International Archives of Allergy and Immunology

Clinical Allergy – Research Article

Int Arch Allergy Immunol
DOI: 10.1159/000526892

Received: May 23, 2022
Accepted: August 17, 2022
Published online: October 24, 2022

Influence of the COVID-19 Pandemic on the Prevalence Pattern of Allergens

Yuanhong Liu Shengbo Yang Yilan Zeng Caifeng Yang Xuemei Li
Xiule Zong Ziting Tang Dan Wang

Department of Dermatology, Third Xiangya Hospital, Central South University, Changsha, China

Keywords
Allergens · Allergic diseases · COVID-19 · Positive rate · Allergen-specific IgE antibody detection

Abstract
Introduction: The effect of the COVID-19 pandemic on allergic diseases is not certain, as people's living habits and the environment have been affected by the pandemic. The present study described the influence of the COVID-19 pandemic on the allergen sensitization rate in patients with allergic diseases in central China. The results provide reliable epidemiological data for the prevention and control of allergic diseases during the COVID-19 epidemic. ***Methods:*** Data were collected from a total of 6,915 patients with symptoms of allergic diseases who visited the Third Xiangya Hospital of Central South University in China for allergen testing from January 1, 2018, to December 31, 2021. Patients were divided into a children group (<14 years old), youth group (15~44 years old), middle-aged group (45~59 years old), and elderly group (>60 years old). Immunoblotting was used to detect 20 serum allergen-specific IgE (sIgE) antibodies in patient serum samples. We compared the positive rates of various allergens in different age and sex groups before and during the COVID-19 epidemic, and the prevalence data of sIgE sensitization were analysed. ***Results:*** Among the 6,915 patients with symptoms of allergic diseases, 2,838 (41.04%) patients were positive for at least one of the allergens. The top three positive rates of inhaled allergens were *Dermatophagoides farinae* (1,764 cases, 25.51%), *Dermatophagoides pteronyssinus* (1,616 cases, 23.37%), and house dust (645 cases, 9.33%). The top three positive rates of food allergens were eggs (686 cases, 9.92%), milk (509 cases, 7.36%), and crabs (192 cases, 2.78%). The total positive rate of allergens was higher in men (46.99%) than in women (37.30%). Compared to 2 years before the COVID-19 epidemic, the rate of sensitization to indoor inhalant allergens increased, but outdoor inhalant allergens showed no significant change. The positive rates of milk and eggs peaked during the outbreak of COVID-19 (2020) then declined in 2021. The total positive rate of allergens was higher in males than females before and during the COVID-19 epidemic, but more allergens were different between males and females during the pandemic. Compared to middle-aged and older adults, the children and youth groups were more susceptible to allergic diseases, and they exhibited an increasing positive rate for most common allergens, especially indoor inhalant allergens, during the COVID-19 epidemic than before the pandemic. ***Conclusion:*** *D.*

Yuanhong Liu and Shengbo Yang contributed equally to this work.
Edited by: H.-U. Simon, Bern.

Karger@karger.com
www.karger.com/iaa

Karger
OPEN ACCESS

Correspondence to:
Dan Wang, drdanwang@163.com

pteronyssinus and *D. farinae* are the most common allergens in South China. Under the background of normalization of epidemic prevention, indoor inhaled allergens should be first in the prevention and control of allergic diseases, and a combination of various indoor cleaning measures should be used to improve the efficiency of interventions.

Introduction

Allergic diseases have become a global public health problem and produce significant socioeconomic burdens. Allergic diseases include eczema, atopic dermatitis, asthma, allergic rhinitis, conjunctivitis, and chronic rhinosinusitis. Food allergies affect more than 25% of the population in industrialized countries, and the sensitization rate is increasing in developing countries [1, 2]. Complex gene-environment interactions likely trigger allergic diseases and affect the development of allergic diseases [3]. Several factors, including climate change, pollution, reduction in biodiversity, urbanization, and changes in lifestyle and eating habits, contribute to changes in the allergen prevalence pattern [1, 2, 4]. Since the outbreak of the coronavirus disease in 2019 (COVID-19), local governments have called on people to adopt various epidemic prevention measures including the wearing of masks, social distancing, strengthening of hand hygiene, and controlling crowd gatherings to stop viral production. People spent more time at home. Outdoor entertainment activities were greatly reduced, and most in-person shopping changed to online shopping. Most schools had delayed openings, classroom courses were changed to online teaching, and remote working became trendy. The changes in people's living habits and the environment may have transformed the type and frequency of allergens that people were exposed to compared to previous years before the COVID-19 pandemic. However, the effect of the COVID-19 pandemic on allergic diseases is not certain.

An accurate diagnosis of allergic diseases is essential to prevent and delay disease development [5]. Allergen testing methods include the patch test, skin prick testing, serum-specific IgE (sIgE) testing, and basophil activation testing. Serum allergen sIgE detection exhibits a high safety profile and provides relatively reliable results, which played a significant role in the prevention and control of allergic diseases during the pandemic. Our study analysed the serum allergen sIgE detection results of 6,915 patients with symptoms of allergic diseases who visited a hospital in Central China for allergen testing before and during the epidemic. We calculated the positive rates of various allergens in patients of different ages and sexes to evaluate the influence of the COVID-19 pandemic on the prevalence pattern of allergens. The results provide reliable epidemiological data for the prevention and control of allergic diseases during normalized epidemic prevention.

Subjects and Methods

Study Population

A total of 6,915 serum allergen sIgE antibody detection data were obtained from the Third Xiangya Hospital of Central South University in Changsha, Hunan Province, from January 1, 2018, to December 31, 2021. Approximately 90.5% of the patients lived in urban areas, and only 6.3% were from rural areas. Approximately 3.2% of the patients had incomplete address information or could not be contacted. We collected the data of patients with suspected or diagnosed allergic diseases, including eczema, atopic dermatitis, asthma, allergic rhinitis, conjunctivitis, and chronic rhinosinusitis. The data we collected included the date of blood sample collection, age, sex, and the sIgE test results of 20 allergens. Our data included 1,275, 1,677, 1,599, and 2,364 patients in 2018, 2019, 2020, and 2021, respectively, with 2,660 male patients and 4,255 female patients. The male-to-female ratio was 1:1.60. The age ranged from 1 to 97 years old, the average age was 30.65 years old, and the median age was 29 (18, 45) years old. The study was performed in accordance with the Declaration of Helsinki.

The Detection Method

Professional staff detected patient serum sIgE using the URANUS AE 85 automatic enzyme immunoassay instrument (Jiangsu Akcome Science & Technology Co., Ltd., China). Allergens detected by the allergen sIgE antibody detection kit (Jiangsu Haoobo Biomedical Co., Ltd., China) included *Dermatophagoides pteronyssinus*, *Dermatophagoides farinae*, cat epithelium, dog epithelium, peanuts, soybeans, milk, crab, shrimp, eggs, beef, cod, wheat flour, lamb, house dust, cockroach, *Alternaria*, willow, ragweed, and mugwort. Sample preparation method: five millilitres of peripheral venous blood drawn from the patient was centrifuged (3,000 r/min for 10 min), and the upper serum was taken. The laboratory staff operated the testing equipment for allergen detection. Experimental principle: the system used the enzyme-linked immunocapture method, which first captures all IgE antibodies in the serum using anti-IgE antibodies encapsulated on a solid-phase carrier. Known standard liquid-phase allergens were added to bind to IgE antibodies. The enzyme-labelled antibody and substrate were added, and the enzyme catalysed the chromogenic reaction of the substrate. The absorbance of the end product was detected to reflect the slgE content of the sample. The grading and interpretation of the results followed the international standard [6]. Grading criteria: grade 0 (0 to <3.50 IU/mL), grade 1 (≥0.35 to <0.70 IU/mL), grade 2 (≥0.70 to <3.50 IU/mL), grade 3 (≥3.50 to <17.50 IU/mL), grade 4 (≥17.50 to <50.00 IU/mL), grade 5 (≥50.00 to <100.00 IU/mL), and grade 6 (≥100.00 IU/mL). A result equal to or greater than 0.35 indicated a positive reaction.

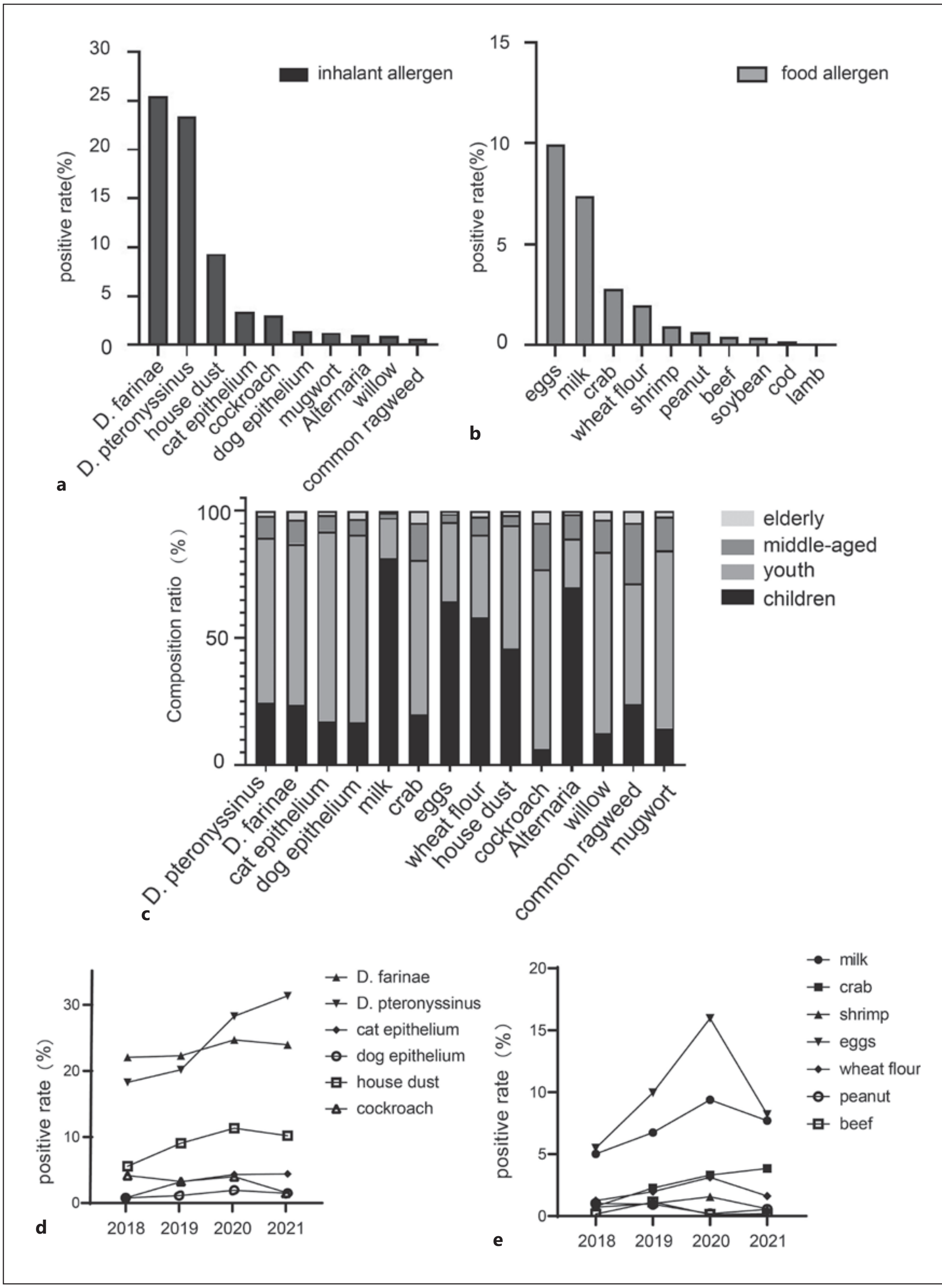

Fig. 1. Analysis of epidemiological data of allergen sIgE detection in 6,915 patients. **a** The total positive rate of inhaled allergens. **b** The total positive rate of food allergens in 6,915 patients. **c** The age distribution of 14 common inhaled and food allergens. **d** Annual changes in inhaled allergens from 2018 to 2021. **e** Yearly changes in food allergens from 2018 to 2021. *D. farinae, Dermatophagoides farinae; D. pteronyssinus, Dermatophagoides pteronyssinus.*

Table 1. Positive rates of allergen, 2018–2021

Allergen	2018, *n* (%) (*n* = 1,275)	2019, *n* (%) (*n* = 1,677)	2020, *n* (%) (*n* = 1,599)	2021, *n* (%) (*n* = 2,364)	χ^2	*p* value
Inhalant						
D. pteronyssinus	281 (22.04)	378 (22.30)	391 (24.70)	566 (23.94)	3.349	0.226
D. farinae	233 (18.27)	338 (20.16)	452 (28.27)	741 (31.35)	109.193	<0.001
Cat epithelium	10 (0.78)	54 (3.22)	69 (4.32)	104 (4.4)	37.683	<0.001
Dog epithelium	10 (0.78)	19 (1.13)	31 (1.94)	35 (1.48)	7.953	0.047
House dust	71 (5.57)	152 (9.06)	181 (11.32)	241 (10.19)	31.042	<0.001
Cockroach	53 (4.16)	55 (3.28)	64 (4)	36 (1.52)	29.486	<0.001
Alternaria	13 (1.02)	16 (0.95)	21 (1.31)	23 (0.97)	1.353	0.717
Willow	8 (0.63)	15 (0.89)	26 (1.63)	14 (0.59)	12.857	0.005
Ragweed	4 (0.31)	18 (1.07)	8 (0.5)	12 (0.51)	8.546	0.036
Mugwort	10 (0.78)	31 (1.85)	26 (1.63)	21 (0.89)	11.215	0.01
Food						
Peanut	13 (1.02)	16 (0.95)	3 (0.19)	13 (0.55)	10.746	0.013
Soybean	6 (0.47)	4 (0.24)	5 (0.31)	9 (0.38)		NA*
Milk	64 (5.02)	113 (6.74)	150 (9.38)	182 (7.7)	21.167	<0.001
Crab	10 (0.78)	38 (2.27)	53 (3.31)	91 (3.85)	32.16	<0.001
Shrimp	9 (0.71)	17 (1.01)	25 (1.56)	14 (0.59)	10.594	0.014
Eggs	70 (5.49)	167 (9.96)	255 (15.95)	194 (8.21)	100.775	<0.001
Beef	2 (0.16)	19 (1.13)	2 (0.13)	4 (0.17)	24.101	<0.001
Cod	0 (0)	4 (0.24)	4 (0.25)	5 (0.21)		NA*
Wheat flour	16 (1.25)	33 (1.97)	50 (3.13)	38 (1.61)	15.975	0.001
Lamb	2 (0.16)	0 (0)	2 (0.13)	1 (0.04)		NA*

D. farinae, *Dermatophagoides farinae*; *D. pteronyssinus*, *Dermatophagoides pteronyssinus*. * NA, not available: the sample size is too small to meet the applicable conditions of χ^2.

Statistical Analysis

SPSS 26.0 software was used for data analyses, and positive rates between groups were compared using the χ^2 and Fisher's tests. A *p* value <0.05 was considered statistically significant.

Results

Analysis of Epidemiological Data of Serum Allergen sIgE Detection in 6,915 Patients

Figure 1a and b show the total positive rates of each inhaled and food allergen in 6,915 patients, respectively. Among the 6,915 patients, the three inhalation allergens with the highest positive rates of sIgE antibody were *D. farinae* (1,764 cases, 25.51%), *D. pteronyssinus* (1,616 cases, 23.37%), and house dust (645 cases, 9.33%). The top three positive rates of food allergens were eggs (686 cases, 9.92%), milk (509 cases, 7.36%), and crabs (192 cases, 2.78%). As shown in Figure 1c, children and young people accounted for the largest proportion of most allergens, and the largest proportion of allergens in the children group were milk (81.34%), *Alternaria* (69.86%), eggs (64.29%), and wheat flour (61.54%). The allergens with the largest proportion in the youth group were *D. pteronyssinus* (64.79%), *D. farinae* (63.38%), cat epithelium (74.68%), dog epithelium (73.68%), house dust (48.68%), cockroaches (70.67%), willows (71.43%), ragweed (47.62%), mugwort (69.88%), and crabs (60.94%) ($p < 0.05$).

Positive rate test analyses for inhaled allergens showed statistically significant differences between the 4 years in *D. farinae*, cat epithelium, dog epithelium, house dust, cockroaches, willows, ragweed, and mugwort. For food allergens, positive rate test analyses showed statistically significant differences over the 4 years in peanuts, milk, crabs, shrimp, eggs, beef, and wheat flour ($p < 0.05$) (Table 1). Figure 1d shows that the sensitization rate of inhaled allergens included *D. farinae*, house dust, cat epithelium, and dog epithelium, which showed an increasing trend over time, and cockroaches showed a decreasing trend. Among the food allergens, the positive rates of eggs, milk, wheat flour, and shrimp increased annually until reaching a peak in 2020, then decreased ($p < 0.05$). However, the positive rate of crabs increased annually (Fig. 1d).

Table 2. Positive rates of allergen by gender in 6,915 patients

Allergen	Female, *n* (%) (*n* = 4,255)	Male, *n* (%) (*n* = 2,660)	χ^2	*p* value
Inhalant				
D. pteronyssinus	896 (21.06)	720 (27.07)	33.014	<0.001
D. farinae	957 (22.49)	807 (30.34)	53.041	<0.001
Cat epithelium	144 (3.38)	93 (3.5)	0.062	0.803
Dog epithelium	64 (1.5)	31 (1.17)	1.386	0.239
House dust	365 (8.58)	280 (10.53)	7.345	0.007
Cockroach	105 (2.47)	103 (3.87)	10.067	0.001
Alternaria	33 (0.78)	40 (1.5)	8.309	0.004
Willow	38 (0.89)	25 (0.94)	0.04	0.842
Ragweed	24 (0.56)	18 (0.68)	0.344	0.557
Mugwort	45 (1.06)	43 (1.62)	4.07	0.044
Food				
Peanut	17 (0.4)	28 (1.05)	10.799	<0.001
Soybean	12 (0.28)	12 (0.45)	1.353	0.245
Milk	270 (5.62)	239 (8.98)	49.332	<0.001
Crab	104 (2.44)	88 (3.31)	4.527	0.033
Shrimp	32 (0.75)	33 (1.24)	4.195	0.041
Eggs	400 (9.4)	286 (10.75)	3.344	0.067
Beef	13 (0.31)	14 (0.53)	2.052	0.152
Cod	8 (0.19)	5 (0.19)		NA*
Wheat flour	75 (1.76)	62 (2.33)	2.721	0.099
Lamb	3 (0.07)	2 (0.08)		NA*

D. farinae, *Dermatophagoides farinae*; *D. pteronyssinus*, *Dermatophagoides pteronyssinus*.
* NA, not available: the sample size is too small to meet the applicable conditions of χ^2.

Among the 6,915 patients, the total positive rates of male patients and female patients were 46.99% (1,251/2,660) and 37.30% (1,587/4,255), respectively. Compared to female patients, positive reactivity to inhaled allergens, including *D. pteronyssinus*, *D. farinae*, house dust, cockroaches, *Alternaria*, mugwort, and food allergens, including peanuts, milk, crabs, and shrimp, was higher in male patients ($p < 0.05$) (Table 2).

Table 3 shows that the differences in the positive rates of allergens in different age groups were statistically significant for allergens, including *D. pteronyssinus*, *D. farinae,* house dust, cat epithelium, dog epithelium, cockroaches, *Alternaria*, peanuts, milk, eggs, and wheat flour ($p < 0.05$). The allergens with the highest positive rates in the children group were eggs (32.84%), *D. farinae* (31.05%), and milk (30.83%). The allergens with the highest positive rates were *D. farinae* (28.11%) and *D. pteronyssinus* (26.33%) in the youth group, *D. farinae* (14.93%) and *D. pteronyssinus* (12.68%) in the middle-aged group, and *D. farina* (13.04%) and *D. pteronyssinus* (6.42%) in the elderly group. No differences were found in other allergens between the four groups.

Changes in the Positive Rates of Various Serum Allergen sIgE Detection during the COVID-19 Pandemic (2020–2021) Compared to before the COVID-19 Pandemic (2018–2019)

As shown in Figure 2a and b, the positive rates of indoor inhaled allergens, including *D. pteronyssinus*, *D. farinae*, house dust, cat epithelium, dog epithelium, and house dust, increased significantly in the 2 years during the pandemic compared to the 2 years before the pandemic, and the positive rate of cockroaches was lower than before the pandemic ($p < 0.05$). The positive rates of food allergens, including milk, eggs, and crab, increased, and the positive rates of peanuts and beef decreased ($p < 0.05$). No differences were found in other allergens before and during the pandemic (Table 4).

Among the 6,915 patients, the total positive rate of allergens in males was 41.44% (455/1,098) and 33.87% (628/1,854) in females before the COVID-19 pandemic. During the COVID-19 pandemic, the positive rate of allergens in males was 50.90% (795/1,562) and 39.94% (959/2,401) in females. The positive rates of allergens in males were higher than females in these two periods ($p < 0.05$). Compared to 2 years before the COVID-19 epi-

Table 3. Positive rates of allergen in different age groups in 6,915 patients

Allergen	≤14 years, *n* (%) (*n* = 1,343)	15~44 years, *n* (%) (*n* = 3,977)	45~59 years, *n* (%) (*n* = 1,112)	≥60 years, *n* (%) (*n* = 483)	χ^2	*p* value
Inhalant						
D. pteronyssinus	397 (29.56)	1,047 (26.33)	141 (12.68)	31 (6.42)	196.617	<0.001
D. farinae	417 (31.05)	1,118 (28.11)	166 (14.93)	63 (13.04)	140.888	<0.001
Cat epithelium	41 (3.05)	177 (4.45)	15 (1.35)	4 (0.83)	37.521	<0.001
Dog epithelium	16 (1.19)	70 (1.76)	6 (0.54)	3 (0.62)	12.442	0.006
House dust	295 (21.97)	314 (7.9)	25 (2.25)	11 (2.28)	357.556	<0.001
Cockroach	13 (0.97)	147 (3.7)	38 (3.42)	10 (2.07)	27.708	<0.001
Alternaria	51 (3.8)	14 (0.35)	7 (0.63)	1 (0.21)	120.77	<0.001
Willow	7 (0.52)	40 (1.01)	7 (0.63)	2 (0.41)		NA*
Ragweed	10 (0.74)	20 (0.5)	10 (0.9)	2 (0.41)		NA*
Mugwort	12 (0.89)	58 (1.46)	11 (0.99)	2 (0.41)	6.235	0.099
Food						
Peanut	20 (1.49)	19 (0.48)	4 (0.36)	2 (0.41)	14.939	0.002
Soybean	12 (0.89)	9 (0.23)	2 (0.18)	1 (0.21)		NA*
Milk	414 (30.83)	81 (2.04)	10 (0.9)	4 (0.83)	1,348.11	<0.001
Crab	38 (2.83)	117 (2.94)	28 (2.52)	9 (1.86)	2.184	0.534
Shrimp	19 (1.41)	39 (0.98)	6 (0.54)	1 (0.21)		NA*
Eggs	441 (32.84)	214 (5.38)	23 (2.07)	8 (1.66)	994.594	<0.001
Beef	14 (1.04)	11 (0.28)	1 (0.09)	1 (0.21)		NA*
Cod	8 (0.6)	5 (0.13)	0 (0)	0 (0)		NA*
Wheat flour	80 (5.96)	44(1.11)	10(0.9)	3 (0.62)	136.284	<0.001
Lamb	2 (0.15)	2 (0.05)	0 (0)	1 (0.21)		NA*

D. farinae, *Dermatophagoides farinae*; *D. pteronyssinus*, *Dermatophagoides pteronyssinus*; yr, years old. * NA, not available: the sample size is too small to meet the applicable conditions of χ^2.

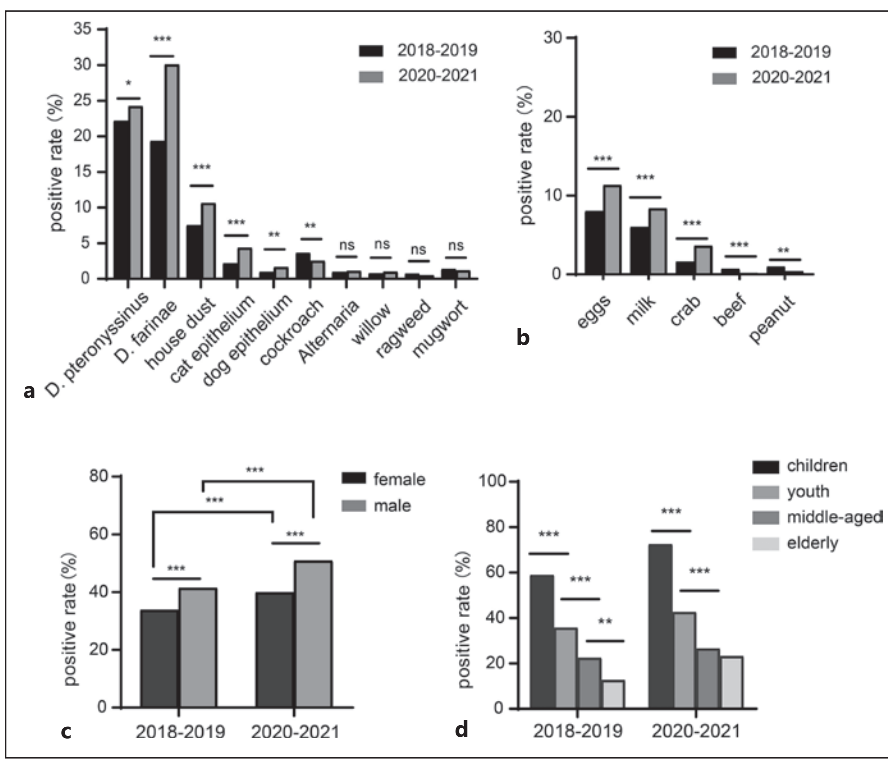

Fig. 2. Comparison of the positive rates of various serum allergen sIgE detection in 2020~2021 (during the COVID-19 pandemic) compared to 2018~2019 (before the COVID-19 pandemic). **a** Comparison of inhaled allergen positivity rates in the 2 years before and during the COVID-19 pandemic. **b** Comparison of food allergen positivity rates in the 2 years before and during the COVID-19 pandemic. **c** Comparison of the total allergen positivity rate in different sexes in the 2 years before and during the COVID-19 pandemic. **d** Comparison of the total allergen positivity rate in different age groups in the 2 years before and during the COVID-19 pandemic. $p < 0.05$. $^{**}p < 0.01$. $^{***}p < 0.001$.

Table 4. Positive rates of allergen in the year 2020~2021 (during the COVID-19 pandemic) compared with the year 2018~2019 (before the COVID-19 pandemic)

Allergen	2018~2019, *n* (%) (*n* = 2,952)	2020~2021, *n* (%) (*n* = 3,963)	χ^2	*p* value
Inhalant				
D. pteronyssinus	659 (22.19)	957 (24.25)	4.013	0.045
D. farinae	571 (19.34)	1,193 (30.1)	103.09	<0.001
Cat epithelium	64 (2.17)	173 (4.37)	24.68	<0.001
Dog epithelium	29 (0.98)	66 (1.67)	5.825	0.016
House dust	223 (7.55)	422 (10.65)	19.153	<0.001
Cockroach	108 (3.66)	100 (2.52)	7.473	0.004
Alternaria	29 (0.98)	44 (1.11)	0.265	0.607
Willow	23 (0.78)	40 (1.01)	0.993	0.319
Ragweed	22 (0.75)	20 (0.5)	1.622	0.203
Mugwort	41 (1.39)	47 (1.19)	0.554	0.457
Food				
Peanut	29 (0.98)	16(0.4)	8.762	0.003
Soybean	10 (0.34)	14 (0.35)	0.01	0.919
Milk	177 (6)	332 (8.38)	14.072	<0.001
Crab	48 (1.63)	144 (3.63)	25.259	<0.001
Shrimp	26 (0.88)	39 (0.98)	0.194	0.66
Eggs	237 (8.03)	449 (11.33)	20.633	<0.001
Beef	21 (0.71)	6(0.15)	13.64	<0.001
Cod	4 (0.14)	9 (0.23)	0.756	0.384
Wheat flour	49 (1.66)	88 (2.22)	2.738	0.098
Lamb	2 (0.07)	3 (0.08)		0.635

D. farinae, *Dermatophagoides farinae*; *D. pteronyssinus*, *Dermatophagoides pteronyssinus*.

demic, the total positive rates of allergens were higher during the epidemic in males and females, and the difference was statistically significant ($p < 0.05$) (Fig. 2c). Compared to the 2 years before the pandemic, the positive rate of males was higher than females for the allergens cat epithelium, cockroaches, peanuts, and eggs during the pandemic. The positive rates of allergens, including *D. pteronyssinus*, *D. farinae*, house dust, cockroaches, *Alternaria*, peanuts, milk, crabs, and shrimp, in males were higher than females, and the difference was statistically significant ($p < 0.05$) (Table 5).

We also analysed the positive rates of serum allergens in different age groups of the 6,915 patients. The total positive rates of allergens in the children group (<14 years old), youth group (15~44 years old), middle-aged group (45~59 years old), and elderly group were 58.92% (337/572), 35.67% (616/1,727), 22.43% (109/486), and 12.57% (21/167) before the COVID-19 pandemic, respectively, and that the rates during the pandemic were 72.37% (558/771), 42.58% (958/2,250), 26.52% (73/626), and 23.10% (73/316), respectively. The total positive rates of allergens in the younger group were significantly higher than those in the older group ($p < 0.05$), but not for the middle-aged group or elderly group during the pandemic (Fig. 2d).

Compared to the 2 years before the pandemic, the positive rates of *D. pteronyssinus*, cat epithelium, house dust, *Alternaria*, milk, crab, eggs, beef, and wheat flour in the children group were higher. The positive rates of *D. farinae,* cat epithelium, peanuts, milk, crab, eggs, and beef in the youth group were higher during the pandemic and cockroaches were lower. The difference was statistically significant ($p < 0.05$). Only the positive rates of dust mites increased in the middle-aged group and the elderly group during the pandemic compared to before the pandemic, and the difference was statistically significant ($p < 0.05$). No differences were found in other allergens (Table 6).

Discussion

The outbreak of the COVID-19 pandemic profoundly changed people's lifestyles and living environments, but the impact of the COVID-19 pandemic on allergic diseases was rarely studied. Some studies showed that the COVID-19 pandemic caused asthma by triggering respi-

Table 5. Positive rates of allergen by gender in the year 2020~2021 (during the COVID-19 pandemic) compared with the year 2018~2019 (before the COVID-19 pandemic)

Allergen	2018~2019, *n* (%) (*n* = 2,952)				2020~2021, *n* (%) (*n* = 3,963)			
	female	male	χ^2	*p* value	female	male	χ^2	*p* value
Inhalant								
D. pteronyssinus	394 (21.25)	260 (23.68)	2.357	0.125	502 (20.91)	460 (29.45)	35.442	<0.001
D. farinae	340 (18.34)	231 (21.04)	3.221	0.073	617 (25.7)	576 (36.88)	56.198	<0.001
Cat epithelium	32 (1.73)	32 (2.91)	4.592	0.032	112 (4.66)	61 (3.91)	1.307	0.144
Dog epithelium	23 (1.24)	6 (0.55)	3.416	0.065	41 (1.71)	25 (1.6)	0.066	0.452
House dust	127 (6.85)	96 (8.74)	3.539	0.06	238 (9.91)	184 (11.78)	3.468	0.036
Cockroach	58 (3.13)	50 (4.55)	3.975	0.046	47 (1.96)	53 (3.39)	7.929	0.004
Alternaria	15 (0.81)	14 (1.28)	1.539	0.215	18(0.75)	26 (1.66)	7.214	0.006
Willow	17 (0.92)	6 (0.55)	1.224	0.268	21 (0.87)	19 (1.22)	1.106	0.186
Ragweed	10 (0.54)	12 (1.09)	2.856	0.091	14 (0.58)	6 (0.38)	0.746	0.267
Mugwort	22 (1.19)	19 (1.73)	1.489	0.222	23 (0.96)	24 (1.54)	2.703	0.069
Food								
Peanut	13 (0.7)	16 (1.46)	4.052	0.044	4 (0.17)	12 (0.77)	8.519	0.004
Soybean	5 (0.27)	5 (0.46)	0.704	0.401	7 (0.29)	7 (0.45)	0.659	0.291
Milk	76 (4.1)	47 (4.28)	0.057	0.812	163 (6.79)	223 (14.28)	60.352	<0.001
Crab	30 (1.62)	18 (1.64)	0.002	0.965	74 (3.08)	70 (4.48)	5.292	0.014
Shrimp	15 (0.81)	11 (1)	0.294	0.588	17 (0.71)	22 (1.41)	4.764	0.023
Eggs	125 (6.74)	113 (10.29)	11.72	0.001	275 (11.45)	173 (11.08)	0.135	0.377
Beef	10 (0.54)	11 (1)	2.088	1.148	3 (0.12)	3 0.19)		0.444
Cod	3 (0.16)	1(0.09)	0.255	0.614	5 (0.21)	4 (0.26)		0.503
Wheat flour	26 (1.4)	23 (2.09)	2.025	0.155	49 (2.04)	39 (2.5)	0.906	0.199
Lamb	1 (0.05)	1 (0.09)		NA*	2 (0.08)	1 (0.06)		0.656

D. farinae, *Dermatophagoides farinae*; *D. pteronyssinus*, *Dermatophagoides pteronyssinus*. *NA, not available: the sample size is too small to meet the applicable conditions of χ^2.

ratory dysfunction. Patients with allergic diseases, such as asthma, are at higher risk for severe COVID-19 after infection [7]. However, a recent sub-cohort study evaluated long-term COVID-19 symptoms at Stanford. This study showed that asthma was not a risk factor for more severe COVID-19. Non-allergic asthmatic patients had twice the risk of hospitalization for COVID-19 compared to allergic asthmatic patients. Lower levels of eosinophils were related to more severe COVID-19 disease [8]. Eosinophil counts are allergic biomarkers. However, most COVID-19 patients had reduced blood eosinophil counts [9]. Therefore, more research is needed to examine whether patients become more or less sensitized to COVID-19 infection.

Changes in lifestyle and living environment may alter people's susceptibility and the population distribution of various allergens [10]. Therefore, it is of great significance to master the epidemiological data of allergic diseases for the prevention and control of allergic diseases during the COVID-19 pandemic. Among the 6,915 patients with allergic diseases in this study, the three inhalation allergens with the highest positive rates were *D. farinae* (25.51%), *D. pteronyssinus* (23.37%), and house dust (9.33%), and the three food allergens with the highest positive rates were eggs (9.92%), milk (7.36%), and crab (2.78%). *D. farinae* is the most common inhaled allergen in our city in Central China. The distribution of allergens varies in different regions due to the geographical environment, climatic conditions, and lifestyles. China has a warm and humid subtropical climate, and *D. farinae* is the most common allergen in most parts of China. *D. farinae* has strong antigenicity, and live mites, mite corpses, and mite faeces are allergenic. They are found in pillows, mattresses, fabric sofas, carpets, and air conditioning filters. *D. farinae* is the most common unavoidable allergen. *D. farinae* grows quickly, has a strong reproductive ability, and is difficult to completely remove [11].

Table 6. Positive rates of allergen in different age groups in the year 2020~2021 (during the COVID-19 pandemic) compared with the year 2018~2019 (before the COVID-19 pandemic)

Allergen	Children group (1~14 years), *n* (%) (*n* = 1,343)				Youth group (15~44 years), *n* (%) (*n* = 3,977)			
	2018~2019 (*n* = 2,952)	2020~2021 (*n* = 3,963)	χ^2	*p* value	2018~2019 (*n* = 2,952)	2020~2021 (*n* = 3,963)	χ^2	*p* value
Inhalant								
D. pteronyssinus	137 (23.95)	261 (33.85)	15.058	<0.001	439 (25.42)	608 (27.02)	1.3	0.255
D. farinae	192 (33.57)	225 (29.18)	2.947	0.086	380 (22)	738 (32.8)	56.356	<0.001
Cat epithelium	11 (1.92)	30 (3.89)	4.297	0.038	49 (2.84)	128 (5.69)	18.683	<0.001
Dog epithelium	3 (0.52)	13 (1.69)	3.764	0.052	24 (1.39)	46 (2.04)	2.422	0.12
House dust	84 (14.69)	211 (27.37)	30.811	<0.001	123 (7.12)	191 (8.49)	2.51	0.113
Cockroach	7 (1.22)	6 (0.78)	0.68	0.41	78 (4.52)	69 (3.07)	5.77	0.016
Alternaria	13 (2.27)	38 (4.93)	6.341	0.012	9 (0.52)	5 (0.22)	2.489	0.115
Willow	2 (0.35)	5 (0.65)		0.706	15 (0.87)	25 (1.11)	0.577	0.447
Ragweed	5 (0.87)	5 (0.65)		0.752	10 (0.58)	10 (0.44)	0.354	0.552
Mugwort	7 (1.22)	5 (0.65)	1.227	0.207	30 (1.74)	28 (1.24)	1.65	0.199
Food								
Peanut	12 (2.1)	8 (1.04)	2.516	0.113	15 (0.87)	4 (0.18)	9.806	0.002
Soybean	4 (0.7)	8 (1.04)	0.424	0.515	4 (0.23)	5 (0.22)		NA*
Milk	148 (25.87)	266 (34.5)	11.46	0.001	24 (1.39)	57 (2.53)	6.405	0.011
Crab	7 (1.22)	31 (4.02)	9.344	0.002	28 (1.62)	89 (3.96)	18.645	<0.001
Shrimp	5 (0.87)	14 (1.82)	2.088	0.148	17 (0.98)	22 (0.98)	0.0	0.983
Eggs	170 (29.72)	271 (35.15)	4.388	0.036	60 (3.47)	154 (6.84)	21.797	<0.001
Beef	10 (1.75)	4 (0.52)	4.812	0.028	9 (0.52)	2 (0.09)	6.618	0.01
Cod	2 (0.35)	6 (0.78)	1.019	0.313	2 (0.12)	3 (0.13)		0.622
Wheat flour	23 (4.02)	57 (7.39)	6.665	0.01	20 (1.16)	24 (1.07)	0.075	0.785
Lamb	0 (0)	2 (0.26)		0.511	2 (0.12)	0 (0)		0.189
Allergen	Middle-aged group (45~59 years), *n* (%) (*n* = 1,112)				Elderly group (60~97 years), *n* (%) (*n* = 483)			
	2018~2019 (*n* = 2,952)	2020~2021 (*n* = 3,963)	χ^2	*p* value	2018~2019 (*n* = 2,952)	2020~2021 (*n* = 3,963)	χ^2	*p* value
Inhalant								
D. pteronyssinus	71 (14.61)	70 (11.18)	2.902	0.088	7 (4.19)	24 (7.59)	2.107	0.147
D. farinae	51 (10.49)	115 (18.37)	13.366	<0.001	11 (6.59)	52 (16.46)	9.382	0.002
Cat epithelium	3 (0.62)	12 (1.92)	3.473	0.062	1 (0.6)	3 (0.95)		0.57
Dog epithelium	1 (0.21)	5 (0.8)		0.24	1 (0.6)	2 (0.63)		0.724
House dust	12 (2.47)	13 (2.08)	0.192	0.661	4 (2.4)	7 (2.22)		0.564
Cockroach	20 (4.12)	18 (2.88)	1.274	0.259	3 (1.8)	7 (2.22)		0.525
Alternaria	6 (1.23)	1 (0.16)		0.048	1 (0.6)	0 (0)		0.346
Willow	5 (1.03)	2 (0.32)		0.25	1 (0.6)	1 (0.32)		0.572
Ragweed	6 (1.23)	4 (0.64)	0.523	0.469	1 (0.6)	1 (0.32)		0.572
Mugwort	3 (0.62)	8 (1.28)	0.638	0.424	1 (0.6)	1 (0.32)		0.572
Food								
Peanut	2 (0.41)	2 (0.32)		NA*	0 (0)	2 (0.63)		0.428
Soybean	2 (0.41)	0 (0)		0.191	0 (0)	1 (0.32)		0.654
Milk	4 (0.82)	6 (0.96)		NA*	1 (0.6)	3 (0.95)		0.57
Crab	10 (2.06)	18 (2.88)	0.745	0.388	3 (1.8)	6 (1.9)		0.62
Shrimp	3 (0.62)	3 (0.48)		NA*	1 (0.6)	0 (0)		0.346
Eggs	6 (1.23)	17 (2.72)	2.963	0.085	1 (0.6)	7 (2.22)		0.173
Beef	1 (0.21)	0 (0)		0.437	1 (0.6)	0 (0)		0.346
Cod	0 (0)	0 (0)			0 (0)	0 (0)		
Wheat flour	4 (0.82)	6 (0.96)		0.538	2 (1.2)	1 (0.32)		0.276
Lamb	0 (0)	0 (0)			0 (0)	1 (0.32)		0.654

D. farinae, *Dermatophagoides farinae*; *D. pteronyssinus*, *Dermatophagoides pteronyssinus*. * NA, not available: the sample size is too small to meet the applicable conditions of χ^2.

The age distribution of different allergens in the children and youth groups accounted for the largest proportion of most allergens. Food accounts for a large proportion of the allergens in children. Inhaled allergens accounted for a large proportion of young people and elderly individuals. Children are more likely to be allergic to food allergens because the gastrointestinal barrier function and the mucosal immune system are not fully competent. The function of the gastrointestinal tract is more complete in youth and older populations, and inhalation allergens gradually predominate [12]. Previous studies have reported that vitamin D deficiency may be a risk factor for food allergy in children [13–16]. During the epidemic, the increased rates of food allergen positivity may be related to the reduced outdoor activities of children and their short exposure to sunlight. There was a statistically significant difference in the positive rates of allergens between the sexes. The total positive rate of allergens in men was higher than in women, and men were more susceptible to most allergens than women, which is consistent with the literature [17, 18].

Since the outbreak of the COVID-19 pandemic, people's living habits and living environment have dramatically transformed compared to before the pandemic. Our data showed that the sensitization rate of indoor inhaled allergens, including *D. farinae*, *D. pteronyssinus*, cat epithelium, dog epithelium, and house dust, increased in the 2 years during COVID-19 compared to the 2 years before the outbreak of COVID-19, which is consistent with the literature [7, 19]. The government tightened controls during the outbreak, and people went out less and isolated themselves as much as possible. Therefore, the exposure time and frequency of indoor allergens increased significantly compared to outdoor allergens. Staying at home for a long time without frequent ventilation and insufficient sunlight may also increase the sensitivity to indoor allergens [7]. During the COVID-19 pandemic, the sensitization rate of food allergens, including eggs, milk, and crabs, peaked in 2020. During the epidemic, people paid more attention to diet and strengthening their nutrition. Eggs and milk are the most common and easily available high-protein foods. Patients with mild allergies or suspected patients were likely to reduce hospital visits during the COVID-19 epidemic. As the epidemic was brought under control in 2021, people's lifestyles gradually returned to normal in 2022. The level of food allergens dropped to pre-epidemic levels in 2021. However, the positive rate varied depending on the severity of the epidemic and epidemic prevention measures in different areas. During the outbreak of the COVID-19 epidemic, more allergens showed differences between men and women than before the outbreak, and the positive rate of men was higher than women. One study of allergic asthma found that boys had higher atopy and allergen sensitization than girls in childhood, but the opposite was true in adulthood. The change may be related to sex hormones and airway diameter [20]. Therefore, the effect of sex on allergen susceptibility must be further explored.

In the context of the normalization of epidemic prevention, the incidence of allergic diseases related to indoor allergens is gradually increasing. Reducing exposure to indoor allergens is a key measure for the prevention and control of allergic diseases. The results of a systematic review abroad suggested that the combined use of acaricides, air purification, carpet cleaning, high-efficiency particulate air filtration vacuum cleaners, mattress covers, mould removal, pest control, and pet cleaning reduced indoor allergies to a certain extent. However, the effect of a single intervention was not clear or ineffective, and no combination of specific interventions was more effective [21]. Therefore, a combination of various intervention measures should be used as much as possible in the prevention and treatment of indoor inhaled allergens to improve the intervention effect. Cross-reactivity and/or co-sensitization of allergens, such as myosin, and arginine kinases in insects were demonstrated in patients with *D. pteronyssinus* and seafood allergies. Researchers recently found that processing and digestion did not reduce the sensitization of insect pan-allergenic myosin and arginine kinases. Therefore, patients with *D. farinae* allergies should be cautious in eating foods that may contain cross-allergens, such as shrimp and mealworms [22].

The present study has some limitations. It was a retrospective study, and the positive rate varied depending on the severity of the epidemic and epidemic prevention measures in different areas. Therefore, it only represents the allergen changes in one urban area in central China before and after the COVID-19 epidemic. More regional data are needed to explore the impact of the COVID-19 epidemic on allergic diseases in the future.

For normalization of epidemic prevention, the data in the present study showed that the positive rates of indoor inhalant allergens and most common food allergens, including eggs and milk, increased during the COVID-19 pandemic. Indoor allergens should be placed first in the prevention and treatment of allergic diseases, and a combination of various indoor cleaning measures should be used to improve the efficiency of interventions. The study provides reliable epidemiological data and guiding advice for the prevention and control of allergic diseases during normalized epidemic prevention.

Statement of Ethics

The need for informed consent was waived by the Ethics Committee of the Third Xiangya Hospital of Central South University. The study protocol was reviewed and approved by the Ethics Committee of the Third Xiangya Hospital of Central South University, approval number (I 22056). The study was carried out in accordance with the Declaration of Helsinki.

Conflict of Interest Statement

All authors declare that there is no conflict of interests.

Funding Sources

This work was supported by the Natural Science Foundation of Changsha (kq2014263). The fund provides financial support for our data collection and analysis.

Author Contributions

Yuanhong Liu and Shengbo Yang: dtata collecting and analysis and drafting the manuscript. Dr. Dan Wang: drafting the manuscript, critical reading of the manuscript and helpful discussions. Yilan Zeng, Caifeng Yang, Xiule Zong, Xuemei Li, and Ziting Tang: data collecting and participated in data analysis. The manuscript has been read and approved by all the authors; each author believes that the manuscript represents honest work.

Data Availability Statement

All data generated or analysed during this study are included in this article. Further enquiries can be directed to the corresponding author.

References

1 Bousquet J, Akdis CA, Grattan C, Eigenmann PA, Hoffmann-Sommergruber K, Agache I, et al. Highlights and recent developments in airway diseases in EAACI journals (2018). Allergy. 2019;74(12):2329–41.

2 Aw Yong PY, Islam F, Harith HH, Israf DA, Tan JW, Tham CL. The potential use of honey as a remedy for allergic diseases: a mini review. Front Pharmacol. 2020;11:599080.

3 Agache I, Akdis CA. Precision medicine and phenotypes, endotypes, genotypes, regiotypes, and theratypes of allergic diseases. J Clin Invest. 2019;129(4):1493–503.

4 Yao Y, Chen CL, Yu D, Liu Z. Roles of follicular helper and regulatory T cells in allergic diseases and allergen immunotherapy. Allergy. 2021;76(2):456–70.

5 Eigenmann PA. Diagnosis of allergy syndromes: do symptoms always mean allergy? Allergy. 2005;60(Suppl 79):6–9.

6 Hamilton RG, Matsson PN, Hovanec-Burns DL, Van Cleve M, Chan S, Kober A, et al. Analytical performance characteristics, quality assurance and clinical utility of immunological assays for human IgE antibodies of defined allergen specificities. (CLSI-ILA20-A3). J Allergy Clin Immun. 2015;135(2):Ab8-Ab.

7 CDC COVID-19 Response Team; Chow N, Fleming-Dutra K, Gierke R, Hall A, Hughes M, et al. Preliminary estimates of the prevalence of selected underlying health conditions among patients with coronavirus disease 2019-United States, February 12–March 28, 2020. MMWR Morb Mortal Wkly Rep. 2020; 69(13):382–6.

8 Eggert LE, He Z, Collins W, Lee AS, Dhondalay G, Jiang SY, et al. Asthma phenotypes, associated comorbidities, and long-term symptoms in COVID-19. Allergy. 2022;77(1):173–85.

9 Xie G, Ding F, Han L, Yin D, Lu H, Zhang M. The role of peripheral blood eosinophil counts in COVID-19 patients. Allergy. 2021; 76(2):471–82.

10 Li Y, Hu H, Zhang T, Wang G, Huang H, Zheng P, et al. Increase in indoor inhalant allergen sensitivity during the COVID-19 pandemic in South China: a Cross-Sectional Study from 2017 to 2020. J Asthma Allergy. 2021;14:1185–95.

11 Sidenius KE, Hallas TE, Stenderup J, Poulsen LK, Mosbech H. Decay of house-dust mite allergen Der f 1 at indoor climatic conditions. Ann Allergy Asthma Immunol. 2002;89:34–7.

12 Kemp A, Chiang WC, Gerez I, Goh A, Liew WK, Shek LP, et al. Childhood food allergy: a Singaporean perspective. Ann Acad Med Singap. 2010;39(5):404–11.

13 Vassallo MF, Banerji A, Rudders SA, Clark S, Camargo CA. Season of birth and food-induced anaphylaxis in Boston. Allergy. 2010 Nov;65(11):1492–3.

14 Sharief S, Jariwala S, Kumar J, Muntner P, Melamed ML. Vitamin D levels and food and environmental allergies in the United States: results from the National Health and Nutrition Examination Survey 2005–2006. J Allergy Clin Immun. 2011 May;127(5):1195–202.

15 Allen KJ, Koplin JJ, Ponsonby AL, Gurrin LC, Wake M, Vuillermin P, et al. Vitamin D insufficiency is associated with challenge-proven food allergy in infants. J Allergy Clin Immun. 2013 Apr;131(4):1109–16, 1116.e1–6.

16 Zdrenghea MT, Makrinioti H, Bagacean C, Bush A, Johnston SL, Stanciu LA. Vitamin D modulation of innate immune responses to respiratory viral infections. Rev Med Virol. 2017 Jan;27(1):e1909.

17 Lu XH, Zhang H, Liu LQ, et al. Analysis of serum allergen-specific IgE antibody test results in patients with allergic skin diseases. Lab Med Clin. 2021;18:3312–6.

18 Chen JX, Liu YZ, Zhang H, Li Z. Determination and analysis of serum specific IgE in patients with allergic diseases in Shenzhen area. Int J Lab Med. 2018;39(11):1340–3.

19 Ye Q, Wang B, Liu H. Influence of the COVID-19 pandemic on the incidence and exacerbation of childhood allergic diseases. J Med Virol. 2022;94(4):1655–69.

20 Holguin F. Sex hormones and asthma. Am J Respir Crit Care Med. 2020;201(2):127–8.

21 Leas BF, D'Anci KE, Apter AJ, Bryant-Stephens T, Lynch MP, Kaczmarek JL, et al. Effectiveness of indoor allergen reduction in asthma management: a systematic review. J Allergy Clin Immunol. 2018;141(5):1854–69.

22 de Gier S, Verhoeckx K. Insect (food) allergy and allergens. Mol Immunol. 2018;100:82–106.