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Increased sensitization rate to tree pollen of allergic children and altered pollen season in Seoul metropolitan area, Korea

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Abstract

Introduction: Children with allergy may increase a chance to sensitize the allergic pollens with several environmental changes. Purpose of this study was to investigate the correlation with alternation of pollination associated with meteorological changes and increased sensitization rate of pollen allergens of children in Seoul metropolitan area, Korea. Methods: There were recruited 8,295 children who visited the pediatric allergic clinics at Hanyang University Seoul and Guri Hospital for allergy symptoms from January 1st, 1998 to December 31st, 2019. The pollen was collected by Burkard 7 days-sampler in 2 hospitals during the study. Meteorological data was investigated from Korea Meteorological Administration. Results: Allergic sensitization of oak, hazel, and alder pollens had the highest rate of increase among major tree pollens, an increase of 0.28% annually. The sensitization rate to pollen was increased with younger age group yearly. The duration of pollen season was 98 days in 1998, but 140 days in 2019. The duration of the pollen seasons and pollen sensitization rate to trees were positively correlated. The relationship between the sensitization rate to pollens and accumulated temperature were also correlated, positively. Conclusions: This study demonstrates the correlation between the weather changes and consequent changes of pollen seasons with increasing the sensitization rate to allergic pollens in children in Seoul metropolitan area. In addition, there was an increase in the sensitization rate in younger age group from year to year. Continuous changes in distribution of pollens raised from meteorological changes are expected from now on.

Introduction

Sensitization to pollen plays a crucial role in the development of allergic disorder,[1] which has been reported to lead to more serious allergic symptoms and to increase the risk of asthma.[2-3.] An interaction between the exposure to pollen and being sensitized to pollen allergens was detected that the effect was less pronounced in individuals who were sensitized to only one type of pollen, compared with who are sensitized to all types of pollen. Furthermore, as different pollen types are released at different periods of the pollen season, atopic individual sensitized to more than one type of pollen are experiencing a longer period of exposure, which may lead to a stronger effect on airway hyperreactivity and reduced lung function.[4]

Pollen season is related to the flowering season, for pollen has to be previously produced and emitted by mature flowers. Weather variables, mainly air temperature, sunshine and rainfall, together with CO_2 are among the main factors affecting phenology and pollen production by plant.

The weather may be the most crucial factor because it can alter the starting and ending of pollination and affect the change of pollen season directly although there are several environmental factors such as

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greenhouse gases, the other air pollutants. Weather conditions may subsequently influence the occurrence of allergic diseases such as asthma, allergic rhinitis. A growing number of people are contracting allergic diseases caused by pollen because of weather change in the world.[5]

The start and end of the pollen season itself, as defined by airborne pollen, may be influenced by factors affecting pollen dispersal, and may not coincide exactly with the maturation of the flowers. Longer pollen season and larger the amount of atmospheric pollen could enhance the human exposure to allergic pollens. These might relate with an increase in allergic sensitization. As the sensitization rate to pollen has increased in children recently, allergic plants which is rapidly proliferating, has emerged as a dangerous element to allergic children. It is now essential to survey pollens around the patient for the management of pollen allergy.[6-8]

A number of studies on the climate change effects on allergenic pollen distribution have focused on analyses of observed pollen counts and their regression relationships with local meteorological factors. Ongoing climate change, through rising the concentration of atmospheric CO_2 and temperatures, contribute to extension of seasonal duration and increase in multiple pollen load.[8] In an experimental study, warming and changes in CO_2 were demonstrated an increase in pollen production.[9,10] Elevated CO_2concentrations resulted in early pollen production from trees and greater seasonal pollen production.[11,12] In addition, weather patterns influence the movement and dispersion of all aeroallergens in the atmosphere through the action of winds, rainfall and depending on the atmospheric stability.

This study investigated the reasons for recent rising pollen allergy and the sensitization rate to pollen has increased in children recently, and the relationships between the changes in start and end dates of pollination and weather changes for the past 22 years in Seoul metropolitan area. The results of the analysis are used in an attempt to predict trends in start dates in future. This study has important implications for the use of phenology as an indicator of weather changes and also for recent rising pollen allergy in children in Korea.

Method and Materials

Pollen identification, counting and definition of pollen season

Pollens were identified and counted from Hanyang University Seoul and Guri hospitals for over 22 years (1998˜2019). Pollen sampling has been undertaken at the sites with Burkard Seven-days Sampler (Burkard Manufacturing Co Ltd., Hertfordshire, UK) on exposed roof tops during the study. Cumulative pollen concentrations and a preset percentage threshold level are used to define the start and end of the pollen season. The present study applied the 5 % threshold method, which gave the smallest standard deviation in the start dates.[13]

Selection of subject and sensitization rate to allergenic tree pollen

Subjects for this study were selected by using the allergy skin prick test and the quantitative serum test for allergen-specific IgE level. Over 3 class levels of a pollen allergen-specific serum IgE or $>$ 3+ level of allergic skin prick test to pollen are an indication of sensitization to the allergenic pollen.[14] Pollen for allergy test were birch, alder, oak, hazel, pine, willow. Sensitization rate to allergenic pollen was defined as a percentage of the number of the patients who sensitized allergenic pollen in the overall population taken allergy tests. Five age group were divided for the evaluation of change of age distribution (3˜5, 6˜9, 10˜12, 13˜15, and 16˜18 age of years).

Meteorological data

Daily records of the climatic variables such as mean temperature, rainfall, accumulated temperature and 7-days sunshine amount from the Korea Meteorological Administration (KMA) were used to represent the daily weather conditions near to the pollen monitoring site. The nearest weather stations to each pollen sampling site were selected to provide a number of meteorological data. The accumulated temperature defined the summed up temperature from 1st January until the starting day of pollination, which is the most influential variables to pollination among meteorological variables and was selected for this study.

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Statistical analysis

We aimed to assess long-term pollen data to ascertain potential links to sensitization rate during the collection period. R version 4.0.2 (The R foundation, https://www.r-project.org) was used to ascertain statistical analysis. The changes of pollen sensitization were assessed by linear regression and time series analysis. A standardized regression coefficient by a method of least square for minimizing the sum of squared residuals is estimated, and which independent variable has a large influence on the dependent variable is found out.[15]

The correlation between the duration of the pollen season with starting date and pollen sensitization was assessed by correlation analysis. Long-term prediction of variation of pollen season was assessed by ARIMA-11 analysis. Time series data are provided after seasonal adjustment. The ARIMA-11 analysis may also backcast previous year data from the starting point of the data, predict the year data from the ending point of the data, and solve the missing value problem by moving average of the expanded data.[16]

Ethics statement

This study was approved by the institutional review board of the Hanyang University Guri Hospital (IRB No. HYI-10-45). The requirement for informed consent from patients was waived, as the study was a retrospective analysis.

Results

1. Study population

In total 8,295 children (male: 4,032, female: 4,263; age: 3˜18 years old) visited two pediatric allergic clinics for allergy symptoms between 1998 and 2019. Table 1 shows the diagnosis of the subjects in this study and allergic rhinitis was most common in the subjects (Allergic rhinitis: 2,295, Atopic dermatitis: 2,259, asthma: 1,736, and the others: 2,005).

2. The sensitization rates to allergic pollen

Allergic sensitization rate for tree pollens has been increased from year to year. The first pollen observations tended to be moved forward and increased the duration of pollen seasons. The sensitization to tree pollens was gradually increased for the last 22 years (Table 2). Sensitization to oak, hazel, and alder pollens had the highest rate of increase (0.28% annually), followed by that to birch, willow, and pine pollens (0.25%, 0.25%, and 0.23%, respectively) (Table 2). Regarding age distribution changes for the last 22 years, sensitization rate to pollens was increased in <10 age of years (Age 3˜5 years: 8.3%, 6˜9 years: 14.4%, 10˜12 years: 24.0%, 13˜15 years: 25.4%, and 16˜18 years: 27.6 at 1998; Age 3˜5 years: 10.7%, 6˜9 years: 17.7%, 10˜12 years: 22.5%, 13˜15 years: 23.9%, and 16˜18 years: 25.3 at 2019) (Fig. 1).

3. Pollen seasons assessment

The start and end dates of pollen season were March 5 and June 7, respectively and the pollination duration was 94 days in 1998. Meanwhile, the the start and end dates were February 15 and July 5, respectively and the pollen season duration was 140 days in 2019 (Fig. 2). Total concentration and peak concentration of pollens were increased gradually for the last 22 years (Fig. 3). These data implied the start and end date of tree pollination in the future at Seoul metropolitan area was predicted to widen the interval as the start day and the end date will be February 9th and June 24th 2027, by using ARIMA-11 analysis. (Table 3). Accumulated temperature is critically correlated to pollination. Herein, the mean accumulated temperature at start day was 182.14±52.02ºC during the pollination (Table 2). Both variables are critical correlated to pollination. Annual changes in the pollen season showed the start date became earlier and the end date later from 1998 to 2019 in Seoul metropolitan area.

4. Relationship of the sensitization rates to pollens with the pollen seasons duration and meteorological observation .

Regression model for each tree demonstrated that sensitization rate to oak, hazel, pine, birch, alder, and willow was increased 0.28%, 0.28%, 0.23%, 0.25%, 0.28%, and 0.25% from year to year during 22 years

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respectively. The duration of the pollen seasons was positively correlated with the sensitization rate to oak, hazel, pine, birch, alder, and willow (r= 0.79, 0.81, 0.85, 0.79, 0.80, and 0.70, respectively). The sensitization rate to pollens was positively correlated with the accumulated temperature also positively correlated (correlation coefficient: Oak 0.71; hazel 0.66; pine; 0.53, birch 0.69; alder 0.53; willow 0.64) (Table 2). The other meteorological data were not shown the significant relation to sensitization rate with pollen seasons duration.

Discussion

Studies of sensitization rate to pollen have been insufficient because of the lower allergenicity of pollen than that of house dust mites. Further, only a few studies have investigated sensitization in childhood. The present study is to investigate the change of sensitization rates to pollen in children with allergic diseases taken allergy test with altered pollen season for last 22 years. The present outcomes have important implications for the use of phenology as an indicator of meteorological changes. A shift in the timing of the common tree pollen season is important as known pollens also may aggravate the symptoms of respiratory allergic diseases. The outcome might be implied to increase the sensitization rate to tree pollen and pollen allergy from year to year for the past 22 years, and the age of sensitization rate to common tree pollens was also extended to younger children under 10 age of year.

Allergic rhinitis and allergic conjunctivitis have been presented over teen aged children[9] but a number of pediatrician and allergists have reported a gradual increase in the prevalence of allergic diseases in children aged <6 years.[17] The present study focused on the allergic children with age 3˜18 years old at Seoul metropolitan area for the last 22 years.

As pollen exposure rates differ depending on annual weather, sensitization rates were characterized according to these differences in the present study. There may be implied 3 primary means by which weather change could influence allergic sensitization to pollen.

First, warmer temperature due to climate change might increase seasonal intensity of the allergenic load and the concentration of pollen.[18] Second, climate change could increase the level of allergenic pollens and allergic symptoms associated with exposure, including impacts on pollen amount, and pollen season.[2,3] Finally, CO_2 concentration and warmer temperature increase pollen concentration. And increased CO_2 might alter the allergenicity, or allergen concentration of the pollen, and symptom severity.[11,12]

The pollen season was expanded and the concentration of pollens and sensitization rate to pollens were increased from year to year in the present study. Sensitization to allergens is an important step in the development of allergic diseases. A longer pollen season and increased pollen amount could increase the opportunity of human exposure to pollen as aeroallergens with consequences for increased allergic sensitization in childhood.[17,19]

There have been a few epidemiological and experimental studies on the relationship between allergic diseases and environmental and climate changes.[20,21] An epidemiological study presented sensitization rate to tree pollens was significantly increased to 36.4% in the 2010s from 19.0% in the 1990s and 8.8% in the 1980s in Korea.[22] The nationwide prevalence of "diagnosis of allergic rhinitis, ever" was reported 15.5%, 20.4%, and 28.5% in 1995, 2000, and 2006, respectively in the Korean version of the International Study of Asthma and Allergies in Childhood of Korean children.[23,24]

Younger children might increase sensitization rate to pollen compared to over 10 years old children with the altered pollen season in this study. A study for children also reported the age for sensitization to weed pollens gradually became younger (4 to 6 year of age, 3.5% in 1997 and 6.2% in 2009; 7 to 9 year of age, 4.2% in 1997 and 6.4% in 2009).[17] Difference in exposure rates to allergens with increasing age result in difference in sensitization rates. Although the effects of environmental change on respiratory allergic diseases are not completely understood, these differences in sensitization rates may be implied different living environments such as the playing outdoor and going to school in young children, conversely adolescent stay the indoor due to hard study or playing videogames with recent trend in Korea. It may be useful to manage allergic diseases

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by continuous investigation and systematical observation of the regional differences and chronological changes of living environments.

Oak, hazel, and alder were shown the sharpest slope to raise sensitization rate among tree species and more related between sensitization rate and pollen season except pine which is no to mild allergenic, during this study. Oak is expected to dominate over other species during the vegetation transition,[25] so that its distribution will be broader. By developing phenological models based on weather conditions, one can assess future oak species distribution and length of the pollen season. Hazel pollen is important, resulting in asthma and allergic rhinitis in hazel pollen-allergic individuals, in particular in early spring.[26,27] Alder pollen also is a significant cause of asthma, allergic rhinitis, and allergic conjunctivitis, in particular in Spring and in conjunction with birch and hazel pollen.[28,29] In patients with poly-sensitization to alder, hazel, and oak pollen who were cross-reactive, initial symptoms occurred as early as February, with abrupt exacerbation in March to May.

The accumulated temperature was the most influential variables to pollination among meteorological variables in this study. Sensitization rate to oak and birch had the highest correlation to accumulated temperature among the subjected trees. Birch has reproductive rhythms of high and low years for the abundance of pollen and subsequent seed and pollination is dependent on the temperature.[30]

In conclusion, this study demonstrated the positive correlation between the consequent changes of pollen seasons and the raising sensitization rate to major tree pollens in childhood in Seoul metropolitan area for the past 22 years and continuous increase in concentration of pollens due to weather changes were expected. The sensitization rate increased in younger children from year to year. This might imply that climate change impact to alter the pollen season and consequently to increase the sensitization rate to allergic tree pollens in children.

AUTHOR CONTRIBUTIONS

Kyung Suk Lee: Conceptualization (equal); Data curation (equal); Formal analysis (equal); Writing-original draft (equal); Writing-review & editing (equal). **Kyunghoon Kim:** Conceptualization (equal); Data curation (equal); Formal analysis (equal); Writing-original draft (equal); Writing-review & editing (equal). **Young-Jin Choi:** Data curation (equal); Formal analysis (supporting); Writing-review & editing (supporting). **Seung Yang:** Formal analysis (equal); Supervision (supporting); Writing-review & editing (supporting). **Chang-Ryul Kim:** Conceptualization (supporting); Formal analysis (equal); Supervision (equal). **Jin-Hwa Moon:** Formal analysis (equal); Supervision (equal); Writing-review & editing (supporting). **Kyu Rang Kim:** Data curation (equal); Formal analysis (equal); Writing-review & editing (equal). **Yung-Seop Lee:** Data curation (equal); Methodology (equal); Formal analysis (equal); Writing-review & editing (equal). **Jae-Won Oh:** Conceptualization (equal); Data curation (equal); Formal analysis (equal); Funding acquisition (lead); Methodology (lead); Supervision (lead); Writing-original draft (equal); Writing-review & editing (equal).

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Tables

Table 1. Diagnosis of the subjects with allergy sensitization to tree pollen

Year	Total	Asthma	Allergic rhinitis	Atopic dermatitis	Others
1998	312	71	75	69	97
1999	331	74	101	77	79
2000	241	44	63	55	79
2001	305	59	88	88	70
2002	336	73	89	88	86
2003	396	81	115	98	102
2004	453	94	103	133	123
2005	423	88	120	115	100
2006	396	78	118	114	86
2007	377	93	100	124	60
2008	415	89	96	135	95
2009	401	76	115	123	87
2010	452	99	113	119	121
2011	422	80	111	120	111
2012	395	72	102	121	100
2013	404	79	108	115	102
2014	407	86	117	122	82
2015	392	81	93	113	105
2016	375	95	85	98	97

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2017	390	72	141	90	87
2018	357	83	136	76	62
2019	315	69	106	66	74
total	8,295	1,736	2,295	2,259	2,005

Table 2. Mean accumulated temperatures and sensitization rate to major tree pollen during the study

Year	**Accumulated temperature (°C)**	**Sensitization rate to pollen (%)**	**Sensitization rate to pollen (%)**	**Sensitization rate to pollen (%)**	**Sensitization rate to pollen (%)**	**Sensitization rate to pollen (%)**	**Sensitization rate to pollen (%)**
		Oak	**Hazel**	**Pine**	**Birch**	**Alder**	**Willow**
1998	206.35	4.7	4.0	3.2	4.2	2.6	3.8
1999	153.80	5.1	3.5	3.3	4.5	4.3	4.7
2000	163.60	4.9	3.1	5.1	4.8	3.3	3.7
2001	140.55	5.3	3.8	4.3	5.1	3.8	4.3
2002	158.85	4.8	4.3	5.4	4.8	4.6	4.7
2003	133.85	5.0	4.1	5.8	5.5	3.8	3.6
2004	170.15	4.5	3.8	4.8	5.3	5.7	3.2
2005	144.20	5.4	3.2	5.5	5.8	6.2	3.5
2006	218.50	5.2	4.7	6.3	5.4	5.9	3.8
2007	130.45	5.7	4.4	4.8	4.6	5.6	4.4
2008	102.35	5.2	5.2	5.7	5.3	6.4	4.2
2009	170.75	5.8	4.8	6.0	5.8	6.5	3.4
2010	105.55	5.5	5.1	6.2	5.7	5.2	4.3
2011	163.35	5.6	6.5	6.2	6.5	6.2	6.5
2012	138.35	7.6	7.3	7.7	7.3	8.7	7.3
2013	189.80	8.5	7.3	8.3	6.3	7.5	6.4
2014	264.30	9.3	9.5	7.3	8.3	8.4	7.2
2015	257.70	9.6	8.7	8.2	9.4	9.7	8.5
2016	245.20	9.9	8.5	8.5	9.7	9.5	8.5
2017	252.90	9.2	8.3	7.5	9.9	8.5	7.3
2018	244.85	9.5	7.6	8.1	8.4	7.4	8.4
2019	251.85	9.8	8.1	8.7	8.7	8.1	8.3
Mean ± SD	182.14±52.02	6.64±2.03	5.72±2.06	6.22±1.63	6.42±1.82	6.27±2.03	5.45±1.93
Correlation coefficient (r, p<0.05)*	Correlation coefficient (r, p<0.05)*	0.71	0.66	0.53	0.69	0.53	0.64

Table 3. The prediction of starting and ending date of tree pollination in future at Seoul metropolitan area by using ARIMA-11 analysis.

Year	Starting date (Month/Day)	Ending date (Month/Day)
2020	2/16	6/21
2021	2/15	6/22
2022	2/14	6/22
2023	2/13	6/22

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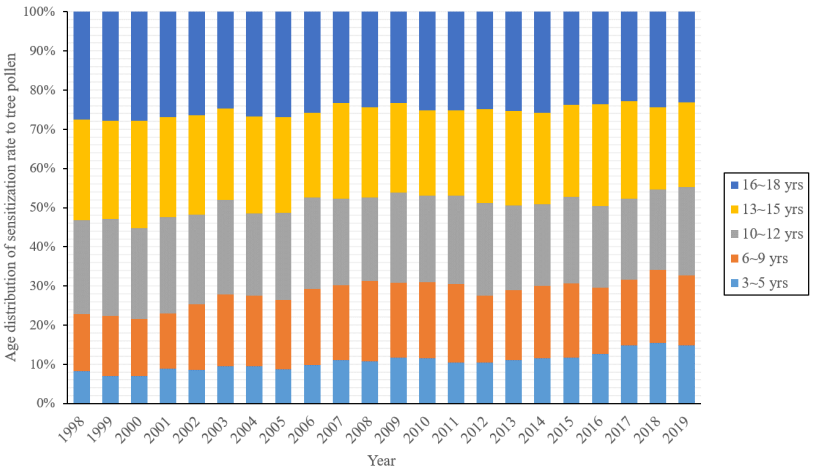
Year	Starting date (Month/Day)	Ending date (Month/Day)
2024	2/12	6/22
2025	2/11	6/23
2026	2/10	6/23
2027	2/09	6/24

Figure legends

Fig 1. Age distribution of sensitization rate to major pollen in Seoul metropolitan area at study period. the pollen sensitization rate increased among <10 age of years children (3˜5 years: 8.3%, 6˜9 years: 14.4%, 10˜12 years: 24.0%, 13˜15 years: 25.4%, and 16˜18 years: 27.6% in 1998; 3˜5 years: 10.7%, 6˜9 years: 17.7%, 10˜12 years: 22.5%, 13˜15 years: 23.9%, and 16˜18 years: 25.3% in 2019).

Fig 2. The start and end dates of pollen season of major allergenic tree pollens in Seoul metropolitan area during the past 22 years. The start and end dates of pollen season were March 5 and June 7 respectively and the pollination duration was 94 days in 1998, with the start and end dates as February 15 and July 5, respectively. Meanwhile, the pollen season duration was 140 days in 2019.

Fig 3. The trend of total concentration of pollens (A) and peak tree pollen concentration (B) in Seoul metropolitan area during the study. Total concentration and peak concentration of pollens were increased gradually for the last 22 years.



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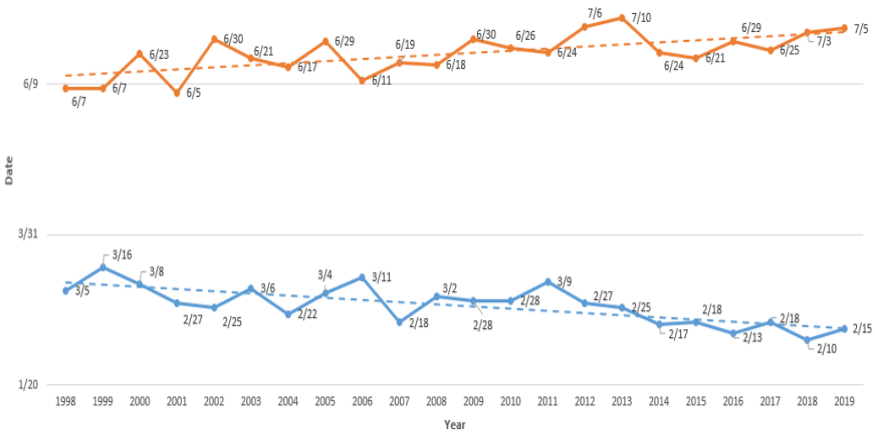

Fig 3.