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ORIGINAL ARTICLE

Different profiles of allergen sensitization in different ages and geographic areas in Changhua, Taiwan

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Background: Environmental factors, different ages, and detection methods might affect the profiles of allergy sensitization and confound the diagnosis of allergic diseases. The purpose of this study was to investigate the different profiles of allergen sensitization in different ages, geographic areas, and detection methods.
Patients and Methods: We analyzed the patients who received allergen sensitization tests by the automated microfluidic-based immunoassay system (BioIC) method at Show Chwan Memorial Hospital in Changhua City and at Chang Bing Show Chwan Hospital in Lu-gang from January 2011 to December 2011. Results were compared in different ages (3–6, 7–18, and ≥19), different geographic areas, and different detection methods and analyzed by Chi-Square or Fisher exact test depending on sample size.
Results: A total of 1145 patients were analyzed. The younger the age, the higher the food allergy sensitization rate is found (26.6% vs. 14.7% vs.11.1% $p < 0.001$). The older the age, the higher the sensitization of *Blomia tropicalis* occurs (33.4% vs.15.1% $p < 0.001$). The food allergen specific IgE directed against egg white was higher in coast area than city (15.4% vs. 3%, $p = 0.015$). A higher rate of pollen sensitization was found in the detection by BioIC method (Bermuda grass, 17.2%; Timothy, 12.3%; ragweed, 5.7%). The sensitization rates of cockroach and cat dander were lower in both city and coast areas.
Conclusion: Children have higher food allergy sensitization and adults have higher *Blomia tropicalis* sensitization. Children living in Changhua area no matter in city or coast area had

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a higher pollen sensitization rate but lower cat or dog dander sensitization rate. Apparently, age, environmental factors, and different methods significantly affect the allergen sensitization in the different areas of Taiwan.

Introduction

Age, environmental factors, and inheritance play important roles in the development of allergy sensitization and allergic diseases. Moreover, sensitivity and specificity of allergy sensitization are also affected by different detection methods.[1–5] Patients from different geographical regions, ages, climates, hospitals with different detection methods may have different allergen sensitization profiles. The presence of allergen-specific Immunoglobulin E (IgE) antibody in the serum of a patient is highly predictive of allergic diseases.[1–5] Skin prick test (SPT) and serology tests for specific IgE (sIgE) including (1) ImmunoCAP-Thermo Fisher Scientific, (2) automated microfluidic-based immunoassay system (BioIC)- Agnitio Scientific technology and multiple radioallergosorbent tests (MAST) are sensitive indicators of allergen-specific IgE antibodies.[6–9] The purpose of this study was to investigate the different profiles of allergen sensitization in different ages, geographic areas, and detection methods. We analyzed the different allergen profiles in patients with different ages at 3—6 years, 7—18 years, and ≥ 19 years old, and compared the different allergen profiles between patients from a city and a coast rural area. Allergen profiles detected with different methods in the literature are also compared.

Materials and methods

Patients studied

Patients included are those suspicious to allergic diseases including bronchial asthma, allergic rhinitis, and/or atopic dermatitis and received allergen specific IgE tests in Changhua Show Chwan Hospital (city) and Chang Bing Show Chwan Hospital (rural coast) between January 2011 and December 2011. The diagnoses of bronchial asthma, allergic rhinitis, and/or atopic dermatitis were made by the chart review based on physician-diagnosed records. The age group categories in this retrospective study were divided into three groups depending on age and its mode clusters. The first group is in preschool age (3—6 years), the second group is in school age (7—18 years), and the third group is adulthood (≥ 19 years). This retrospective study was approved by the Institutional Review Board of Show Chwan Hospital. There were 1145 patients analyzed in this study.

Detection of allergen sensitization

We used the automated BioIC method to measure allergen sIgE in sera. The levels equal to or greater than Class 1 (≥0.35 IU/mL) were considered positive. The sIgE to common allergens, including *Dermatophagoides pteronyssinus, Dermatophagoides farinae, Blomia tropicalis*, dog dander, cat dander, German cockroach, pollen allergens: Bermuda grass, Timothy grass, ragweed and mold allergens: *Candida, Aspergillus* were detected.

Comparison and statistical analysis

The positive prevalence rates of sIgE to various allergens were analyzed. Results were compared in different ages with 3—6 years, 7—18 years, and ≥ 19 years of age, different geographic areas, different allergic diseases, and different detection methods, including those published in the literature, and analyzed by Pearson Chi-Square or Fisher exact test depending on number of each allergen sensitization rates. All statistical tests were performed using SPSS statistical software, version 17.0 for Windows XP (SPSS Inc, Chicago, IL, USA).

Table 1 Allergen sensitization detected by the BioIC method in different age populations

3—6 years age group	7—18 years age group	≥19 years age group
D farinae (63.3%)	*D farinae* (64.1%)	*D farinae* (59.4%)
D pteronyssinus (59%)	*D pteronyssinus* (67%)	*D pteronyssinus* (50.5%)
B tropicalis (15.1%)	*B tropicalis* (34.2%)	*B tropicalis* (33.4%)
Bermuda grass (25.2%)	Bermuda grass (17.2%)	Bermuda grass (15.6%)
Soybean (26.6%)	Soybean (14.7%)	Soybean (11.1%)
Egg white (23%)	Egg white (9.8%)	Timothy (11.6%)
Crab (12.9%)	Crab (13.2%)	Crab (15.7%)
Shrimp (9.4%)	Shrimp (7.2%)	Shrimp (4.6%)
Timothy (18%)	Ragweed (5.2%)	Ragweed (5.2%)
Wheat (7.9%)	Milk (4.9%)	German cockroach (5.3%)

D pteronyssinus = Dermatophagoides pteronyssinus; D farinae = Dermatophagoides farinae; B tropicalis = Blomia tropicalis.

Table 2 Different food allergen sensitization between city and coastal area in children 3—6 years of age

	City, *n* (%)	Coast, *n* (%)	*p*	Odds ratio	95% CI
Soybean	14 (14%)	7 (17.9%)	0.365	0.744	0.275—2.011
Crab	6 (6%)	2 (5.1%)	0.602	1.181	0.228—6.117
Shrimp	4 (4%)	3 (7.7%)	0.307	0.500	0.107—2.344
Egg white	3 (3%)	6 (15.4%)	0.015	0.170	0.040—0.719
Wheat	2 (2%)	0 (0)	0.561		
Peanut	2 (2%)	1 (2.6%)	0.631	0.776	0.068—8.805
Milk	2 (2%)	0 (0)	0.516		

Results

Different allergen profiles in patients of different ages

A total of 1145 patients were analyzed in this study as shown in Table 1. The first two common allergens were *D pteronyssinus and D farinae*. The younger the age, the higher the food allergy sensitization rate found (26.6% vs. 14.7% vs.11.1% $p < 0.001$). In contrast, the older the age, the lower the sensitization of shrimp occurred (9.4% vs.7.2% vs. 4.6% $p = 0.049$). The older the age, the higher the sensitization of *Blomia tropicalis* found (33.4% vs.15.1% $p < 0.001$). The sIgE directed against Bermuda grass is over 20% in the 3—6 years of age population while compared to the population older than 7 years of age ($p = 0.006$). The sIgE sensitization to the cockroach became more predominant in the adult patients $\geq$ 19 years of age. The most common two allergens were *D pteronyssinus* (50%—67%) and *D farinae* (59%—63%). The food allergen sIgE directed against egg white is different between 3—6 years and 7—18 years of age (23% vs. 9.8% $p < 0.001$).

Different allergen sensitization profiles in city and coastal rural areas

The presence of allergen-specific IgE to inhalant and food allergen between two areas was shown in Tables 2 and 3. Based on the detection of allergen-specific IgE by BioIC testing, the top five allergen sensitization antigens were the same between these two areas, with the highest at 62.9% and 60.1% for *D farinae*. The pollen sensitization rates were over 10% in both city and rural coast areas in Changhua County. The pollen sensitization rate was 17.8% for Bermuda grass and 12.3% for Timothy. The specific IgE directed against *Blomia tropicalis* was higher in coast area than city (34.2% vs. 29.5%, $N = 359$; $p = 0.091$). Soybean sensitization was significantly higher in city than in coast area (8.8 vs. 6.0%, $p = 0.076$). In contrast, sensitization rates of cockroach and cat dander were lower than 5% in both areas. Lower positive prevalence (< 10%) was detected for food allergen including shrimp, crab, milk, egg white, peanut, wheat, and soybean. The profiles of specific IgE directed against food allergens were different among different age groups as shown in Table 2. The specific IgE to egg white was higher in coast area than city (15.4% vs. 3%, $p = 0.015$) in children 3—6 years of age.

Different allergen sensitization profiles in atopic dermatitis (AD), allergic rhinitis (AR), and bronchial asthma (BA)

In patients with AD, AR, and BA, the allergy sensitization profiles were similar, but the ranking of common allergens was a little bit different (Tables 3,4 and 5). House mite allergens were the most prevalent than other antigens in patients with any allergic disease in both areas. As shown in Table 6, *D pteronyssinus* and *D farinae* were the two most common allergens in both areas. In allergic rhinitis, the specific IgE directed against soybean was significantly higher

Table 3 Different allergen sensitization profiles between city and coastal area

Allergen	City ($N =$ l 692)	Coast ($N = 453$)	*p*	Odds ratio	95% CI
D farinae	416 (60.1%)	285 (62.9%)	0.342	0.888	0.696—1.134
D pteronyssinus	391 (56.5%)	255 (56.3%)	0.944	1.009	0.794—1.281
B tropicalis	204 (29.5%)	155 (34.2%)	0.091	0.804	0.624—1.036
Bermuda grass	123 (17.8%)	75 (16.6%)	0.594	1.089	0.795—1.493
Timothy	85 (12.3%)	46 (10.2%)	0.268	1.239	0.847—1.812
Soybean	61 (8.8%)	27 (6%)	0.076	1.525	0.954—2.439
Crab	48 (6.9%)	26 (5.7%)	0.421	1.224	0.748—2.003
Ragweed	30 (4.3%)	26 (5.7%)	0.281	0.744	0.434—1.276
Shrimp	23 (3.3%)	12 (2.6%)	0.517	1.263	0.622—2.565
German cockroach	27 (3.9%)	24 (5.3%)	0.263	0.726	0.413—1.274
Cat Dander	15 (2.2%)	14 (3.1%)	0.331	0.695	0.332—1.454
Eggwhite	14 (2%)	12 (2.6%)	0.487	0.759	0.348—1.656
Aspergillus	12 (1.7%)	9 (2%)	0.755	0.871	0.364—2.083
Candida	12 (1.7%)	8 (1.8%)	0.968	0.982	0.398—2.421
Almond	10 (1.4%)	8 (1.8%)	0.669	0.816	0.319—2.082
Peanut	8 (1.2%)	4 (0.9%)	0.450	1.313	0.393—4.386
Dog dander	7 (1.0%)	4 (0.9%)	0.545	1.147	0.334—3.941
Milk	8 (1.2%)	3 (0.7%)	0.306	1.754	0.463—6.648
Wheat	8 (1.2%)	2 (0.4%)	0.173	2.637	0.558—12.476

Table 4 Different allergen sensitization profiles in allergic rhinitis between city and coastal area

Allergen	City, *n* (%)	Coast, *n* (%)	*p*	Odds ratio	95% CI
D farinae	342 (60.3)	244 (62.9)	0.740	0.897	0.688—1.170
D pteronyssinus	332 (58.6)	223 (57.5)	0.423	1.045	0.805—1.358
B tropicalis	171 (30.2)	134 (34.5)	0.154	0.819	0.621—1.078
Bermuda grass	100 (17.6)	60 (15.5)	0.377	1.171	0.825—1.661
Timothy	69 (12.2)	35 (9)	0.125	1.397	0.910—2.146
Soybean	55 (9.7)	22 (5.7)	0.025	1.787	1.071—2.983
Crab	37 (6.5)	22 (5.7)	0.590	1.161	0.674—2.001
Ragweed	27 (4.8)	21 (5.4)	0.651	0.874	0.487—1.569
German cockroach	19 (3.4)	19 (4.9)	0.230	0.673	0.352—1.289
Shrimp	17 (3)	11 (2.8)	0.883	1.059	0.491—2.287
Egg white	13 (2.3)	9 (2.3)	0.978	0.988	0.418—2.335
Cat dander	12 (2.1)	13 (3.4)	0.241	0.624	0.282—1.382
Aspergillus	10 (1.8)	8 (2.1)	0.739	0.853	0.334—2.180
Candida	10 (1.8)	7 (1.8)	0.963	0.977	0.369—2.590
Milk	8 (1.4)	3 (0.8)	0.280	1.837	0.484—6.967
Peanut	8 (1.4)	3 (0.8)	0.280	1.837	0.484—6.967
Dog dander	7 (1.2)	4 (1)	0.515	1.200	0.349—4.127
Wheat	7 (1.2)	2 (0.5)	0.219	2.413	0.499—11.675

in city area than coast area (9.7% vs. 5.7%, $p = 0.025$) as shown in Table 4. The most common specific IgE directed against food allergen in city and the coast is soybean (14.0—17.9%). Of the 134 patients with BA, 80 comorbided with BA and AR. Distribution of different atopic diseases is shown in Table 7. BA patients without allergic sensitization were 24.3%; AR patients without allergic sensitization were 21.7%; AD patients without allergic sensitization were 23.9%.

Different allergen sensitization profiles in different detection methods

Patients in different geographical regions and hospitals who received sIgE detection by different detection methods may have different allergen sensitization profiles. Comparing allergen sensitization profiles from the northern to the southern Taiwan, we found that the ranking of allergen sensitization profiles was different as shown in Table 8. Overall, the most two common allergens were *D pteronyssinus* (67—90%) and *D farinae* (64—88%). A survey in Pingtung County showed that the positive prevalence rate of specific IgE to *D farinae* was the highest at 90.5%.The sIgE directed against *B tropicalis* in Taichung (76.7%) was the highest in these studies. Comparing the sIgE directed against cockroach in different geographical regions, the positive prevalence rate in Pingtung County was the highest at 35.5% in these studies. A higher rate of mite sensitization (*D pteronyssinus* 90.7% and *D farinae* 88.2%) was found in the detection method by ImmunoCAP;

Table 5 Different allergen sensitization profiles in asthma between city and coastal area

Allergen	City, *n* (%)	Coast, *n* (%)	*p*	Odds ratio	95% CI
D farinae	80 (61.5)	27 (57.4)	0.623	1.185	0.602—2.334
D pteronyssinus	69 (53.1)	26 (55.3)	0.792	0.914	0.467—1.786
B tropicalis	34 (26.2)	13 (27.7)	0.841	0.926	0.438—1.960
Bermuda grass	27 (20.8)	7 (14.9)	0.381	1.498	0.604—3.714
Timothy	19 (14.6)	6 (12.8)	0.755	1.170	0.437—3.133
Crab	10 (7.7)	3 (6.4)	0.530	1.222	0.321—4.647
Soybean	8 (6.2)	7 (14.9)	0.065	0.375	0.128—1.098
Ragweed	8 (6.2)	1 (2.1)	0.257	3.016	0.367—24.789
German cockroach	5 (3.8)	3 (6.4)	0.359	0.587	0.135—2.557
Aspergillus	4 (3.1)	0 (0)	0.287		
Almond	3 (2.3)	0 (0)	0.394		
Shrimp	4 (3.1)	0 (0)	0.287		
Cat dander	2 (1.5)	3 (6.4)	0.117	0.229	0.037—1.417
Egg white	2 (1.5)	2 (4.3)	0.287	0.352	0.048—2.570
Candida	2 (1.5)	1 (2.1)	0.606	0.719	0.064—8.115
Dog dander	1 (0.8)	0 (0)	0.734		
Milk	1 (0.8)	0 (0)	0.734		

Table 6 Different allergen sensitization profiles in atopic dermatitis between city and coastal area

Allergen	City, *n* (%)	Coast, *n* (%)	*p*	Odds ratio	95% CI
D farinae	64 (62.1)	35 (62.5)	0.964	0.985	0.503—1.927
D pteronyssinus	50 (48.5)	28 (50)	0.861	0.943	0.492—1.809
B tropicalis	32 (31.1)	20 (35.7)	0.551	0.811	0.408—1.614
Bermuda grass	22 (21.4)	14 (25)	0.600	0.815	0.379—1.754
Timothy	15 (14.6)	9 (16.1)	0.800	0.890	0.362—2.187
Crab	10 (9.7)	3 (5.4)	0.263	1.900	0.501—7.208
German cockroach	9 (8.7)	3 (5.4)	0.333	1.691	0.439—6.520
Soybean	5 (4.9)	3 (5.4)	0.581	0.901	0.207—3.920
Shrimp	5 (4.9)	2 (3.6)	0.526	1.378	0.259—7.341
Cat dander	3 (2.9)	1 (1.8)	0.559	1.650	0.168—16.244
Ragweed	3 (2.9)	4 (7.1)	0.199	0.390	0.084—1.808
Aspergillus	3 (2.9)	1 (1.8)	0.559	1.650	0.168—16.244
Almond	2 (1.9)	4 (7.1)	0.115	0.257	0.046—1.452
Candida	2 (1.9)	1 (1.8)	0.717	1.089	0.097—12.283
Egg white	1 (1)	4 (7.1)	0.052	0.127	0.014—1.170
Wheat	1 (1)	0(0)	0.648		
Peanut	0 (0)	1 (1.8)	0.352		

a higher rate of pollen sensitization was found in the detection by the BioIC method (Bermuda grass, 17.2%; Timothy, 12.3%; ragweed, 5.7%). The lowest sensitization to food allergens is found in the detection by the BioIC method; the highest sensitization to pet danders is found in the detection by the ImmunoCAP and MAST.

Discussion

Sensitization to allergen plays a crucial role in the development of atopic disorders. Studies in coast and/or subtropical countries identified that house dust mite is the most common allergen, while those in continental countries have pointed to pollens as dominating allergens.[3,6,9—14] Our study focused on the influence of geographical regions, ages, and different allergic diseases on the allergen sensitization profiles in Changhua County. We found that house dust mites are the most common allergens. However, we also found the younger the age the higher the food allergy sensitization rate; the older the age, the higher the sensitization of *B tropicalis* occurs.

The primary factor affecting mite reproduction and survival was relative humidity, rather than temperature.[10,15—18] According to annual statistics of the Taiwan Central Weather Bureau, there are no significant differences in relative humidity and ambient temperature between central Taiwan and Taipei.[19] However, the period of warmer weather is of longer duration in central Taiwan than in Taipei.[19] We found that the sensitization to mites is not different between Changhua City and the Chang Bing coast area. However, the prevalence rates of positive specific IgE to pollens are higher in the Changhua area. Furthermore, comparing the sensitization profiles between Taichung City and Changhua City, it was found that house dust mite is the most common allergen in Taichung City (90.2%)[20] and Changhua City (61.5%). The sensitization to soybean is 2% in Taichung City[20] and 8.8% in Changhua City.

The distribution of inhalant allergens is changing as a result of climate change. Particularly, the ragweed-pollen production had been reported to be stimulated by increased atmospheric CO2 concentration.[17] In our study, the most common pollen allergens were Bermuda grass (16—17%), Timothy (10—12%), and ragweed (4—5%). In Western countries, weed or grass pollens that cause most allergies are mugwort, ragweed, Parietaria, and Bermuda grasses. Most residents living in Changhua, which is an agricultural or semiagricultural area, may be more frequently exposed to grasslands, farmlands, and agricultural products in their daily activities.[19] In addition,

Table 7 Different allergen sensitization profiles in different allergic diseases

	Positive allergen sensitization	Negative allergen sensitization	Total
Bronchial asthma (BA)	134 (75.7%)	43(24.3%)	177 (100%)
Allergic rhinitis (AR)	748 (78.3%)	207 (21.7%)	955 (100%)
Atopic dermatitis (AD)	121 (76.1%)	38 (23.9%)	159 (100%)
AD + AR	34 (82.9%)	7 (17.1%)	41 (100%)
AD + BA	3 (75%)	1 (25%)	4 (100%)
BA + AR	80 (76.9%)	24 (23.1%)	104 (100%)
BA + AR + AD	2 (100%)	0 (0)	2 (100%)

Table 8 Ranking of allergen in different cities and detection methods

Rank	Taipei	Changhua	Taichung	Ping Tung
	CAP	BioIC	CAP	MAST
1.	*D pteronyssinus* (90.7%)	D pteronyssinus (67%)	*D pteronyssinus* (90.2%)	*D farinae* (90.5%)
2.	*D farinae* (88.2%)	*D farinae* (64.1%)	*D farinae* (88.2%)	*D pteronyssinus* (76.8%)
3.	Dog dander (28.9%)	*B tropicalis* (34.2%)	*D microceras* (79.5%)	Dust house mixture (49.5%)
4.	American cockroach (16.7%)	Bermuda grass (17.2%)	*B tropicalis* (76.7%)	Cockroach mix (American and German) (35.5%)
5.	German cockroach (15.4%)	Soybean (14.7%)	Cockroach (25.3%)	Dog dander (20.5%)
6.	Cat dander (8.6%)	Crab (13.2%)	Shrimp (11.5%)	Cat dander (20.5%)
7.		Egg white (9.8%)	Crab (8.6%)	Feather mix (13.2%)
8.		Shrimp (7.2%)	Milk (7.5%)	Bermuda grass (13.2%)
9.		Ragweed (5.2%)	Dog dander (6.9%)	Grass mix (10.9%)
10.		Milk (4.9%)	Egg white (4%)	

D pteronyssinus = Dermatophagoides pteronyssinus; D farinae = Dermatophagoides farinae; B tropicalis = Blomia tropicalis.

residents may also expose to ragweed pollen. The high sensitization to pollens in Changhua County may be a reflection of climate, including strong wind in coast areas.

Sensitization to cockroaches is a strong risk factor for asthma in children living in the inner-city. In our study, we also observed the specific IgE directed against cockroaches increased substantially with the increase of age. The sensitization rate to cockroaches in northern Taiwan was 38.3%,[14] in Pingtung County 35.5% and in Taichung 25.3%, while it is much lower at 3—5% in Changhua County, which may be explained by less crowded living conditions in this population. Of the animal allergens, sensitization to dog dander (0.9—1.0%) and cat dander (2—3%) were also low in Changhua County. The sensitization rates of specific IgE directed against dog dander (10—26%) and cat dander (4—10%) are higher in northern and southern Taiwan.[14,15] A lower popularity of raising pets in Changhua county might attribute to the low prevalence rate. Of the food allergens, the most common ones are soybean, shrimp, and egg white. While compared to older population (over 19 years of age), younger children (3—6 years) also had higher rates of sensitization to soybean, egg white, and crab.

In previous studies, soybean sensitization was rarely been discussed in Taiwan. The population in Changhua County may eat more beans, especially in costal area, that may be responsible for a higher soybean sensitization in costal area. Diet and climate may also contribute to the different sensitization profiles between different geographic areas. The higher sensitization to aeroallergen in Changhua County may be a reflection of climate, especially the strong wind in coastal area. However, the aeroallergen sensitization between coastal area and city was not significantly different. The reason may be because the distance of two geographic areas is quite close.

The radioallergosorbent test was the first routine technique for the determination of sIgE antibodies in serum in 1967.[4—9] Nowadays, the in vitro testing of sIgE has become a major tool to help diagnose allergic sensitization. The Pharmacia second-generation ImmunoCAP method is widely used and has generated adequate results compatible to the skin prick test.[1—3,11] Shyur *et al.*[11] reported that both BioIC and ImmunoCAP methods have nearly the similar performance of sensitivity and specificity in comparison to the skin prick test results. However, they did not evaluate the specific IgE to the pollens. We found that the sensitization to pollen is higher in this study. However, it is not excluded that a higher rate of pollen sensitization in this study is associated with the antibody crossreaction detected by the BioIC method.

In summary, children have higher food allergy sensitization and adults have higher *B tropicalis* sensitization. Children living in Changhua area no matter in city or coast area had a higher pollen sensitization rates but lower risk to cat or dog dander sensitization. This may be related to different detection system or different environments. By contrast, sensitization rates of *B tropicalis* and egg white were higher in coast than city area. Apparently, age, environmental factors, and different methods significantly affect the allergen sensitization in the different areas of Taiwan.

In this retrospective analysis, there may be a sample selection bias. In the future, a prospective assessment will be a better tool to evaluate the sensitization profiles of different allergens in different age populations in different geographic areas.

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