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Research Article

Analysis of Specific Allergens in the Serum of Patients with Allergic Diseases in the Shanxi Region of China

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The aim of this study is to analyze the distribution characteristics of specific allergens based on the immunoglobulin E (IgE) test, performed using the sera of patients with allergic diseases in the Shanxi region of China. Sera from 3141 patients with allergic diseases were analyzed with immunoblotting for IgE antibodies specific to inhaled and ingested allergens. The distribution of allergens and association with factors such as disease profile, sex, age, and cosensitization of the patients who tested positive were analyzed. The most common positive rate of IgE specific to inhaled allergens was mugwort, followed by dust mite mix and common ragweed. The most common positive rate of IgE specific to ingested allergens was crab, followed by egg white and sea fish mix. When analyzed according to disease profile, mugwort was the most common allergen in asthma, rhinitis, and asthma combined with rhinitis. When analyzed by season, the allergens with the highest positive rates included tree mix (willow/poplar/elm), common ragweed, mugwort, and hop pollen from July through September. When analyzed by age, the allergens with the highest positive rates were tree mix, common ragweed, hop, house dust, cow's milk, mutton/lamb, and peanut in participants aged 0–18 years and egg white in those aged ≥60 years. The radar charts showed cosensitization to multiple allergens. In the Shanxi region, the primary inhaled allergens were mugwort, dust mite mix (1: house dust mite/dust mite), and common ragweed. The primary ingested allergens were crab, egg white, and sea fish mix. There were differences in the positive rates of the allergens between genders, age groups, and seasons, and multiple allergens can cosensitize patients.

1. Introduction

Allergic diseases constitute a global challenge to public health and include diseases such as asthma, allergic rhinitis, atopic dermatitis, chronic sinusitis, and conjunctivitis [1]. Allergies are defined as abnormal or hypersensitive immune reactions to many substances (e.g., pollutants, foods, and dust). A dysfunctional immune system is often characterized by both of allergy and autoimmunity, and there are close connections between allergic responses and autoimmune responses. An important prerequisite for treating autoimmune diseases is to identify the source of antigens that trigger and/or drive the autoimmune responses in various kinds of diseases. It has been reported that allergens from food and atmosphere may be able to trigger the development and seriousness of autoimmune diseases. In the past few decades, the number of patients with allergic diseases has significantly increased worldwide [2]. This number has reached approximately one billion globally, as shown by epidemiologic studies, and more than 25% of such patients live in industrialized countries [3, 4]. There are numerous types of allergic diseases, of which IgE-mediated allergy is the most common type [5]. IgE is typically found in small amounts in the human body; however, IgE concentration rises significantly when allergic patients repeatedly experience allergen stimulation. The IgE antibodies bound to the surface of sensitization effector cells are cross-linked and activated to release inflammatory mediators, leading to clinical allergic

Table 1: Distribution of allergen-positive patients in allergen-specific immunoglobulin E test by disease.

Allergens	Diseases					χ^2	p
	Asthma ($n = 512$)	Rhinitis ($n = 252$)	Asthma+rhinitis ($n = 180$)	Cough ($n = 146$)	Other allergies ($n = 343$)		
ts20 (tree mix)	57 (11.1)	53 (21.0)	33 (18.3)	14 (9.6)	45 (13.1)	19.111	0.001
w1 (common ragweed)	92 (18.0)	78 (31.0)	47 (26.1)	21 (14.4)	60 (17.5)	27.271	<0.001
w6 (mugwort)	263 (51.4)	205 (81.3)	125 (69.4)	73 (50.0)	175 (51.0)	86.146	<0.001
ds1 (dust mite mix)	129 (25.2)	27 (10.7)	50 (27.8)	27 (18.5)	68 (19.8)	27.32	<0.001
h1 (house dust)	40 (7.8)	20 (7.9)	23 (12.8)	11 (7.5)	21 (6.1)	7.272	0.122
e1 (cat hair)	109 (21.3)	55 (21.8)	43 (23.9)	28 (19.2)	60 (17.5)	3.777	0.437
e2 (dogskin)	46 (9.0)	14 (5.6)	13 (7.2)	15 (10.3)	24 (7.0)	4.389	0.356
i6 (cockroach)	65 (12.7)	8 (3.2)	12 (6.7)	18 (12.3)	40 (11.7)	21.37	<0.001
ms1 (mold mix)	50 (9.8)	6 (2.4)	12 (6.7)	16 (11.0)	25 (7.3)	28.713	<0.001
u80 (hop)	35 (6.8)	37 (14.7)	21 (11.7)	8 (5.5)	30 (8.7)	16.396	0.003
f1 (egg white)	55 (10.7)	14 (5.6)	10 (5.6)	9 (6.2)	43 (12.5)	14.585	0.006
f2 (cow's milk)	13 (2.5)	8 (3.2)	1 (0.6)	6 (4.1)	11 (3.2)	4.817	0.307
f13 (peanut)	16 (3.1)	15 (6.0)	8 (4.4)	2 (1.4)	11 (3.2)	6.909	0.141
f14 (soybean)	22 (4.3)	7 (2.8)	5 (2.8)	12 (8.2)	11 (3.2)	9.175	0.057
f27 (beef)	14 (2.7)	6 (2.4)	2 (1.1)	8 (5.5)	11 (3.2)	5.971	0.201
f88 (mutton/lamb)	25 (4.9)	12 (4.8)	2 (1.1)	6 (4.1)	6 (1.7)	10.221	0.037
fs33 (sea fish mix)	46 (9.0)	14 (5.6)	6 (3.3)	16 (11.0)	40 (11.7)	14.664	0.005
fs24 (shrimp/prawn)	18 (3.5)	2 (0.8)	4 (2.2)	3 (2.1)	12 (3.5)	5.954	0.203
f23 (crab)	69 (13.5)	10 (4.0)	19 (10.6)	14 (9.6)	35 (10.2)	16.68	0.002

Note: $p < 0.05$ was considered statistically significant.

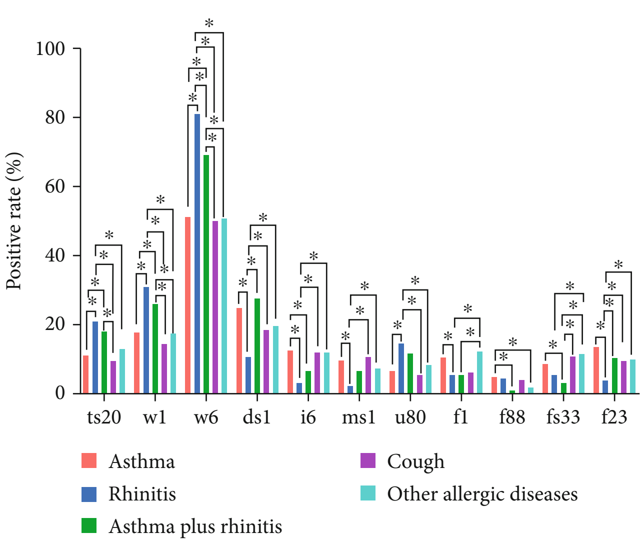

Figure 1: Paired comparison of positive rates of allergens between disease groups. $^*p < 0.05$ indicates statistically significant differences.

symptoms [6]. Allergen blood tests have been widely used in clinical practice owing to their numerous advantages, such as easy operation, high accuracy, and a wide panel of test items [7]. This study is aimed at exploring the characteristics of the specific IgE spectrum in the sera of patients with allergic diseases in the Shanxi region to provide a theoretical basis for clinical diagnosis and treatment and to further guide patients in early prevention.

2. Materials and Methods

2.1. Participants. From September 2020 to October 2021, 3141 patients with allergic symptoms such as asthma, cough, respiratory symptoms, rash, and itching who were treated in the Department of Respiratory and Critical Care Medicine of our hospital and had serum-specific IgE determinations were collected as research subjects. Informed consent of the patients was obtained in this study. This study was approved by the Institutional Ethics Committee (IEC/IRB approval number YXLL-2022-028).

2.2. Methodology. Using a separation gel vacuum tube, a 5 mL blood sample was collected from each participant under fasting conditions and centrifuged at 3500 revolutions/min for 10 min after the blood had completely coagulated to separate the serum.

The fully automated immunoblotting device (EURO-Blot-Master II) and the specific IgE antibody testing kits for ingested and inhaled allergens were provided by EURO-Line Diagnostics Co. Ltd.

Among the 19 serum allergens tested, 10 were inhaled allergens, including tree mix, weed pollens (Artemisia sieversiana, Ambrosia artemisiifolia, and Humulus scandens), dust mite mix (Dermatophagoides pteronyssinus and Dermatophagoides farinae), house dust, cat hair, dogskin, cockroach (Blattella germanica), mold mix (Alternaria alternata, Aspergillus fumigatus, Cladosporium cladosporioides, and Penicillium chrysogenum), and hop (Humulus), and 9 were ingested allergens, including egg white, cow's milk, peanut,

Table 2: Distribution of allergen-specific immunoglobulin E by sex.

Allergens	Male ($n = 659$)	Female ($n = 774$)	χ^2	p
ts20 (tree mix)	124 (18.8)	78 (10.1)	22.448	<0.001
w1 (common ragweed)	150 (22.8)	148 (19.1)	2.864	0.091
w6 (mugwort)	386 (58.6)	455 (58.8)	0.007	0.935
ds1 (dust mite mix)	134 (20.3)	167 (21.6)	0.331	0.565
h1 (house dust)	67 (10.2)	48 (6.2)	7.583	0.006
e1 (cat)	153 (23.2)	142 (18.3)	5.165	0.023
e2 (dog)	46 (7.0)	66 (8.5)	1.182	0.277
i6 (cockroach)	80 (12.1)	63 (8.1)	6.34	0.012
ms1 (mold mix)	47 (7.1)	62 (8.0)	0.391	0.532
u80 (hop)	74 (11.2)	57 (7.4)	6.401	0.011
f1 (egg white)	58 (8.8)	73 (9.4)	0.17	0.68
f2 (cow's milk)	22 (3.3)	17 (2.2)	1.753	0.185
f13 (peanut)	25 (3.8)	27 (3.5)	0.095	0.758
f14 (soybean)	23 (3.5)	34 (4.4)	0.759	0.384
f27 (beef)	21 (3.2)	20 (2.6)	0.465	0.495
f88 (mutton/lamb)	23 (3.5)	28 (3.6)	0.017	0.897
fs33 (sea fish mix)	54 (8.2)	68 (8.8)	0.16	0.689
f24 (shrimp/prawn)	18 (2.7)	21 (2.7)	0.0004	0.983
f23 (crab)	87 (13.2)	60 (7.8)	11.484	0.001

Note: $p < 0.05$ was considered statistically significant.

soybean, beef, mutton/lamb, sea fish mix (cod/lobster/shell), shrimp/prawn, and crab.

2.3. Interpretation of Results. The allergens were scored on a grading scale of 0–7 based on their concentrations in the serum. Positive IgE tests were categorized into 6 classes: class 1 (0.35to <0.70 kUA/L), class 2 (0.70 to <3.50 kUA/L), class 3 (3.50 to <17.50 kUA/L), class 4 (17.50 to <50.00 kUA/L), class 5 (50.00 to <100.00 kUA/L), and class 6 (100.00 kUA/L or above).

2.4. Statistical Methods. All data were analyzed with SPSS 25.0. Count data are presented as frequency and percentage. Intergroup comparison was performed using the chi-squared test or Fisher's exact test. All tests were two-sided, and p values < 0.05 were considered significant. Characteristics of multiple allergens were analyzed using radar charts.

3. Results

3.1. Analysis of Overall Allergens. A total of 3141 participants were included in the statistical analysis after excluding 58 participants who tested positive for cross-reactive carbohydrate determinant epitopes. According to disease symptoms and diagnostic guidelines, allergen-positive patients were divided into asthma [8] (1158 cases), allergic rhinitis [9] (333 cases), asthma combined with allergic rhinitis (291 cases), chronic cough [10] (418 cases), and other allergic diseases (941 cases). A total of 1433 patients were positive for at least one allergen. In order to further study the characteristics of serum-specific IgE antibody profiles in allergen-positive patients, they were grouped by disease, gender, age, and season. Among them were 512 cases of asthmatic and 252 cases of allergic rhinitis, 180 cases of asthma combined with allergic rhinitis, 146 cases of cough, 343 cases of other allergic diseases, 659 cases of males, and 774 cases of females. Aged between 0 and 98 years, they were divided into four groups, 256 cases of 0-18 years old, 656 cases of 19-39 years old, and 377 cases of 40-59 years old, and grouped by month, 174 cases from January to March, 211 cases from April to June, 732 cases from July to September, and 316 cases from October to December. Of the 3141 participants, 1433 tested positive for allergens, showing a positive rate of 47.12%. The positive rate was 35.73% for patients with asthma alone, 75.68% for those with allergic rhinitis, 61.86% for those with asthma combined with rhinitis, 34.93% for those with chronic cough, and 36.45% for those suspected of having allergies. Among the inhaled allergens, the prevalence of mugwort sensitization reached 26.74%, followed by dust mite mix (9.55%) and common ragweed (9.46%). Among the ingested allergens, the crab had the highest positive rate (4.68%), followed by egg white (4.17%) and sea fish mix (3.88%). All the inhaled allergens had higher positive rates than the ingested allergens.

3.2. Analysis of Allergen Characteristics by Disease. The differences between the disease groups in the positive rates for tree mix, common ragweed, mugwort, dust mite mix, cockroach, mold mix, hop, egg white, mutton/lamb, sea fish mix, and crab were significant ($p < 0.05$) (Table 1), and a paired comparison showed that mugwort had the highest positive rate of sensitization. In the allergic rhinitis group, the positive rates for tree mix, common ragweed, hop, and mugwort were higher ($p < 0.05$), and the positive rates for cockroach, mold mix, and dust mite mix were lower ($p < 0.05$) than those of the other disease groups. The positive rate for egg white in the suspected allergy group was higher than that in the other disease groups ($p < 0.05$). The positive rate for mutton/lamb in the asthma alone group was higher than that in the other disease groups ($p < 0.05$). The positive rate for sea fish mix in the asthma plus rhinitis group was higher than that in the other disease groups ($p < 0.05$). The positive rate for crab in the rhinitis group was lower than that in the other disease groups ($p < 0.05$) (Figure 1).

3.3. Analysis of Allergen Characteristics by Sex. Of the 1433 patients who tested positive for allergens, 659 (45.99%) were men and 774 (54.01%) were women. The results showed that a higher percentage of male patients tested positive for tree mix, house dust, cat, cockroach, hop, and crab allergens than the female patients ($p < 0.05$). There was no statistically significant difference in the positive rates of the other allergens between different sex ($p > 0.05$) (Table 2).

3.4. Analysis of Allergen Characteristics by Season. The positive rates for tree mix, common ragweed, mugwort, dogskin, cockroach, hop, egg white, cow's milk, soybean, beef, mutton/lamb, sea fish mix, and crab allergens showed significant differences among seasons ($p < 0.05$); however, there was no

Table 3: Distribution of serum allergen-positive IgE by month.

Allergens	Months January-March ($n = 174$)	April-June ($n = 211$)	July-September ($n = 732$)	October-December ($n = 316$)	χ^2	p
ts20 (tree mix)	17 (9.8)	13 (6.2)	125 (17.1)	46 (14.6)	19.159	<0.001
w1 (common ragweed)	19 (10.9)	22 (10.4)	196 (26.8)	60 (19.0)	40.696	<0.001
w6 (mugwort)	69 (39.7)	75 (35.5)	514 (70.2)	182 (57.6)	112.847	<0.001
ds1 (dust mite mix)	38 (21.8)	53 (25.1)	156 (21.3)	54 (17.1)	5.187	0.159
h1 (house dust)	17 (9.8)	11 (5.2)	57 (7.8)	30 (9.5)	3.958	0.266
e1 (cat)	48 (27.6)	36 (17.1)	143 (19.5)	68 (21.5)	7.481	0.058
e2 (dog)	19 (10.9)	15 (7.1)	44 (6.0)	34 (10.8)	9.583	0.022
i6 (cockroach)	22 (12.6)	22 (10.4)	55 (7.5)	43 (13.6)	11.068	0.011
ms1 (mold mix)	20 (11.5)	17 (8.1)	45 (6.1)	25 (7.9)	6.125	0.106
u80 (hop)	13 (7.5)	6 (2.8)	81 (11.1)	31 (9.8)	14.093	0.003
f1 (egg white)	23 (13.2)	34 (16.1)	51 (7.0)	23 (7.3)	21.318	<0.001
f2 (cow's milk)	10 (5.7)	1 (0.5)	13 (1.8)	15 (4.7)	17.411	0.001
f13 (peanut)	9 (5.2)	8 (3.8)	24 (3.3)	11 (3.5)	1.478	0.687
f14 (soybean)	13 (7.5)	13 (6.2)	23 (3.1)	7 (2.2)	12.291	0.006
f27 (beef)	12 (6.9)	3 (1.4)	11 (1.5)	15 (4.7)	20.671	<0.001
f88 (mutton/lamb)	7 (4.0)	4 (1.9)	20 (2.7)	20 (6.3)	10.332	0.016
fs33 (sea fish mix)	17 (9.8)	21 (10.0)	44 (6.0)	36 (11.4)	10.327	0.016
fs24 (shrimp/prawn)	4 (2.3)	9 (4.3)	16 (2.2)	9 (2.8)	2.875	0.411
f23 (crab)	18 (10.3)	32 (15.2)	59 (8.1)	35 (11.1)	9.701	0.021

Note: $p < 0.05$ was considered statistically significant.

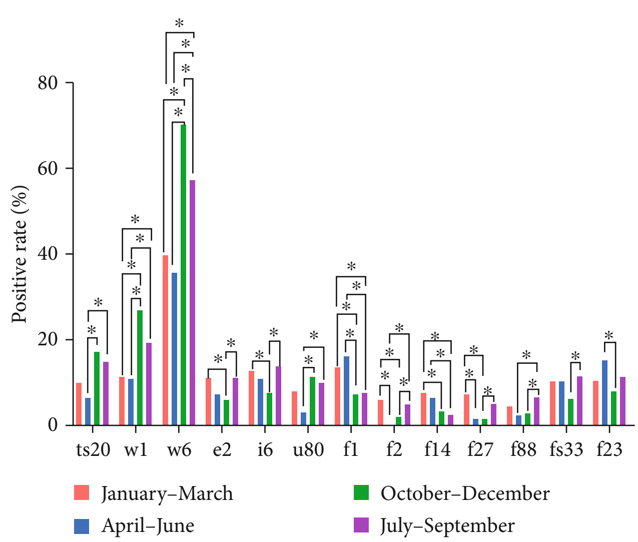

Figure 2: Paired comparison of positive rates of allergens between months. $^*p < 0.05$ indicates statistically significant differences.

significant difference in the other allergens ($p > 0.05$) (Table 3). A paired comparison of the allergens with significant differences indicated that mugwort had the highest positive rate in all seasons combined; common ragweed, mugwort, tree mix, and hop had the highest positive rates from July to September ($p < 0.05$); dogskin and i6 had the highest positive rates from January to March and October to December ($p < 0.05$); f1 had the highest positive rate from January to March and April to June ($p < 0.05$); cow's milk, soybean, and beef had the highest positive rates from January to March and October to December ($p < 0.05$); mutton/lamb and sea fish mix had the highest positive rates from October to December ($p < 0.05$); and more patients tested positive for crab allergens from April to June than July to September ($p < 0.05$). The results are shown in Figure 2.

3.5. Analysis of Allergen Characteristics by Age. The positive rates for the tree mix, common ragweed, mugwort, house dust, cat, cockroach, hop, egg white, cow's milk, peanut, mutton/lamb, sea fish mix, shrimp/prawn, and crab allergens showed significant differences between age groups ($p < 0.05$); however, there were no significant differences in terms of the other allergens (Table 4). A paired comparison of the allergens with statistically significant differences indicated that mugwort had the highest positive rate in all age groups combined; tree mix, common ragweed, hop, and house dust had the highest positive rates in the group aged 0–18 years, followed by the group aged 19–39 years ($p < 0.05$); cow's milk, mutton/lamb, and peanut had the highest positive rates in the group aged 0–18 years ($p < 0.05$); cockroach and sea fish mix had the lowest positive rates in the group aged 0–18 years ($p < 0.05$); mugwort and cat hair showed positive rates that gradually decreased with age ($p < 0.05$); egg white had the lowest positive rate in the group aged 19–39 years and a higher positive rate in the group aged ≥60 years than in the group aged 0–18 years ($p < 0.05$); and shrimp/prawn and crab had higher positive rates in the group aged 40–59 and ≥60 years than the group

Table 4: Distribution of serum allergen-positive immunoglobulin E by age.

Allergens	Age group				χ^2	p
	0-18 years ($n = 256$)	19-39 years ($n = 656$)	40-59 years ($n = 377$)	≥60 years ($n = 144$)		
ts20 (tree mix)	79 (30.9)	85 (13.0)	31 (8.2)	6 (4.2)	82.912	<0.001
w1 (common ragweed)	87 (34.0)	142 (21.6)	56 (14.9)	12 (8.3)	49.099	<0.001
w6 (mugwort)	201 (78.5)	425 (64.8)	17 (45.1)	44 (30.6)	127.253	<0.001
ds1 (dust mite mix)	44 (17.2)	158 (24.1)	74 (19.6)	25 (17.4)	7.582	0.055
h1 (house dust)	42 (16.4)	55 (8.4)	16 (4.2)	2 (1.4)	40.371	<0.001
e1 (cat)	82 (32.0)	162 (24.7)	45 (11.9)	6 (4.2)	68.288	<0.001
e2 (dog)	17 (6.6)	60 (9.1)	28 (7.4)	7 (4.9)	3.927	0.270
i6 (cockroach)	8 (3.1)	64 (9.8)	51 (13.5)	19 (13.2)	20.486	<0.001
ms1 (mold mix)	21 (8.2)	45 (6.9)	30 (8.0)	11 (7.6)	0.688	0.876
u80 (hop)	48 (18.8)	62 (9.5)	18 (4.8)	3 (2.1)	45.824	<0.001
f1 (egg white)	24 (9.4)	31 (4.7)	51 (13.5)	25 (17.4)	35.864	<0.001
f2 (cow's milk)	16 (6.3)	16 (2.4)	5 (1.3)	2 (1.4)	15.975	0.001
f13 (peanut)	18 (7.0)	23 (3.5)	7 (1.9)	4 (2.8)	12.186	0.007
f14 (soybean)	12 (4.7)	18 (2.7)	16 (4.2)	10 (6.9)	6.430	0.092
f27 (beef)	13 (5.1)	13 (2.0)	12 (3.2)	3 (2.1)	6.807	0.078
f88 (mutton/lamb)	18 (7.0)	24 (3.7)	8 (2.1)	1 (0.7)	14.722	0.002
fs33 (sea fish mix)	9 (3.5)	52 (7.9)	39 (10.3)	18 (12.5)	13.315	0.004
f24 (shrimp/prawn)	2 (0.8)	15 (2.3)	14 (3.7)	7 (4.9)	8.178	0.042
f23 (crab)	17 (6.6)	54 (8.2)	51 (13.5)	22 (15.3)	15.090	0.002

Note: $p < 0.05$ was considered statistically significant.

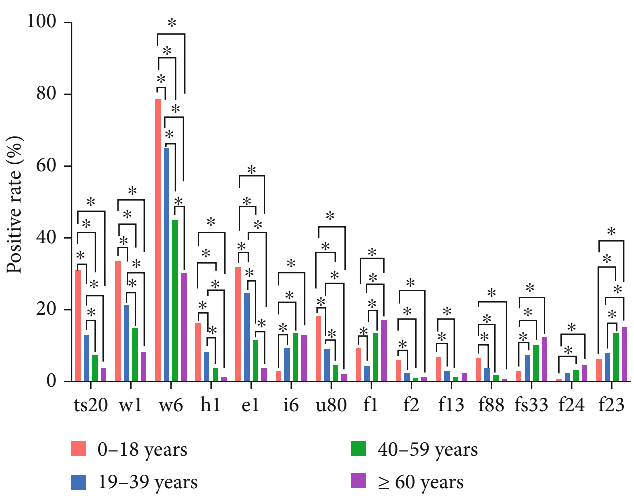

Figure 3: Paired comparison of positive rates of allergens between age groups. $^*p < 0.05$ indicates statistically significant differences.

aged 0–18 years ($p < 0.05$). The results are shown in Figure 3.

3.6. Analysis of Overlapping Allergen Characteristics. The mugwort allergens had the highest positive rate, overlapping with the tree mix, common ragweed, dust mite mix, house dust, cat, cockroach, hop, egg white, peanut, soybean, and sea fish mix allergens ($p < 0.05$). Those patients were positive for dog and mutton/lamb allergens presented with the highest positive rate for cat allergens ($p < 0.05$). Those patients positive for mold mix and crab allergens also had the highest positive rate for dust mite mix allergens ($p < 0.05$). Those patients positive for cow's milk had the highest positive rate for beef and mutton/lamb allergens ($p < 0.05$), and those positive for shrimp/prawn had the highest positive rate for crab allergens ($p < 0.05$) (Figures 4 and 5).

4. Discussion

Allergies are hypersensitivity reactions to foreign and normally harmless molecules of the environment and are mediated by innate and adaptive immune responses and epithelial cells. Most common allergies are those mediated by IgE antibodies [11, 12]. With climate change, reduced biodiversity, and shifts in human lifestyles and dietary habits, the prevalence of allergic diseases and the sources of allergens have been increasing annually, thereby leading to enormous social and economic burdens [13]. Elucidating the allergen-specific IgE distribution is, therefore, of critical importance to the diagnosis, treatment, and early prevention of these diseases.

There are a wide variety of natural allergens, which are distributed unevenly across regions owing to differences in geographic environment, climate, customs, diet, and economic conditions. In this study, we tested serum-specific IgE antibodies in 3141 patients with allergic disease. We found that the top three inhaled allergens in the Shanxi region were mugwort, dust mite mix, and common ragweed, whereas in the southern area of China, the most common inhaled allergen was dust mite mix [14, 15]. The primary inhaled allergen was pollen in certain northern places, and dust mite was the primary inhaled allergen in certain other

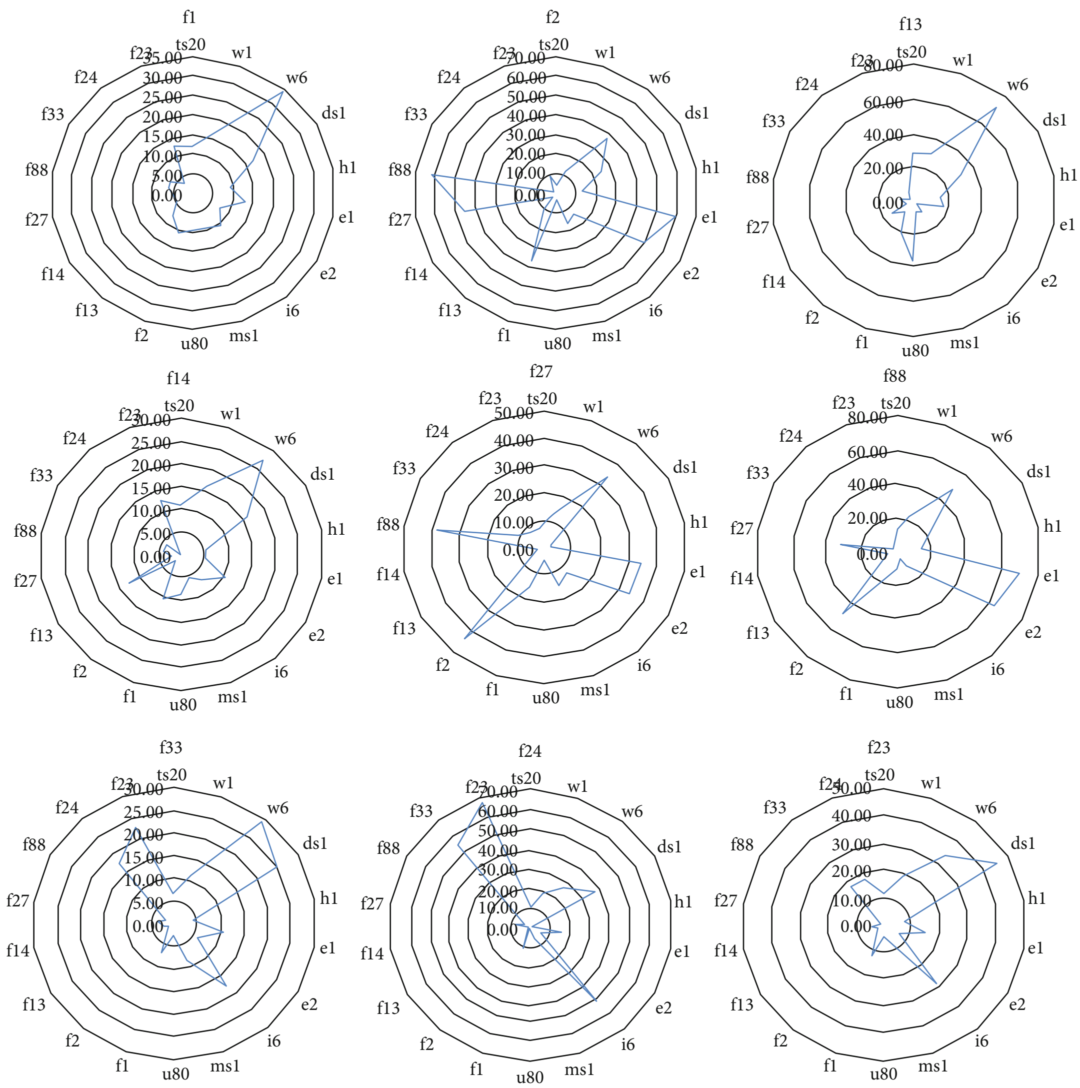

Figure 4: The radar charts of ingested allergens. The radar chart represents the positive correlation between a single allergen and other allergens, and the single allergen is marked on the top of each radar chart.

areas of China [16, 17]. A study on allergic skin diseases also found that the top three positive rates of inhaled allergens in Shanxi were dust mites, Artemisia/ragweed, and fungi [18], which were similar to those of the studies in the literature. More importantly, mugwort has replaced household dust mites and fungi as the first allergen in Shanxi, also reported in another study as one of the major allergens in China [19]. In the Shanxi region, Artemisia plants, which have advantages in reproduction and are highly adapted to the environment, have been grown in large quantities as part of the control and management strategy for windblown dust, resulting in highly increased amounts of Artemisia pollen. In the southern and certain northern regions, the warm and humid climate favors the reproduction of mites. In recent years, with the constant improvement in economics, the use of air conditioners has increased significantly, leading to an increased positive rate for dust mite mix in Shanxi. The top three ingested allergens were crab, egg white, and sea fish mix; however, their positive rates were relatively lower than those observed in other regions. This can be attributable to the reduced access to seafood products in Shanxi compared with the southern regions. However, the lower positive rate for egg white is associated with the small probability of egg white sensitization in adults with a fully matured digestive system, who were the majority of the participants in this study.

The distribution analysis of allergens in the Shanxi region showed that, among the three disease groups (asthma alone, allergic rhinitis, and asthma plus rhinitis), the most common allergen was mugwort. The positive rates for tree mix, house dust, cat, cockroach, hop, and crab allergens were all higher for the male participants than the female participants, which was consistent with other studies [20, 21]; this is determined by a combination of hormone levels, genetic factors, and the chance of exposure. Studies have found that estrogen has a proallergic effect, and androgen has an antiallergic effect. Before puberty, men are more likely to develop allergic diseases. After puberty, the probability of women

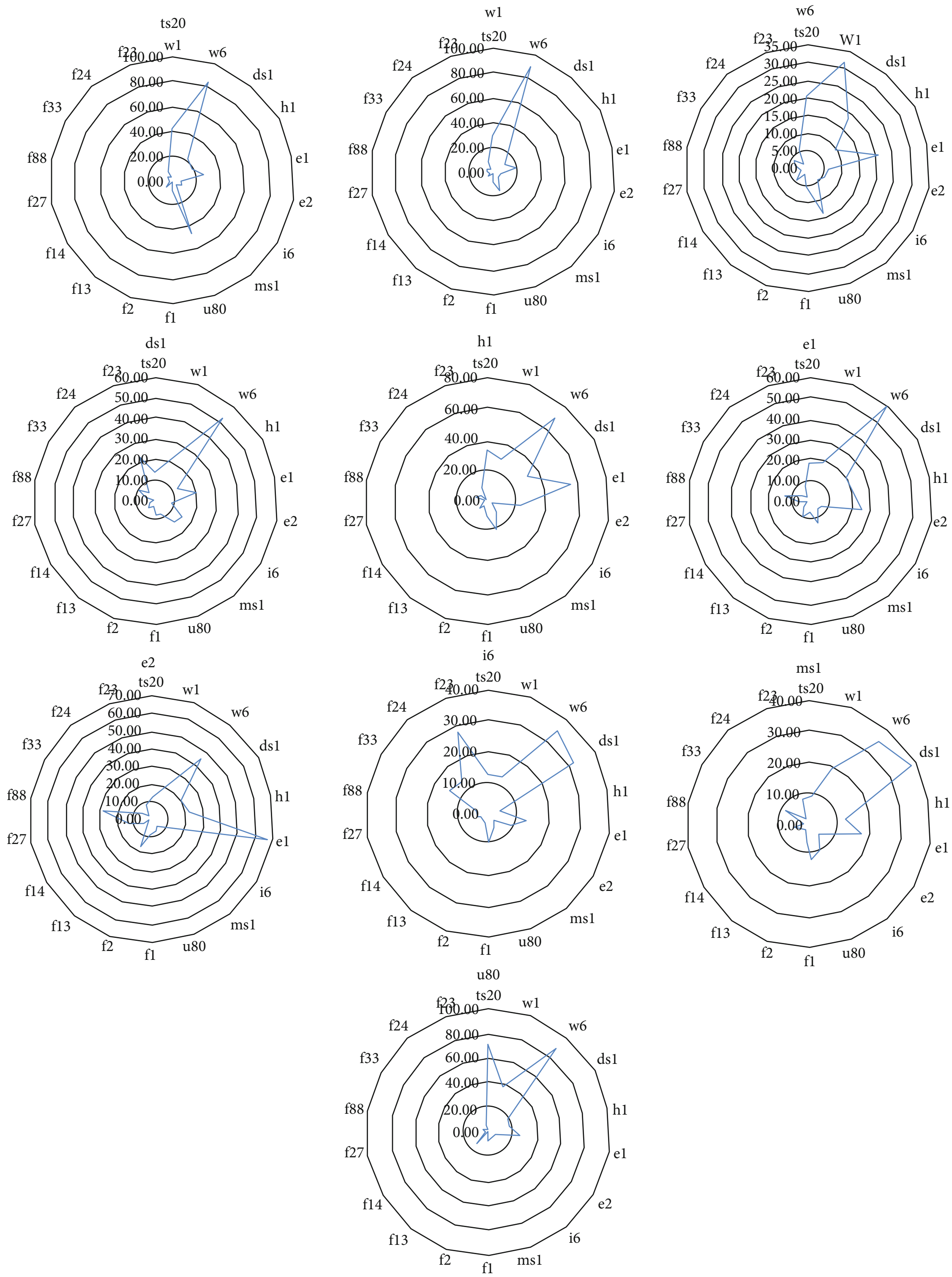

Figure 5: The radar charts of inhaled allergens. The radar chart represents the positive correlation between a single allergen and other allergens, and the single allergen is marked on the top of each radar chart.

developing allergic symptoms increases with the increase of estrogen levels, exceeding puberty. But the IgE positivity rate of men is still higher than that of women [22]. When analyzed by season, the inhaled allergens of pollen from the tree mix, common ragweed, mugwort, and hop had the highest positive rates from July to September, possibly because pollen particles are scattered in the air in autumn, leading to an increased probability of sensitization. In addition, the dog and cockroach allergens claimed higher positive rates from both January to March and October to December, as compared with

July to September. For ingested allergens, egg white had the highest positive rate from April to June, cow's milk and beef had the highest positive rates from January to March, and mutton/lamb and sea fish mix had the highest positive rates from October to December, which were possibly associated with the amount consumed and the local dietary habits.

Among the age groups, the participants younger than 18 years showed the highest positive rates for tree mix, ragweed, hop, and house dust, and the positive rates for mugwort and cat allergens gradually decreased with age. These results are associated with the climate and geographic characteristics of Shanxi area where people are exposed to pollen allergens in high concentrations for long periods. The positive rates for ingested allergens of cow's milk, peanut, and mutton/lamb were also the highest in the group aged 0–18 years. Young people do not have fully developed immune functions in gastric mucosa, with incomplete synthesis and excretion of digestive enzymes and a low level of excretory IgA. Subsequently, ingested allergens were not fully digested, which leads to allergies [23]. However, in this study, egg white showed the highest positive rate in the group ≥60 years old, which was inconsistent with other studies [21, 24]. This finding is possibly related to the small number of children aged 0–6 years in this study. Furthermore, we found that patients aged >40 years had a high positive rate for i6 allergens, which was probably because older individuals might live in places with cockroach problems.

Allergens are composed of proteins. When the IgE produced by the body for an allergen binds or identifies a similar protein of a different source, allergen cross-reaction occurs [25]. Current studies have shown that many allergens have strong cross-reactivity, and identification of the cross-reactivity of allergens is critical, given that among the tens of thousands of natural substances that can induce allergic reactions, only a small number of allergens can be tested clinically. This study used radar charts to explore the cross-reactivity in allergen pairs, and the results showed that among the patients in Shanxi area who tested positive for the tree mix, common ragweed, dust mite mix, house dust, cat, cockroach, hop, egg white, peanut, soybean, and sea fish mix allergens, most of them tested positive for mugwort. This finding is probably owing to the unique geographic and climate features of Shanxi, where the high concentration of airborne mugwort pollen persists for a long time. In the patients positive for mold mix and crab allergens, most were also positive for dust mite mix, and most of those positive for shrimp/prawn allergens were also positive for crab allergen owing to the cross-IgE-reactions caused by the highly conservative and homologous tropomyosins in invertebrates [26]. Numerous foods are highly cross-reactive. A study by Martelli et al. [27] showed that nearly 10% of children allergic to milk were also allergic to beef and nearly 93% of the children allergic to beef were also allergic to milk, which was consistent with the results of the present study, in which most of the patients positive for dog and mutton/lamb allergens were also positive for cat allergens. This finding was likely attributable to the similarities in protein structures of these animals. However, the specific protein structures need further investigation.

This large sample size study on the allergen-specific IgE test in serum revealed that the most common inhaled allergens in Shanxi area were mugwort, dust mite mix, and common ragweed and the most common ingested allergens are crab, egg white, and sea fish mix. Furthermore, this study explored the distribution characteristics and patterns of the allergens according to disease, age, season, and sex, as well as the clinical relevance of the cross-reactions among various allergens. This study provides a theoretical basis for improved prevention, diagnosis, and treatment of allergic diseases.

Data Availability

Data for this study is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Authors' Contributions

Jing Wu and Yuee Liu participated in the design of this study, and Min Xie and Jing Yang performed the statistical analysis. Yanzhi Cui and Hongxia Zhang carried out the study and collected background information. Yaona Wei and Lei Wang drafted the manuscript. All authors read and approved the final manuscript. Jing Wu and Yuee Liu contributed equally to this work.

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