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Research Article

Impact of the COVID-19 Epidemic on Inhalant Allergen Sensitization in Children

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Objective. To explore the impact of non-pharmacological interventions on inhaled allergen sensitization in children during the COVID-19 pandemic. *Methods*. The positive rate of inhaled allergens, allergens sIgE grade, and multiple sensitization rates before and during the pandemic were analyzed retrospectively in this study. Logistic regression analysis was used to compare the positive rate of allergens before and during the pandemic, using odds ratio (OR) and OR 95% CI to investigate the impact of the pandemic on allergen sensitization. *Results*. Positive rates of d1 (49.5% vs. 38.5%), d2 (50.2% vs. 32.2%), e2 (10.1% vs. 6.1%), e1 (6.2% vs. 1.7%), mx2 (10.1% vs. 2.7%), sycamore (7.2% vs. 2.1%), w1 (4.0% vs. 1.7%), elm (3.1% vs. 0.6%), w6 (3.0% vs. 1.7%), and u80 (1.3% vs. 0.5%) increased significantly during the COVID-19 pandemic. After adjusting gender, age, season, and other potential influencing factors, the COVID-19 pandemic was found to be a risk factor for the positive rate of d1 (OR = 1.174, 95% CI = 1.015–1.358), d2 (OR = 1.301, 95% CI = 1.093–1.549), e2 (OR = 1.499, 95% CI = 1.280–1.756), mx2 (OR = 3.959, 95% CI = 3.358–4.446), w1 (OR = 1.828, 95% CI = 1.353–2.470, w6 (OR = 1.538, 95% CI = 1.123–2.106)), and u80 (OR = 2.521, 95% CI = 1.413–4.497) ($P < 0.05$). In addition, d1 and d2 allergen sIgE grades increased during the COVID-19 pandemic (d1: $\chi^2 = 9.576$, $P < 0.05$; d2: $\chi^2 = 39.063$, $P < 0.05$). The proportion of multiple allergies was significantly higher than that before the pandemic, with a statistical significance ($\chi^2 = 1621.815$, $P < 0.05$). *Conclusion*. During the COVID-19 pandemic, non-pharmacological interventions increased the positive rate of both indoor and outdoor allergens in children. The sIgE grade of dust mite allergen and multiple sensitization rates were significantly higher than those before COVID-19.

1. Introduction

Non-pharmacological interventions (NPIs) are prevention and control measures adopted during pandemic periods of infectious diseases, including closing public spaces, restricting gatherings, reducing unnecessary outings, and maintaining social distancing wearing masks and keeping hand hygiene. NPIs not only play an important role in preventing the spread of infection, they also influence allergic diseases [1].

Allergies are chronic immune-mediated diseases that have become a worldwide public health problem [2]. An epidemiological survey conducted by the World Allergy Organization revealed that between 20% and 30% of the population suffers from allergic diseases in the world [3]. In high-income countries, 20% of children have atopic dermatitis [4]. In addition, the incidence of allergic diseases has been and will continue to rise in the future [5]. For individuals, allergic diseases can reduce quality of life and productivity. A study in Canada found that 48.7% of asthmatic patients recruited experienced a drop in productivity due to asthma [6]. Allergic diseases have caused a tremendous socioeconomic burden as well. For example, researches have shown that the United States has spent over $960 billion annually on asthma management [7].

Coronavirus Disease 2019 (COVID-19) outbreak was declared a global pandemic after the first case of COVID-19 was identified in Wuhan, Hubei Province, China, in 2019. During the pandemic, NPIs have been adopted worldwide, particularly in China. These NPIs have influenced people's living environments and lifestyles, leading to higher indoor allergen concentrations and more time spent indoors [8]. Exposure to outdoor allergens also rises as people travel more after the lifting of certain travel restrictions. These are bound to bring changes in allergen sensitization. Yet, few researchers have studied the impact of COVID-19 on allergen sensitization. Understanding allergen sensitization during the pandemic can help patients identify allergens, as well as take steps to reduce allergen sensitization and allergic disease progression in a period of regular epidemic prevention and control. In this study, we analyzed the positive rates of inhaled allergen sIgE (specific antibody immunoglobulin IgE, sIgE) before and during COVID-19 to investigate its impact on allergy sensitization.

2. Materials and Methods

2.1. Study Subjects. In this study, 29,926 inhaled allergen sIgE test results were retrospectively analyzed in Hunan Children's Hospital from 2014 to 2021. The inclusion criteria were listed as follows: (1) under 18 years old. The exclusion criteria were listed as follows: (1) lacking complete basic personal information and (2) infected with COVID-19. The collected information includes the patient's name, gender, age, medical record number, testing time, serum sIgE test items, and results. According to the timing of the COVID-19 outbreak, the subjects were divided into two groups: before COVID-19 (January 1, 2014–January 31, 2020) and during COVID-19 (after January 31, 2020). They were divided into four age groups by the developmental stage: infancy (<3 years old), preschool (3–5 years old), school age (6–9 years old), and adolescence (10–18 years old), as well as spring (March–May), summer (June–August), autumn (September–November), and winter (December–February) groups based on the timing of the test.

The examined allergens include *D. pteronyssinus* (d1), *D. farinae* (d2), dog hair (e2), cat hair (e1), cockroaches (i6), mulberry (T70), sycamore pollen (sycamore), elm pollen (elm), grass pollen (u80), mugwort pollen (w6), common ragweed pollen (w1), amaranth (w14), green oysters (f37), and mold (mx2). The testing of E1, elm, and sycamore began in November 2019.

2.2. Allergy Screen Test. Allergen test kits used Allergen Specific sIgE Antibody Test Kit (Suzhou Hao Ou Bo Biomedical Co., Ltd.). Allergen detection principle: patient's blood sample was incubated with the test strip so that the allergen sIgE antibody in the sample binds to the reaction zone on the test strip. The unbound antibody was then removed. The enzyme antibody was added and incubated with the allergen–antigen–antibody complex. The unconjugated enzyme-labelled antibody was then washed and the enzyme substrate solution was added to the reaction. Finally, the results were read.

Results were interpreted into the following groups: grade 0 (<0.35 KU/L), grade 1 (0.35–0.7 KU/L), grade 2 (0.7–3.5 KU/L), grade 3 (3.5–17.5 KU/L), grade 4 (17.5–50.0 KU/L), grade 5 (50.0–100.0 KU/L), and grade 6 (≥100.0 KU/L). The positive is ≥0.35 KU/L. The grades 1–3 were classified as the lower grade group, and grades 4–6 were classified as the high-grade group [9].

2.3. Statistical Method. SPSS 25.0 software was applied for statistical analysis. The positive rate of this allergen = number of positive of this allergen/number of examined cases for this allergen. The positive rate of allergens during and before COVID-19 was tested by the χ^2-test. Further analyzed the differences of allergens positive rate in different subgroups by gender, season, and age. Univariate regression analyses were adopted to calculate the odds ratio (OR) and 95% CI for the associations between the COVID-19 pandemic and allergen sensitization. Multivariate regression analyses were used to calculate the adjusted OR for each allergen during the pandemic compared to that before the pandemic, after adjusting confounding factors such as sex, age, and season. $P < 0.05$ was considered to have statistical significance.

3. Results

3.1. Characteristics of Study Population. A total of 29,926 inhaled allergen sIgE test results were included from 2014 to 2021, including 12,484 cases before COVID-19 and 17,442 cases during COVID-19. There were 19,125 males and 10,801 females, with an average age of 4.59 ± 3.103 years (age range: 0–18 years). The number of people in each age and season group is shown in Table 1. The number of examined cases and positive cases of each allergen is shown in Table 1.

3.2. Comparison of the Number of Allergen-Examined Cases and Positive Rates before and during COVID-19. Some of the allergens with high positive rates in Changsha, Hunan province, were d1 (44.39%, 2,711/6,107), d2 (38.5%, 2,053/4,801), followed by e2 (9.19%, 1,976/21,510), mx2 (7.4%, 1,947/26,334), sycamore (6.71%, 916/13,747), and e1 (5.77%, 834/14,460), whether before or during COVID-19. Except for t70 and w14, the number of positive allergens was higher than that before COVID-19. The positive rates of d1, d2, e2, mx2, sycamore, e1, w1, elm, and w6 during COVID-19 were significantly higher than those before COVID-19, with a statistical significance ($P < 0.05$). There was no significant difference in the positive rates of i6, w14, t70, and f37 before and during COVID-19 (Table S1).

The number of examined cases and positive numbers of allergens during and before COVID-19 in each month are shown in Figure S1. The number of d1, d2, e2, mx2, i6, w1, w6, and u80 examined cases and positive cases in the majority of months during COVID-19 was higher than before. Figure 1 shows the positive rates of allergens during and before COVID-19 in each month. Except for i6 and w6, the positive rates of other allergens during COVID-19 were significantly higher than those before COVID-19 in each month. From June to September during COVID-19, the positive rate of w6 was higher than before.

3.3. Logistics Regression Analysis. The positive rate of allergens was different in gender, age, and season (Tables S2–S4). Tables S5–S7, respectively, described the impact of the

Table 1: General information about the study population and the allergens examined.

Characteristic	Total (*n*)	Before COVID-19 (*n*)	During COVID-19 (*n*)
Total (*n*)	29,926	12,484	17,442
Sex (male/female)	19,125/10,801	8,050/4,434	11,075/6,367
Age (mean ± SD)	4.59 ± 3.103	4.21 ± 3.145	4.86 ± 3.043
Age group			
Infant (*n*)	8,353	4,444	3,909
Preschool (*n*)	12,388	4,593	7,795
School (*n*)	6,566	2,432	4,134
Adolescence (*n*)	2,619	1,015	1,604
Season			
Spring (3–5) (*n*)	7,660	3,064	4,596
Summer (6–8) (*n*)	8,122	3,306	4,816
Autumn (9–11) (*n*)	8,154	3,109	5,045
Winter (12–2) (*n*)	5,990	3,005	2,985
Allergen (*n*)			
d1	6,107	2,854	3,253
d2	4,801	1,990	2,811
e2	21,510	5,063	16,447
mx2	26,334	9,699	16,635
Sycamore	13,645	1,318	12,327
e1	14,460	1,318	13,142
w1	19,904	3,932	15,972
elm	13,647	1,318	12,329
w6	19,656	4,156	15,500
i6	21,593	5,142	16,451
w14	1,592	1,131	461
t70	1,592	1,131	461
u80	19,898	3,932	15,966
f37	1,592	1,131	461

Abbreviations. Dermatophagoides pteronyssinus (d1), *Dermatophagoides farinae* (d2), dog hair (e2), cat hair (e1), cockroaches (i6), mulberry (t70), sycamore pollen (sycamore), elm pollen (elm), grass pollen (u80), mugwort pollen (w6), common ragweed pollen (w1), amaranth (w14), green oysters (f37), and mold (mx2).

COVID-19 pandemic on allergen sensitization in subgroups by gender groups, age groups, and season groups.

The positive rate of allergens were used as the dependent variable, and the time before and during COVID-19 was used as the independent variable. Multivariate regression analysis was conducted after adjusting gender, age, and season. The results showed that the risk of d1, d2, mx2, e1, e2, w1, elm, and w6 positive rates during COVID-19 was significantly higher than that before, with a statistical difference (d1 (OR = 1.174, 95% CI = 1.015–1.358), d2 (OR = 1.301, 95% CI = 1.093–1.549), e2 (OR = 1.499, 95% CI = 1.280–1.756), mx2 (OR = 3.959, 95% CI = 3.358–4.446), sycamore (OR = 2.510, 95% CI = 1.522–4.139), e1 (OR = 4.249, 95% CI = 2.338–7.722), w1 (OR = 1.828, 95% CI = 1.353–2.470), elm (OR = 3.576, 95% CI = 1.425–8.974), w6 (OR = 1.538, 95% CI = 1.123–2.106), u80 (OR = 2.521, 95% CI = 1.413–4.497)) (all $P < 0.05$) (Table 2).

3.4. The Difference in Inhaled Allergen sIgE Grade before and during COVID-19. The inhaled allergen sIgE grade distribution before and during COVID-19 was as follows: The sIgE grades of d1 and d2 were mainly between grades 4–6 (high-grade group), while the sIgE grades of other inhaled allergens were mainly between grades 1 and 3 (low-grade group). During COVID-19, the proportion of d1 and d2 high-grade groups increased compared with that before COVID-19, the difference was statistically significant ($P < 0.05$), while the proportion of mx2 and e2 high-grade groups decreased compared with that before COVID-19, with a statistical difference (d1: $\chi^2 = 9.576$, $P < 0.05$; d2: $\chi 2 = 39.063$, $P < 0.05$) (Table 3).

3.5. Multiple Allergy Differences before and after COVID-19. The proportion of people sensitized by allergens during COVID-19 increased noticeably compared with that before COVID-19, and the proportion of people with multiple sensitivities also increased considerably, with a statistical significance ($\chi^2 = 1{,}621.815$, $P < 0.05$, Table 4). Before COVID-19, 8.5% of patients were sensitized to one allergen, 5.7% to two allergens, and 0.5% to three or more allergens. However, 18.0% of patients were sensitized to one allergen, 12.8% to two allergens, 3.0% to three allergens, and 1.3% to four or more allergens during COVID-19. Additionally, explore the

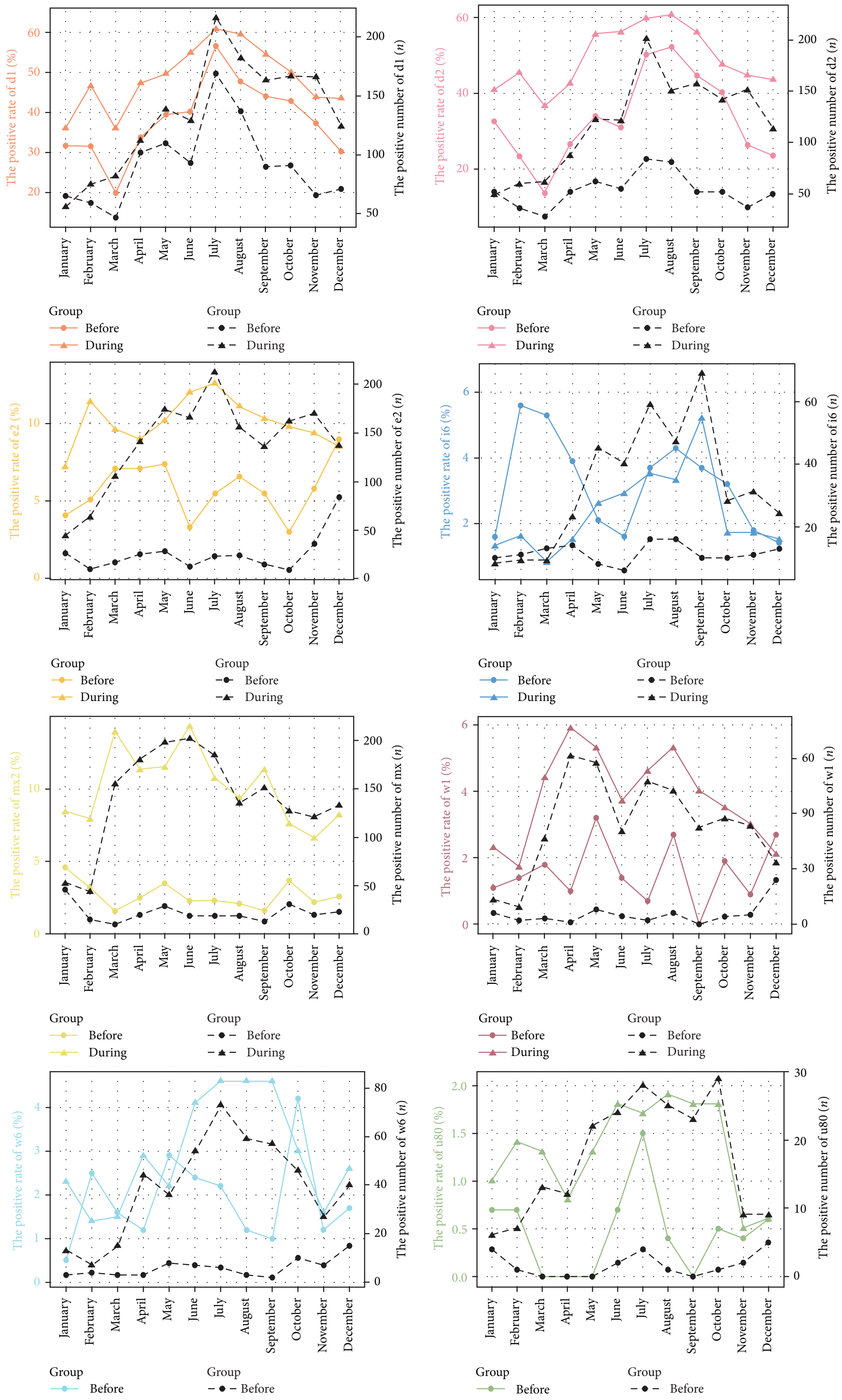

FIGURE 1: The number of allergen positive rates and positive cases in each month during and before COVID-19. Abbreviations: *Dermatophagoides pteronyssinus* (d1), *Dermatophagoides farinae* (d2), dog hair (e2), cockroaches (i6), grass pollen (u80), mugwort pollen (w6), common ragweed pollen (w1), and mold (mx2).

Table 2: Logistics regression analysis of positive rate of inhaled allergens before and during COVID-19.

Allergen	Univariate regression analysis				Multivariate regression analysis			
	Wald χ^2	P	OR[a]	OR 95% CI	Wald χ^2	P	OR[b]	OR 95% CI
d1	73.933	<0.001	1.564	1.413–1.732	4.641	0.031	1.174	1.015–1.358
d2	152.380	<0.001	2.124	1.885–2.394	8.760	0.003	1.301	1.093–1.549
e2	73.835	<0.001	1.735	1.530–1.968	25.261	<0.001	1.499	1.280–1.756
mx2	425.378	<0.001	4.023	3.524–4.592	268.628	<0.001	3.959	3.358–4.667
Sycamore	43.075	<0.001	3.576	2.444–5.233	13.013	<0.001	2.510	1.522–4.139
e1	38.662	<0.001	3.879	2.530–5.948	22.527	<0.001	4.249	2.338–7.722
w1	47.907	<0.001	2.483	1.919–3.213	15.457	<0.001	1.828	1.353–2.470
elm	21.405	<0.001	5.250	2.601–10.598	7.372	0.007	3.576	1.425–8.974
w6	21.038	<0.001	1.803	1.402–2.320	7.202	0.007	1.538	1.123–2.106
i6	1.480	0.224	0.885	0.727–1.077	1.396	0.237	0.862	0.675–1.102
w14	0.494	0.482	0.751	0.337–1.670	0.833	0.361	0.686	0.305–1.541
t70	0.062	0.804	1.106	0.500–2.448	0.029	0.866	1.072	0.479–2.397
U80	16.146	<0.001	2.569	1.621–4.071	9.799	0.002	2.521	1.413–4.497
F37	0.808	0.369	2.460	0.345–17.514	1.028	0.327	2.741	0.365–20.566

Note. [a]Univariate regression analysis was performed in groups before and during COVID-19. [b]Adjusted for gender, age, and season. Abbreviations: *Dermatophagoides pteronyssinus* (d1), *Dermatophagoides farinae* (d2), dog hair (e2), cat hair (e1), cockroaches (i6), mulberry (t70), sycamore pollen (sycamore), elm pollen (elm), grass pollen (u80), mugwort pollen (w6), common ragweed pollen (w1), amaranth (w14), green oysters (f37), and mold (mx2).

cross-allergy of five common allergens (Figure S2). Only 1.2% (16/1,276) and 0.54% (7/1,276) of the patients were sensitized to single d1 and d2, respectively. In other words, patients with d1 and d2 allergies were often sensitized to other allergens. A total of 610 patients with d1 and/or d2 sensitization were identified with dust mite sensitization. The most common cosensitization was e2, with a rate of 15.9% (97/610), and dust mite as the most common allergen.

4. Discussion

During the COVID-19 pandemic, the NPIs have profoundly impacted allergen sensitization. This study reached the following conclusions by analyzing the results of inhaled allergen sIgE testing in 29,926 cases before and during the COVID-19 pandemic: (1) during the pandemic, the positive rate of indoor and outdoor allergens increased significantly, and the outcome remained the same after adjusting potential influencing factors such as gender, season, and age. (2) Dust mite allergen sIgE grade and multiple sensitization rate have increased during the COVID-19 pandemic. (3) The allergens sensitization differed by gender, age, and season.

The risk of indoor allergen sensitization during COVID-19 is 1.2–4 times higher than that before COVID-19 (OR range: 1.194–4.014, $P < 0.05$). Li et al. [10] discovered that the positive rate of indoor allergens in South China increased dramatically during the COVID-19 pandemic. The study of Ye et al. [11, 12] also observed that the positive rate of allergens during COVID-19 was 51.50%, higher than 42.23% before COVID-19, while the number of positive allergens decreased. But in our study, except for w14 and t70, the number of positive allergens was increased remarkably during COVID-19. The following factors may be studied to determine the reason for increased positive rate of indoor allergens: (1) during the COVID-19 pandemic, indoor population density, indoor temperature, and humidity increased as people stayed indoors for longer periods of time due to NPIs [13]. As well as the time that pets spent indoors [14], causing the growth of indoor allergen concentrations [11]. Wahn et al. [15] found a dose–response relationship between inhaled allergen exposure and allergen sensitization. Another study [16] indicated that 2 μg/g of dust mites in the air was a risk factor for sensitization, whereas 10 μg/g was a risk factor for asthma among dust mite-sensitized persons. (2) The increasing concentrations of other allergens in the air, such as mold and animal fur, will also increase the risk of dust mite allergens sensitization because of the cross-reaction [17]. (3) During the COVID-19 pandemic, children spent more time indoors, which increased their chances of being exposed to indoor allergens [18]. Repeated exposure is easy to cause allergens sensitization. It is recommended that individuals use dehumidifiers, vacuuming, air purification, acaricides, and open windows frequently for ventilation to reduce indoor temperature and humidity. Additionally, allergen-reducing measures, including removing carpets and fabric curtains, washing and replacing mattresses and pillows, and cleaning air conditioners, should be adopted to reduce the accumulation of indoor allergens [19].

Though wearing disposable medical masks for a longer period during the pandemic can prevent the inhalation of allergens theoretically, this study revealed that the positive rate of outdoor allergens actually increased during the pandemic ($P < 0.05$). The result contradicts the study of Ye et al. [12]. There are five factors contributing to the increase in outdoor allergen sensitization rate during the pandemic. First, the masks currently used on children are merely scaled-down copies of masks created for adults which have not been specifically tested or approved [20]. A research on filtering face piece masks proved that wearing a mask could

Table 3: Difference in inhaled allergen sIgE grade before and during COVID-19 ((*n*) %).

Allergens	Before COVID-19		During COVID-19		χ^2	*P*
	Lower group *n* (%)	High group *n* (%)	Lower group *n* (%)	High group *n* (%)		
d1	509 (46.3)	591 (53.7)	649 (40.3)	962 (59.7)	9.576	0.002
d2	331 (51.6)	310 (48.4)	522 (37.0)	890 (63.0)	39.063	<0.001
e2	303 (98.1)	6 (1.9)	1,601 (96.2)	63 (3.8)	2.612	0.106
mx2	258 (97.7)	6 (2.3)	1,670 (99.2)	13 (0.8)	5.316	0.021
Sycamore	28 (100.0)	0 (0.0)	886 (99.6)	4 (0.4)	0.126	0.722
e1	20 (90.0)	2 (9.1)	796 (98.0)	16 (2.0)	5.143	0.023
w1	65 (100.0)	0 (0.0)	640 (100.0)	0 (0.0)	—	—
elm	8 (100.0)	0 (0.0)	382 (99.7)	1 (0.3)	0.021	0.885
w6	68 (95.8)	3 (4.2)	464 (98.5)	7 (1.5)	2.556	0.110
i6	135 (97.8)	3 (2.2)	385 (98.2)	7 (1.8)	0.083	0.773
w14	25 (96.2)	1 (3.8)	8 (100.0)	0 (0.0)	0.317	0.573
t70	20 (100.0)	0 (0.0)	9 (100.0)	0 (0.0)	—	—
u80	19 (95.0)	1 (5.0)	206 (99.5)	1 (0.5)	4.261	0.039
f37	2 (100.0)	0 (0.0)	2 (100.0)	0 (0.0)	—	—

Note. This table shows the proportion of the number of positives for the allergen in the lower group and high group; "—" indicates that there are no data for this item. Abbreviations: *Dermatophagoides pteronyssinus* (d1), *Dermatophagoides farinae* (d2), dog hair (e2), cat hair (e1), cockroaches (i6), mulberry (t70), sycamore pollen (sycamore), elm pollen (elm), grass pollen (u80), mugwort pollen (w6), common ragweed pollen (w1), amaranth (w14), green oysters (f37), and mold (mx2).

Table 4: Differences in the number of allergens sensitized before and during COVID-19.

Number of allergens	Before COVID-19 ($n = 12{,}484$) *n* (%)	During COVID-19 ($n = 17{,}422$) *n* (%)	χ^2	*P*
0	10,648 (85.3)	11,331 (65.0)	1621.815	<0.001
1	1,060 (8.5)	3,137 (18.0)		
2	707 (5.7)	2,227 (12.8)		
3	49 (0.4)	526 (3.0)		
4	12 (0.1)	139 (0.8)		
>4	8 (0.1)	82 (0.5)		

Note. This table shows the proportion of people with different positive allergen numbers in the population before and during COVID-19.

not completely prevent allergen inhalation due to facial leakage penetration and increased total inward leakage caused by higher breathing frequencies [21]. Second, several studies have demonstrated that long-term mask use without change increases the chance of severe skin reactions [22], and the impaired skin barrier provides a pathway for allergen sensitization [23, 24]. Moreover, outdoor activity and allergen exposure increased with the gradual resumption of work and school in the second half of 2020, which is proved by a significant rise in the positive rate of w6 from June to September during COVID-19 in this study. Furthermore, as children usually feel hot and have breathing difficulties while wearing masks, some of them may remove the masks during physical activities [20], raising the prevalence of outdoor allergens during the pandemic. To decrease allergen stimulation and allergy symptoms, it is recommended that children reduce outside activities and use adequate masks with timely replacement during the pollen season.

During the COVID-19 pandemic, the proportion of medium and high-level sIgE to dust mite allergens increased, whereas the proportion of middle and high-level sIgE to mold and cockroach allergens dropped ($P < 0.05$). In the same study, Ye et al. [11] discovered that, except for dust mite allergens, the majority of allergen-specific IgE levels were lower than those before the pandemic. This may also contribute to increased exposure to dust mite allergens by spending longer time indoors during the pandemic [18].

Moreover, the proportion of multiple sensitivities grew greatly during COVID-19 compared to that before the same period ($P < 0.05$). Studies have pointed out that dust mite sensitization is often associated with other allergens due to antigen-cross and cosensitivity across allergens [25]. Therefore, when advising patients to avoid allergens, doctors should not only focus on the target allergen while ignoring other frequent allergens. Studies have shown that avoiding a single allergen cannot prevent allergy sensitization, whereas reducing the levels of numerous inhaled allergens together can achieve this purpose [26].

There were gender differences in the positive rate of allergens, which has been reported in other pieces of literature [27], yet the reason and mechanism remain unknown. It could be the different living habits between men and women, which may result in varied allergen exposure [27], or the difference in hormone secretion between the two genders [28].

The positive rate of inhaled allergens changes with age. The positive rates of dust mites and cockroaches increased with age, as found in the studies of Ying et al. [27] and D'souza et al. [29]. The differences in allergen sensitization at different ages, due to the different ranges of activity at different ages, might result in differences in allergen exposure. Clinicians should give proper recommendations to patients on avoiding allergen sensitization based on the distribution characteristics of allergens in different age groups and the trend of allergen sensitization with age.

This study also discovered that the positive rate of inhaled allergens was higher in summer and autumn than in winter and spring, and similar conclusions were found in an analysis of allergen sensitization in children in Shanghai, China [27]. This is due to seasonal differences in allergen concentrations in the air caused by the characteristics of various allergens. Dust mite reproduction peaks in July and August and begins to decline in October [30]. Animal hair sheds primarily in the summer and autumn. Trees bloom in the spring, grasses in the late spring to early summer, and weeds in the autumn [31]. As a result, patients who are sensitive to inhalation allergens should wear masks based on the seasonal distribution characteristics of local allergens to avoid contact with allergens and reduce allergen stimulation and allergic reactions.

There are currently few studies investigating the impact of the COVID-19 pandemic on allergen distributions. This study offers nearly 30,000 test results from a large sample size and includes an analysis of indoor and outdoor allergens, which can be used as a reference for the prevention and control of allergens sensitization under normal pandemic conditions. Nevertheless, this study has some limitations. It lacks data on allergy diseases in the study population for the privacy of the study population, making it impossible to assess the association between the COVID-19 pandemic and allergic diseases. Future studies should therefore investigate whether the COVID-19 pandemic influences the prevalence of allergy diseases.

5. Conclusion

NPIs during the COVID-19 pandemic are a risk factor for indoor and outdoor allergen sensitization. It was also found that allergen grade of dust mite and rates of multiple sensitizations were significantly higher than those before COVID-19. To reduce indoor allergen concentrations, we recommend (1) use a dehumidifier, vacuum, air purification, or mite removal instrument and open windows frequently for ventilation; (2) no use of carpets and fabric curtains and regularly wash and replace mattresses and pillows; (3) avoid keeping pets; (4) avoid going out during pollen season, wear a mask when going out, and change masks on time frequently; and (5) avoid allergens based on their age and seasonal characteristics.

Data Availability

All data pertaining to this study are within the manuscript, and further inquiries can be directed to the corresponding author.

Ethical Approval

The studies involving human participants were reviewed and approved by the Ethics Committee of the Hunan Children's Hospital. This study is retrospective, and the clinical test data of previous inpatients are analyzed and collated. The results of this study are not intended for clinical diagnosis and do not require the name of the patient to be known. And the clinical study does not have any risks to the subjects and does not require the subject to know.

Disclosure

A preprint has previously been published [32].

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Authors' Contributions

HXS, QJ, and CYP contributed to conception and design of the work. QJ, YM, and MY provisioned the study materials or patients. HXS collected and assembled the data, performed and interpretated the statistical analyses and interpretated, and drafted the manuscript. HXS and QJ revised the manuscript for important intellectual content. All authors contributed to the manuscript writing and also read and approved the final version of manuscript.

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Supplementary Materials

The supplementary materials analyzed the difference of the positive rate of inhaled allergens in children before and after the COVID-19 pandemic from three dimensions: sex, age, and season. In addition, gender, age, and seasonal differences in the positive rates of inhaled allergens in children before and after the COVID-19 pandemic were analyzed. It is helpful to understand the characteristics of the positive rate of inhaled allergens in children. Table S1: differences in positive rates of inhaled allergens during and during the COVID-19. Table S2: gender difference in the positive rate of inhaled allergens before and during COVID-19. Table S3: age differences in the positive rate of allergens before and during COVID-19. Table S4: seasonal differences in the positive rate of allergens before and during the COVID-19.

Table S5: impact of COVID-19 pandemic on allergen sensitization in subgroups by genders ((*n*) %). Table S6: impact of COVID-19 pandemic on allergen sensitization in subgroups by age groups ((*n*) %). Table S7: impact of COVID-19 pandemic on allergen sensitization in subgroups by season groups ((*n*) %). Figure S1: the number of examined detection cases and positive cases in each month during and before COVID-19. Figure S2: cosensitization of common inhaled allergens. (*Supplementary Materials*)

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