)	1.9 (1.8-2.0)	0.9 (0.8-1.0)	**-0.036 (-0.058 to -0.015)**	**-0.135 (-0.153 to -0.116)**	**-0.099 (-0.127 to -0.071)**	**0.483 (0.427-0.546)**
Overweight or obese	2.8 (2.6-3.1)	2.9 (2.6-3.1)	2.6 (2.4-2.8)	2.5 (2.3-2.8)	1.4 (1.2-1.7)	**-0.050 (-0.096 to -0.003)**	**-0.115 (-0.152 to -0.079)**	**-0.065 (-0.124 to -0.006)**	**0.568 (0.464-0.695)**
Region of residence									
Rural	2.3 (2.2-2.4)	2.4 (2.3-2.5)	2.4 (2.2-2.5)	2.0 (1.9-2.2)	1.0 (0.9-1.2)	**-0.034 (-0.061 to -0.007)**	**-0.127 (-0.150 to -0.105)**	**-0.093 (-0.128 to -0.058)**	**0.513 (0.448-0.588)**
Urban	2.1 (20.-2.2)	2.2 (2.1-2.3)	2.1 (2.0-2.2)	1.9 (1.8-2.1)	1.0 (0.9-1.2)	**-0.032 (-0.060 to -0.003)**	**-0.129 (-0.156 to -0.103)**	**-0.097 (-0.180 to -0.014)**	**0.504 (0.426-0.596)**

BMI, body mass index; CI, confidence interval; KYRBS, Korea Youth Risk Behavior Web-based Survey; OR, odds ratio. †We defined Period I as 2009–2011; Period II, 2012–2014; Period III, 2015–2017; Period IV, 2018–2019; and Period V, 2020. [a]The estimated β (95% CI) was derived using linear regression, and this analysis included the KYRBS cycle (Period I, II, III, IV, V) as a continuous variable. [b]The estimated OR (95% CI) was derived using binomial regression, and this analysis included the KYRBS cycle (Period IV and V) as a categorical variable. Numbers in bold indicate a significant difference ($p < 0.05$).

Table IV. Allergic rhinitis weighted prevalence and trend in the Korean general adolescent population using the KYRBS from 2009 to 2020.

	Trends in current allergic rhinitis								
	Pre-COVID-19 pandemic era				COVID-19 pandemic	Trend before entering the COVID-19 pandemic, β_{bc} (95% CI) [a]	Trend after entering the COVID-19 pandemic, β_{ac} (95% CI) [a]	Trend difference, β_{diff} (95% CI)	Odds for prevalence of current asthma before and after entering the COVID-19 pandemic, OR (95% CI)[b]
	Period I†	Period II†	Period III†	Period IV†	Period V†	Period I† to IV†	Period IV† to V†	β_{ac} - β_{bc}	Period IV† to V†
Current allergic rhinitis, weighted % (95% CI)									
Overall	17.8 (17.5-18.0)	17.9 (17.6-18.1)	19.1 (18.9-19.3)	20.4 (20.1-20.8)	16.8 (16.4-17.3)	**0.062 (0.053 to 0.071)**	**-0.051 (-0.058 to -0.044)**	**-0.113 (-0.124 to -0.102)**	**-0.113 (-0.124 to -0.102)**
Sex									
Male	17.8 (17.5-18.2)	17.5 (17.2-17.8)	18.6 (18.3-18.9)	19.2 (18.8-19.7)	16.1 (15.6-16.7)	**0.036 (0.023 to 0.048)**	**-0.046 (-0.056 to -0.035)**	**-0.082 (-0.113 to -0.051)**	**0.807 (0.767-0.850)**
Female	17.7 (17.4-18.1)	18.3 (18.0-18.6)	19.7 (19.4-20.0)	21.8 (21.3-22.2)	17.6 (17.0-18.1)	**0.090 (0.078 to 0.102)**	**-0.057 (-0.066 to -0.047)**	**-0.147 (-0.162 to -0.132)**	**0.766 (0.731-0.803)**
BMI									
Normal or less	17.7 (17.4-18.0)	17.9 (17.6-18.1)	19.0 (18.8-19.3)	20.5 (20.1-20.8)	16.6 (16.1-17.1)	**0.062 (0.053 to 0.072)**	**-0.054 (-0.062 to -0.046)**	**-0.116 (-0.128 to -0.104)**	**0.774 (0.744-0.806)**
Overweight or obese	18.5 (17.9-19.1)	18.0 (17.5-18.5)	19.6 (19.1-20.1)	20.4 (19.8-21.0)	17.6 (16.8-18.4)	**0.053 (0.034 to 0.073)**	**-0.041 (-0.055 to -0.026)**	**-0.094 (-0.128 to -0.060)**	**0.833 (0.779-0.890)**
Region of residence									
Rural	18.1 (17.7-18.5)	17.8 (17.5-18.1)	19.1 (18.8-19.4)	20.4 (20.0-20.9)	16.5 (15.9-17.1)	**0.055 (0.042 to 0.068)**	**-0.055 (-0.066 to -0.045)**	**-0.110 (-0.127 to -0.093)**	**0.808 (0.768-0.850)**
Urban	17.5 (17.1-17.8)	18.0 (17.7-18.3)	19.1 (18.8-19.5)	20.5 (20.0-20.9)	17.2 (16.6-17.8)	**0.070 (0.058 to 0.082)**	**-0.045 (-0.056 to -0.035)**	**-0.115 (-0.131 to -0.099)**	**0.771 (0.733-0.812)**

BMI, body mass index; CI, confidence interval; KYRBS, Korea Youth Risk Behavior Web-based Survey; OR, odds ratio. †We defined Period I as 2009–2011; Period II, 2012–2014; Period III, 2015–2017; Period IV, 2018–2019; and Period V, 2020. [a]The estimated β (95% CI) was derived using linear regression, and this analysis included the KYRBS cycle (Period I, II, III, IV, V) as a continuous variable. [b]The estimated OR (95% CI) was derived using binomial regression, and this analysis included the KYRBS cycle (Period IV and V) as a categorical variable. Numbers in bold indicate a significant difference ($p < 0.05$).

CI did not overlap (Table IV). However, the overall prevalence declined significantly between Periods IV and V. The difference in the change of prevalence between before and during the pandemic was significant (β_{diff} = −0.113; 95% CI, −0.124 to −0.102). The change in slope was evident regardless of sex, obesity status, and area of residence. The prevalence of allergic rhinitis decreased significantly by 21.3% from Periods IV to V (Table IV).

The prevalence of atopic dermatitis increased slowly from Periods I to IV, but the change was not significant (β_{bc} = 0.011; 95% CI, −0.001 to 0.022) (Table V). In the subgroup analysis, there was a significant increasing trend only among females, but the slope was significantly small. With the onset of the COVID-19 pandemic, the prevalence declined slightly but significantly (β = −0.011; 95% CI, −0.021 to −0.001). Compared with the pre-COVID-19 pandemic trend, the prevalence decreased significantly (β_{diff} = −0.022; 95% CI, −0.037 to −0.007) during the pandemic. Such a change in slope was consistent between the female participants and rural resident group in the subgroup analysis. However, there were no statistically significant changes in the prevalence of atopic dermatitis between Periods IV and V (Table V).

Supplementary Table II in the Online Repository shows the changes in obesity, smoking, physical activity, and sleep satisfaction between 2009 and 2020. The proportion of participants who were overweight or had obesity increased from Periods I to IV and from Periods IV to V; however, there was no significant change in the increasing trend (β_{diff} = −0.199; 95% CI, −0.215 to −0.183). The smoking rate decreased from Periods I to IV and from Periods IV to V, and the declining trend was significantly diminished after the COVID-19 outbreak (β_{diff} = 0.199; 95% CI, 0.172 to 0.226). Sleep satisfaction steadily decreased prior to the COVID-19 pandemic but significantly increased since the COVID-19 outbreak, and the change was significant (β_{diff} = 0.181; 95% CI, 0.169 to 0.193). The proportion of participants engaging in physical activity at least twice a week increased from Periods I to Period IV but decreased during Period V, and the change in this slope was significant ($\beta_{diff.}$ = −0.153; 95% CI, −0.168 to −0.138). The proportion of participants engaging in active physical activity decreased significantly by 5.2% from Periods IV to V.

Discussion

To the best of our knowledge, this is the first large-scale study to compare the changes in the prevalence trend of allergic diseases among adolescents during the COVID-19 pandemic with the trend during the 11 years preceding the pandemic. The current prevalence of asthma, allergic rhinitis, and atopic dermatitis was 1.0%, 16.8%, and 6.5%, respectively, among adolescents during the pandemic. The KYRBS is the only database that has disclosed the prevalence of allergies during the pandemic. Consequently, we cannot compare these results with those of other countries or age groups. Nonetheless, the International Study of Asthma and Allergies in Childhood phase 3 study conducted between 2002 and 2003 reported the prevalence of current asthma, allergic rhinitis, and atopic dermatitis among teenagers in the Asia-Pacific region to be 5.2-13.0%, 4.8-22.6%, and 1.4-9.9%, respectively[13]. Subsequent Global Asthma Network phase 1 studies conducted in low- and middle-income countries have reported that the current prevalence rates of asthma and allergic rhinitis are 11.6-15.8%[14,15] and 7.0-30.1%[16], respectively. Atopic dermatitis was found to have a prevalence rate of 9.7-17.0% among adolescents[17]. The prevalence of asthma and atopic dermatitis during the COVID-19 pandemic was lower than those reported previously. However, the prevalence rate of allergic rhinitis was not lower than that reported in previous studies. Further, considering the previously reported symptom-based prevalence rates for asthma (0.9-8.3%), allergic rhinitis (16.4-25.5%), and atopic dermatitis (7.3-11.4%) among Korean teenagers[5], the prevalence of all allergic diseases decreased during the pandemic.

In this study, the allergic disease prevalence trends among adolescents in the past 11 years differed according to specific allergic diseases; however, the prevalence rate of allergic morbidity increased steadily. The prevalence rate of allergic rhinitis, which was the most prevalent, increased steadily, whereas that of atopic dermatitis remained unchanged. In contrast, the prevalence rate of asthma declined. The inconsistent trends across allergic diseases are presumably due to the different contributing factors for each disease. The increasing prevalence rate of allergic rhinitis is observed worldwide[16], and this is currently attributed to increased particulate matter and allergens, such as pollen, as a result of global warming[18]. The stagnant trend for atopic dermatitis is attributed to the heavy influence of personal factors, including genetic factors (e.g., family history), damaged skin barrier, breastfeeding, westernized diet, and small family sizes, rather than external factors[19]. There are charac-

Table V. Atopic dermatitis weighted prevalence and trend in the Korean general adolescent population using the KYRBS from 2009 to 2020.

	Trends in current atopic dermatitis, weighted								Odds for prevalence of current asthma before and after entering the COVID-19 pandemic, OR (95% CI)[b]
	Pre-COVID-19 pandemic era				COVID-19 pandemic	Trend before entering the COVID-19 pandemic, β_{bc} (95% CI) [a]	Trend after entering the COVID-19 pandemic, β_{ac} (95% CI) [a]	Trend difference, β_{diff} (95% CI)	
	Period I†	Period II†	Period III†	Period IV†	Period V†	Period I† to IV†	Period IV† to V†	β_{ac} - β_{bc}	Period IV† to V†
Current atopic dermatitis, weighted % (95% CI)									
Overall	6.7 (6.6-6.9)	6.8 (6.7-6.9)	7.0 (6.9-7.1)	6.8 (6.7-7.0)	6.5 (6.3-6.7)	0.011 (-0.001 to 0.022)	**--0.011 (-0.021 to -0.001)**	**-0.022 (-0.037 to -0.007)**	**0.962 (0.922-1.004)**
Sex									
Male	5.8 (5.6-6.0)	5.7 (5.6-5.9)	5.9 (5.7-6.1)	5.7 (5.5-5.9)	5.5 (5.2-5.8)	0.000 (-0.017 to 0.017))	-0.009 (-0.023 to 0.006)	-0.009 (-0.031 to 0.013)	0.961 (0.898-1.028)
Female	7.8 (7.6-8.0)	8.0 (7.8-8.2)	8.2 (8.0-8.4)	8.0 (7.8-8.3)	7.6 (7.3-7.9)	**0.018 (0.003 to 0.033)**	**-0.013 (-0.026 to -0.001)**	**-0.031 (-0.051 to -0.011)**	**0.940 (0.887-0.996)**
BMI									
Normal or less	6.6 (6.5-6.8)	6.7 (6.5-6.8)	6.8 (6.7-7.0)	6.6 (6.5-6.8)	6.3 (6.1-6.6)	0.007 (-0.005 to 0.020)	-0.011 (-0.022 to 0.001)	-0.018 (-0.035 to -0.001)	0.950 (0.902-1.001)
Overweight or obese	7.6 (7.3-8.0)	7.7 (7.4-8.1)	7.8 (7.5-8.2)	7.6 (7.2-8.0)	7.1 (6.6-7.7)	0.001 (-0.026 to 0.028)	-0.015 (-0.037 to 0.007)	-0.016 (-0.051 to 0.019)	0.935 (0.846-1.032)
Region of residence									
Rural	18.1 (17.7-18.5)	6.8 (6.7-7.0)	7.1 (6.9-7.3)	7.0 (6.8-7.3)	6.5 (6.2-6.8)	0.015 (-0.001 to 0.030)	**-0.018 (-0.031 to -0.005)**	**-0.033 (-0.053 to -0.013)**	**0.921 (0.866-0.980)**
Urban	6.6 (6.4-6.8)	18.0 (17.7-18.3)	19.1 (18.8-19.5)	20.5 (20.0-20.9)	17.2 (16.6-17.8)	**0.070 (0.058 to 0.082)**	-0.002 (-0.017 to 0.013)	-0.006 (-0.028 to 0.016)	0.990 (0.925-1.061)

BMI, body mass index; CI, confidence interval; KYRBS, Korea Youth Risk Behavior Web-based Survey; OR, odds ratio. †We defined Period I as 2009–2011; Period II, 2012–2014; Period III, 2015–2017; Period IV, 2018–2019; and Period V, 2020. [a]The estimated β (95% CI) was derived using linear regression, and this analysis included the KYRBS cycle (Period I, II, III, IV, V) as a continuous variable. [b]The estimated OR (95% CI) was derived using binomial regression, and this analysis included the KYRBS cycle (Period IV and V) as a categorical variable. Numbers in bold indicate a significant difference ($p < 0.05$).

teristic asthma trends in different countries. Previously, the worldwide prevalence rate of asthma increased steadily; however, this prevalence has started to decrease or plateau in developed countries[20]. In Korea, the prevalence rate of asthma increased during the urbanization period in the 1990s; however, some reports[5] have shown that the prevalence rate has decreased in recent years since Korea became a developed country. The proposed reasons for this include a higher number of no-smoking zones and a greater distribution of protective equipment, such as air purifiers[21]. Local governments have also strived to implement early interventions by establishing community education and information centers for atopy and asthma. Moreover, they have launched campaigns for allergic disease prevention and management. Furthermore, atopy and asthma safe schools have been implemented from elementary school upward to promote school health[22]. In Finland, the prevalence rate of asthma has decreased since the society-wide implementation of allergy programs[23].

A recent study[10] that has also used KYRBS data made a simple comparison of the prevalence of allergic diseases between 2020 and 2019, and to the best of our knowledge, this is the only study on this topic. However, the report could not determine whether the observed change in prevalence was due to the pandemic or simply a continuation of the previous trend. The direction and size of the change in prevalence became clearer when interpreted in relation to the trend over a prolonged period. We observed that the prevalence of allergic morbidity increased steadily until the outbreak of the pandemic began to decline since the outbreak, and this trend was more evident for allergic rhinitis. The prevalence of atopic dermatitis remained stagnant and started to decline since the outbreak of the pandemic. Furthermore, the prevalence of asthma had already been declining but decreased more drastically during the pandemic. In other words, the overall prevalence of allergic diseases decreased, and this change has been influenced by the pandemic, as opposed to a continuation of the previous trend.

In this study, we examined the trends in individuals' health behaviors associated with allergic diseases. Previous studies[24,25] have reported that increased smoking and overweight prevalence elevates the risk of asthma and atopic dermatitis. Further, increased physical activity has been reported to lower the risk of asthma, allergic rhinitis, and atopic dermatitis among adolescents[26]. In this study, the smoking rate decreased. Although this can partially explain the recent decrease in the prevalence of allergic diseases, smoking rates have been steadily declining since the pre-COVID-19 period. Therefore, a lower smoking rate cannot adequately account for the changes during the pandemic period. The prevalence of overweight has also been steadily increasing; therefore, this cannot explain the decreased prevalence of allergic diseases during the pandemic period. However, sleep satisfaction has been decreasing prior to the pandemic but began to increase since the onset of the pandemic. Furthermore, physical activity has been increasing prior to the pandemic but took a downturn during the pandemic. This implies that individuals are sleeping more adequately but cut back on outdoor activities. The adequate rest with less physical contact with other people may partially explain the reduced prevalence. However, the collected data cannot clearly explain the changes in prevalence. This suggests that other unanalyzed factors, such as sensitized antigen or air pollutant exposure, effort to avoid allergens, and differences in preference for utilizing health care, have a greater effect[27].

The greatest strength of this study is that the trends were analyzed based on data from the KYRBS, the only database for the prevalence of allergic diseases since the outbreak of the COVID-19 pandemic. Globally, countries could not investigate the prevalence of allergic diseases due to various measures, such as lockdowns, implemented to combat the COVID-19 pandemic. This survey was possible because the data for the survey were collected in a non-face-to-face manner since before the pandemic[11]. Data were collected from adolescents in puberty through anonymous self-report online questionnaires completed at school computer laboratories due to the sensitive survey content[11]. Thus, the trends observed in this study are not biased by differences in survey methods. Another strength of this study is that we investigated the direct and indirect effects of a communicable disease pandemic on the prevalence of non-communicable diseases using nationwide data. However, the data were collected from the adolescent population of a single country (Korea)[11]. Nonetheless, the study showed that the trends of various allergic diseases changed during the pandemic compared with before the pandemic. Moreover, it showed that the prevalence of these diseases has declined since the pandemic. The number of pediatric COVID-19 patients is

significantly small in Korea[28]; thus, our findings present generalized knowledge on the effects of changes in the external environment on the prevalence of allergic diseases, the most common non-communicable disease among adolescents. Although Korea has experienced a few epidemics in the past, such as the severe acute respiratory syndrome and Middle East respiratory syndrome epidemics[29], these outbreaks were only confined to a few regions and were eradicated within a few months. Consequently, the effect of a pandemic on the prevalence of allergic diseases could not be examined at that time.

A limitation of this study was that the survey was based on self-reported answers, and we did not make actual measurements or objective assessments. For example, pulmonary function tests were not performed for the diagnosis of asthma. However, large-scale studies[30] have also calculated the prevalence of allergic diseases based on self-reported questionnaires. Furthermore, the reliability of the KYRBS data used in our study has been confirmed, and the kappa value for allergic diseases was 0.74-0.80[12]. Regarding the overall decline in the prevalence of allergic diseases observed in this study, some may argue that the prevalence was simply underestimated due to the lower healthcare utilization since the outbreak of the pandemic in Korea. The lack of reports on this issue prohibits us from advocating or refuting this issue. Hence, this should be verified by subsequent comparisons with reports from other countries that have implemented different types of social distancing practices and healthcare for allergic diseases.

Conclusions

The first allergic disease prevalence report during the COVID-19 pandemic showed a decline in the prevalence of all allergic diseases among adolescents. The declining trend was consistent across all allergic diseases, in contrast to the different trends across diseases during the 11 years preceding the pandemic. Subsequent studies should examine whether such a declining trend in allergic disease prevalence is reproduced by follow-up reports on other age groups and countries.

Conflicts of interest

The authors declare that they have no conflict of interest.

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