

Study on the Epidemiological Status and Influencing Factors of Allergic Diseases in Children Aged 0-6: A Population-Based Survey

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Abstract

Introduction: Childhood allergic diseases represent a significant and escalating global health burden, particularly among children aged 0–6 years. Evidence on the associations of lifestyle factors, household environment, and prenatal exposures with these conditions remains inconsistent and heterogeneous, and epidemiological data for this key age group are still limited. This study aims to develop a standardized screening questionnaire and to assess these associations.

Methods: A population-based cross-sectional study was conducted in Minhang District, Shanghai, China. Eight community health service centers and fifteen kindergartens were randomly selected. A screening questionnaire developed and confirmed in a nested case-control study was used to identify childhood asthma, allergic rhinitis (AR), atopic dermatitis (AD), and food allergies (FA). Multivariable logistic regression models were employed to examine associations of neonatal factors, residential environment, and family-related factors with allergic diseases.

Results: Among 3064 children aged 0–6 years, the overall prevalence of FA, asthma, AD, and AR was 14.7%, 8.4%, 18.9%, and 20.0%, respectively. Male sex, higher socioeconomic status, only-child status, history of antibiotic use and pneumonia, and family history of allergy were associated with elevated risk of allergic diseases. In contrast, sleep duration > 12 h/day and window-opening ventilation were protective factors. Age effects varied by condition: the adjusted odds ratio (AOR) for atopic dermatitis decreased with age ($AOR = 0.85$, 95% $CI\ 0.80–0.92$), whereas that for allergic rhinitis increased ($AOR = 1.23$, 95% $CI\ 1.14–1.32$). The Childhood Allergy and Asthma Comprehensive Screening Questionnaire (CACSQ) exhibited strong diagnostic performance, with an AUC of 0.88 ($P < 0.001$), sensitivity of 92%, specificity of 76%, and Kappa coefficient of 0.698.

Conclusion: Genetic predisposition and modifiable environmental/lifestyle factors increase the risk of allergic diseases in children aged 0–6, whereas longer sleep duration and window ventilation may mitigate the risk. These findings carry important implications for clinical practice and public health policy. The validated CACSQ offers a reliable and effective screening tool for detection and support future longitudinal studies on the atopic march and temporal risk patterns.

Registry: Chinese Clinical Trial Registry, TRN: ChiCTR2500102075, Registration date: 8 May 2025.

1. Introduction

Allergic diseases, including asthma, allergic rhinitis (AR) atopic dermatitis (AD), and food allergies (FA), constitute a major global public health challenge with a steadily increasing prevalence over the past few decades (1). These conditions represent a significant source of morbidity, impairing quality of life, sleep, and cognitive development, and imposing a substantial economic burden on healthcare systems and families worldwide (2–5). The rising trend in pediatric allergic diseases is particularly evident in China, where they remain a pressing concern. Recent multicenter studies reveal a high and age-dependent burden: among children aged 6–11 years, the prevalence of FA is 11% (6), while the diagnosis rates of AR, AD, and asthma in children aged 6–18 years are 14.2%, 11.4%, and 9.2%, respectively (7). More strikingly, among younger children aged 3–14 years, current prevalence rates escalate dramatically to 28.8% for AR, 38.8% for AD, and 20.2% for asthma (8).

This gradient underscores early childhood as a period of exceptional vulnerability, a notion strongly supported by a specialized database survey in Shanghai which found that over 80% of pediatric allergy cases have their onset in the 0–6-year age group, with half of all initial diagnoses occurring in preschool children (3–6 years) (9). Despite the recognized vulnerability of early childhood, epidemiological data specifically for the 0–6 years age group in China remain scattered, hindering targeted intervention. To address these problems, we conducted a population-based cross-sectional study to determine the current prevalence and influencing factors of allergic diseases among children aged

0–6 years in China. Furthermore, we developed and implemented a standardized screening questionnaire to ensure rigorous and consistent case definition across this pivotal pediatric age group.

2. Methods

2.1 Study participants

A district-wide cross-sectional survey was conducted in Minhang District, Shanghai from June to October 2025. To obtain a representative sample, this study employed multi-stage stratified random sampling based on the regional distribution of the child population. A total of 8 community health service centers and 15 kindergartens and childcare institutions were randomly selected from the southern, central, and northern areas of Minhang District. As the project was funded by the Minhang District Health Commission, we received strong support from all participating institutions. The sample size was estimated based on an assumed allergic disease prevalence of 20% (10), a margin of error of 2%, and a confidence level of 95%, requiring a minimum of 2,000 participants. Our final sample exceeded this requirement.

In accordance with ethical principles, both participants and their guardians were informed of the study's purpose and procedures prior to enrollment, and written informed consent was obtained from all guardians.

Before the epidemiological investigation, we held online and offline meetings with administrators of selected institutions and physicians from community health centers to detail the study plan (including objectives, methodology, implementation, and feedback of results). Subsequently, school administrators notified parents to ensure full understanding and cooperation, while community health centers promoted participation through posters and physician education. Nearly all sampled parents completed the questionnaire, with 3,133 initial responses. After excluding children over 6 years old or without guardian consent, 3,064 (97.8%) children aged 0–6 were ultimately included (Fig. 1).

The studies involving humans were approved by Medical Ethics Committee of Shanghai Fifth People's Hospital Affiliated to Fudan University (2024177) and registered at the Chinese Clinical Trial Registry (Trial Registration Number: ChiCTR2500102075, Registration date: 8 May 2025).

2.2 Questionnaire

The questionnaire covered four common pediatric allergic diseases (food allergy, allergic asthma, atopic dermatitis, and allergic rhinitis), general characteristics of children and their parents, parental educational background, personal and family history of allergies, prenatal exposures, children's lifestyle habits and early-life household environmental exposures, dietary patterns after complementary feeding, as well as history of infections and medication use.

2.3 Assessment of allergic diseases

The Childhood Allergy and Asthma Comprehensive Screening Questionnaire (CACSQ) was developed to assess for four types of allergic diseases in children aged 0–6 years. The scale was adapted from established questionnaires, including ISAAC (International Study of Asthma and Allergies in Childhood) (11) and CECAQ (Comprehensive Early Childhood Allergy Questionnaire) (12). Following Brislin's translation model, the instrument underwent a rigorous process of forward translation, synthesis, and back-translation by bilingual experts, with subsequent revision until consensus was achieved. The preliminary CACSQ was further refined through two rounds of Delphi consultation with a multidisciplinary expert panel (n = 8), resulting in the incorporation of seven key suggestions. A pilot test (n = 28) confirmed the clarity and feasibility of the final questionnaire.

To evaluate its psychometric properties, a hospital-based nested case-control study was conducted, using physician diagnosis as the gold standard. The study enrolled 196 participants, comprising 98 cases and 98 matched controls. The

CACSQ demonstrated excellent discriminant validity, with an area under the receiver operating characteristic curve (AUC) of 0.88 ($P < 0.001$), a sensitivity of 92%, and a specificity of 76% against the physician's diagnosis.

2.4 Assessment of independent variables

The variables included general characteristics of the children and their parents, socioeconomic status (educational background), personal and family history of allergies, prenatal exposures, children's lifestyle habits and early-life household environmental exposures, residential surroundings, etc.

2.5 Subgroup and sensitivity analyses

Subgroup analyses were conducted based on a priori considerations of potential effect modification, as informed by tests of statistical interaction. Given the distinct peak age ranges and immune maturation patterns within the 0–6-year spectrum, participants were stratified into two age groups: the window period (< 3 years) and the transitional period (3–6 years). Additional stratification was performed by sex.

For sensitivity analysis, we assessed the robustness of our findings by adjusting for the number of children in the household and by applying the standard deviation method to account for extreme values in birth weight.

2.6 Statistical analysis

Categorical variables were described using frequencies and percentages, and differences in the prevalence of allergic diseases across different populations were assessed using the Pearson chi-square test. For continuous variables, those following a normal distribution were described as mean $\pm$ standard deviation (SD), differences between diseased and non-diseased populations were evaluated using Welch's t-test or t'-test.

Univariable logistic regression models were used to calculate the odds ratios (OR) and 95% confidence intervals (CI) for factors such as child sex, age, birth weight, mode of delivery, breastfeeding duration, only child status, and family history of allergies. Multivariable logistic regression models were employed to calculate the adjusted odds ratios (AOR) and 95% CIs after controlling for confounding factors.

Validity assessment metrics of CACSQ included ROC curve analysis, sensitivity, specificity, likelihood ratio, and Youden index, while reliability was evaluated via: Cronbach's α (internal consistency), Split-half reliability (Spearman-Brown correction was used) and Kappa coefficients (test–retest responders). All statistical analyses were performed using R 4.5.2.

3. Results

3.1 Characteristics of the sample

This study investigated 3064 children aged 0–6 with an average age of 3.2 ± 2.1 years, including 1626 boys (53.1%) and 1438 girls (46.9%). The overall prevalence rates of FA, asthma, AD, and AR among children were 14.7%, 8.4%, 18.9%, and 20.0%, respectively. Overall, allergic diseases were more common in boys than in girls. Notably, the incidence of asthma was significantly higher in boys ($P < 0.001$) (Table 1).

Table 1

Summary statistics of characteristics and the prevalence of asthma and allergic diseases among different groups

Variable	Total, n (%)	Food allergy, n (%)	P-Value	Asthma, n (%)	P-Value	Atopic dermatitis, n (%)	P-Value	Allergic rhinitis, n (%)	P-Value
	3064	451 (14.7%)		256 (8.4%)		578 (18.9%)		612 (20.0%)	
Gender			0.586		< 0.001		0.946		0.573
Girls	1438 (46.9%)	217 (15.1%)		86 (6.0%)		272 (18.9%)		281 (19.5%)	
Boys	1626 (53.1%)	234 (14.4%)		170 (10.5%)		306 (18.8%)		331 (20.4%)	
Age (year)			< 0.001		< 0.001		< 0.001		< 0.001
< 1	742 (24.2%)	42 (5.7%)		17 (2.3%)		153 (20.6%)		27 (3.6%)	
~ 2	265 (8.6%)	51 (19.2%)		7 (2.6%)		69 (26.0%)		20 (7.5%)	
~ 3	250 (8.2%)	36 (14.4%)		22 (8.8%)		52 (20.8%)		55 (22.0%)	
~ 4	568 (18.5%)	121 (21.3%)		78 (13.7%)		123 (21.7%)		169 (29.8%)	
~ 5	423 (13.8%)	68 (16.1%)		54 (12.8%)		70 (16.5%)		120 (28.4%)	
~ 6	816 (26.6%)	133 (16.3%)		78 (9.6%)		111 (13.6%)		221 (27.1%)	
Race			0.027		0.386		0.884		0.099
Han ethnicity	2961 (96.6%)	428 (14.5%)		245 (8.3%)		558 (18.8%)		598 (20.2%)	
Others	103 (3.4%)	23 (22.3%)		11 (10.7%)		20 (19.4%)		14 (13.6%)	
Number of children			0.138		0.844		0.010		0.052
0	1904 (62.1%)	302 (15.9%)		154 (8.1%)		391 (20.5%)		408 (21.4%)	
1	1040 (33.9%)	134 (12.9%)		90 (8.7%)		164 (15.8%)		182 (17.5%)	
2	107 (3.5%)	14 (13.1%)		11 (10.3%)		22 (20.6%)		21 (19.6%)	
≥ 3	13 (0.4%)	1 (7.7%)		1 (7.7%)		1 (7.7%)		1 (7.7%)	
Degree of mother			< 0.001		0.057		0.222		< 0.001
Data were presented with frequency and percentage; p-value was calculated by Pearson's chi-squared (χ^2) test;									

Variable	Total, n (%)	Food allergy, n (%)	P-Value	Asthma, n (%)	P-Value	Atopic dermatitis, n (%)	P-Value	Allergic rhinitis, n (%)	P-Value
Junior high school and below	136 (4.4%)	6 (4.4%)		4 (2.9%)		25 (18.4%)		10 (7.4%)	
High school/vocational high school	250 (8.2%)	14 (5.6%)		16 (6.4%)		36 (14.4%)		26 (10.4%)	
Undergraduate	2059 (67.2%)	323 (15.7%)		178 (8.6%)		390 (18.9%)		445 (21.6%)	
Postgraduate	619 (20.2%)	108 (17.4%)		58 (9.4%)		127 (20.5%)		131 (21.2%)	
Degree of father			< 0.001		0.107		0.018		< 0.001
Junior high school and below	130 (4.2%)	11 (8.5%)		6 (4.6%)		18 (13.8%)		9 (6.9%)	
High school/vocational high school	266 (8.7%)	20 (7.5%)		15 (5.6%)		34 (12.8%)		25 (9.4%)	
Undergraduate	1985 (64.8%)	303 (15.3%)		179 (9.0%)		387 (19.5%)		426 (21.5%)	
Postgraduate	683 (22.3%)	117 (17.1%)		56 (8.2%)		139 (20.4%)		152 (22.3%)	
Premature birth			0.005		0.312		0.746		< 0.001
No	333 (10.9%)	32 (9.6%)		23 (6.9%)		65 (19.5%)		39 (11.7%)	
Yes	2731 (89.1%)	419 (15.3%)		233 (8.5%)		513 (18.8%)		573 (21.0%)	
Birth mode			0.156		0.749		0.031		0.445
Vaginal delivery	1419 (46.3%)	195 (13.7%)		121 (8.5%)		291 (20.5%)		275 (19.4%)	
Cesarean section	1645 (53.7%)	256 (15.6%)		135 (8.2%)		287 (17.4%)		337 (20.5%)	
Breastfeeding duration			0.547		0.149		0.964		0.749
< 6 m	920 (30.0%)	130 (14.1%)		87 (9.5%)		174 (18.9%)		187 (20.3%)	
≥ 6 m	2144 (70.0%)	321 (15.0%)		169 (7.9%)		404 (18.8%)		425 (19.8%)	
Has the child ever had pneumonia?			< 0.001		< 0.001		0.062		< 0.001
No	2293 (74.8%)	271 (11.8%)		98 (4.3%)		415 (18.1%)		357 (15.6%)	
Data were presented with frequency and percentage; p-value was calculated by Pearson's chi-squared (χ^2) test;									

Variable	Total, n (%)	Food allergy, n (%)	P-Value	Asthma, n (%)	P-Value	Atopic dermatitis, n (%)	P-Value	Allergic rhinitis, n (%)	P-Value
Yes	771 (25.2%)	180 (23.3%)		158 (20.5%)		163 (21.1%)		255 (33.1%)	
Has the child ever had Pediatric inflammation?			0.011		0.003		0.012		< 0.001
No	2874 (93.8%)	411 (14.3%)		229 (8.0%)		529 (18.4%)		543 (18.9%)	
Yes	190 (6.2%)	40 (21.1%)		27 (14.2%)		49 (25.8%)		69 (36.3%)	
Has the child ever received antibiotic treatment?			< 0.001		< 0.001		0.046		< 0.001
No	1274 (41.6%)	115 (9.0%)		30 (2.4%)		219 (17.2%)		115 (9.0%)	
Yes	1790 (58.4%)	336 (18.8%)		226 (12.6%)		359 (20.1%)		497 (27.8%)	
Family allergy history			< 0.001		< 0.001		< 0.001		< 0.001
No	1482 (48.4%)	122 (8.2%)		66 (4.5%)		179 (12.1%)		156 (10.5%)	
Yes	1582 (51.6%)	329 (20.8%)		190 (12.0%)		399 (25.2%)		456 (28.8%)	
Keep pets			0.322		0.280		0.288		0.450
No	2574 (84.0%)	386 (15.0%)		209 (8.1%)		494 (19.2%)		508 (19.7%)	
Yes	490 (16.0%)	65 (13.3%)		47 (9.6%)		84 (17.1%)		104 (21.2%)	
Raising plants			0.078		0.133		0.538		0.005
No	1693 (55.3%)	232 (13.7%)		130 (7.7%)		326 (19.3%)		307 (18.1%)	
Yes	1371 (44.7%)	219 (16.0%)		126 (9.2%)		252 (18.4%)		305 (22.2%)	
Fresh air systems use			0.749		0.034		0.063		0.017
No	2556 (83.4%)	380 (14.9%)		221 (8.6%)		501 (19.6%)		534 (20.9%)	
Sometimes	323 (10.5%)	43 (13.3%)		29 (9.0%)		50 (15.5%)		50 (15.5%)	
Often	185 (6.0%)	28 (15.1%)		6 (3.2%)		27 (14.6%)		28 (15.1%)	
Data were presented with frequency and percentage; p-value was calculated by Pearson's chi-squared (χ^2) test;									

Variable	Total, n (%)	Food allergy, n (%)	P-Value	Asthma, n (%)	P-Value	Atopic dermatitis, n (%)	P-Value	Allergic rhinitis, n (%)	P-Value
Mosquito repellents/mosquito repellents use			0.021		0.215		0.394		0.011
No	1447 (47.2%)	201 (13.9%)		115 (7.9%)		270 (18.7%)		271 (18.7%)	
Sometimes	1373 (44.8%)	225 (16.4%)		126 (9.2%)		254 (18.5%)		304 (22.1%)	
Often	244 (8.0%)	25 (10.2%)		15 (6.1%)		54 (22.1%)		37 (15.2%)	
Air purifiers use			0.025		0.814		0.904		0.168
No	1839 (60.0%)	252 (13.7%)		153 (8.3%)		344 (18.7%)		354 (19.2%)	
Sometimes	761 (24.8%)	135 (17.7%)		61 (8.0%)		143 (18.8%)		170 (22.3%)	
Often	464 (15.1%)	64 (13.8%)		42 (9.1%)		91 (19.6%)		88 (19.0%)	
Incense/air fresheners use			0.618		0.545		0.227		0.006
No	2513 (82.0%)	368 (14.6%)		207 (8.2%)		487 (19.4%)		475 (18.9%)	
Sometimes	444 (14.5%)	70 (15.8%)		42 (9.5%)		76 (17.1%)		109 (24.5%)	
Often	107 (3.5%)	13 (12.1%)		7 (6.5%)		15 (14.0%)		28 (26.2%)	
Times of open the windows for ventilation			0.675		0.010		0.096		0.110
0 time	18 (0.6%)	4 (22.2%)		4 (22.2%)		7 (38.9%)		4 (22.2%)	
1 time	524 (17.1%)	81 (15.5%)		58 (11.1%)		107 (20.4%)		94 (17.9%)	
2 times	675 (22.0%)	103 (15.3%)		55 (8.1%)		130 (19.3%)		119 (17.6%)	
≥ 3	1847 (60.3%)	263 (14.2%)		139 (7.5%)		334 (18.1%)		395 (21.4%)	
Daily exercise time for children (hour)			0.395		0.639		0.497		0.600
< 2 h	1849 (60.3%)	264 (14.3%)		158 (8.5%)		356 (19.3%)		375 (20.3%)	
≥ 2 h	1215 (39.7%)	187 (15.4%)		98 (8.1%)		222 (18.3%)		237 (19.5%)	
Data were presented with frequency and percentage; p-value was calculated by Pearson's chi-squared (χ^2) test;									

Variable	Total, n (%)	Food allergy, n (%)	P-Value	Asthma, n (%)	P-Value	Atopic dermatitis, n (%)	P-Value	Allergic rhinitis, n (%)	P-Value
Daily sleep time of children (hour)			< 0.001		< 0.001		0.003		< 0.001
< 10 h	1552 (50.7%)	261 (16.8%)		161 (10.4%)		256 (16.5%)		387 (24.9%)	
10–12 h	860 (28.1%)	140 (16.3%)		78 (9.1%)		188 (21.9%)		197 (22.9%)	
≥ 12 h	652 (21.3%)	50 (7.7%)		17 (2.6%)		134 (20.6%)		28 (4.3%)	
Environment near the residence (Close to rivers, lakes, parks and green spaces?)			0.403		0.758		0.235		0.002
No	2809 (91.7%)	418 (14.9%)		236 (8.4%)		537 (19.1%)		580 (20.6%)	
Yes	255 (8.3%)	33 (12.9%)		20 (7.8%)		41 (16.1%)		32 (12.5%)	
Residential floor			0.186		0.716		0.049		0.016
1–3 floors	1104 (36.0%)	147 (13.3%)		95 (8.6%)		183 (16.6%)		207 (18.8%)	
4–6 floors	1066 (34.8%)	159 (14.9%)		92 (8.6%)		218 (20.5%)		243 (22.8%)	
≥ 7 floors	894 (29.2%)	145 (16.2%)		69 (7.7%)		177 (19.8%)		162 (18.1%)	
Decoration situation of the permanent residence			0.001		< 0.001		0.575		< 0.001
No	2385 (77.8%)	320 (13.4%)		177 (7.4%)		448 (18.8%)		442 (18.5%)	
Before pregnancy	184 (6.0%)	38 (20.7%)		15 (8.2%)		29 (15.8%)		40 (21.7%)	
during pregnancy	82 (2.7%)	18 (22.0%)		9 (11.0%)		16 (19.5%)		10 (12.2%)	
after birth	413 (13.5%)	75 (18.2%)		55 (13.3%)		85 (20.6%)		120 (29.1%)	
Wall materials for children's rooms			0.219		0.145		0.014		0.002
Seaweed mud	25 (0.8%)	4 (16.0%)		3 (12.0%)		6 (24.0%)		7 (28.0%)	
wallpaper	396 (12.9%)	57 (14.4%)		24 (6.1%)		74 (18.7%)		80 (20.2%)	

Data were presented with frequency and percentage; p-value was calculated by Pearson's chi-squared (χ^2) test;

Variable	Total, n (%)	Food allergy, n (%)	P-Value	Asthma, n (%)	P-Value	Atopic dermatitis, n (%)	P-Value	Allergic rhinitis, n (%)	P-Value
water-based paint/latex paint	1427 (46.6%)	232 (16.3%)		139 (9.7%)		270 (18.9%)		322 (22.6%)	
oil-based paint	36 (1.2%)	5 (13.9%)		2 (5.6%)		10 (27.8%)		4 (11.1%)	
wooden board	47 (1.5%)	3 (6.4%)		5 (10.6%)		5 (10.6%)		8 (17.0%)	
lime/cement	91 (3.0%)	10 (11.0%)		9 (9.9%)		9 (9.9%)		14 (15.4%)	
wall painting	916 (29.9%)	128 (14.0%)		68 (7.4%)		191 (20.9%)		166 (18.1%)	
Others	126 (4.1%)	12 (9.5%)		6 (4.8%)		13 (10.3%)		11 (8.7%)	
Habit of keeping windows open in spring			0.013		0.482		0.194		0.764
No	951 (31.0%)	162 (17.0%)		83 (8.7%)		197 (20.7%)		196 (20.6%)	
Sometimes	1026 (33.5%)	154 (15.0%)		91 (8.9%)		181 (17.6%)		206 (20.1%)	
Often	1087 (35.5%)	135 (12.4%)		82 (7.5%)		200 (18.4%)		210 (19.3%)	
Habit of keeping windows open in summer			0.046		0.504		< 0.001		0.880
No	1241 (40.5%)	205 (16.5%)		109 (8.8%)		271 (21.8%)		243 (19.6%)	
Sometimes	899 (29.3%)	128 (14.2%)		78 (8.7%)		172 (19.1%)		180 (20.0%)	
Often	924 (30.2%)	118 (12.8%)		69 (7.5%)		135 (14.6%)		189 (20.5%)	
Habit of keeping windows open in fall			0.010		0.449		0.136		0.872
No	947 (30.9%)	163 (17.2%)		85 (9.0%)		198 (20.9%)		193 (20.4%)	
Sometimes	1039 (33.9%)	154 (14.8%)		90 (8.7%)		191 (18.4%)		209 (20.1%)	
Often	1078 (35.2%)	134 (12.4%)		81 (7.5%)		189 (17.5%)		210 (19.5%)	
Habit of keeping Windows open in winter			0.004		< 0.001		0.043		0.024
Data were presented with frequency and percentage; p-value was calculated by Pearson's chi-squared (χ^2) test;									

Variable	Total, n (%)	Food allergy, n (%)	P-Value	Asthma, n (%)	P-Value	Atopic dermatitis, n (%)	P-Value	Allergic rhinitis, n (%)	P-Value
No	1790 (58.4%)	293 (16.4%)		178 (9.9%)		354 (19.8%)		386 (21.6%)	
Sometimes	747 (24.4%)	101 (13.5%)		50 (6.7%)		145 (19.4%)		138 (18.5%)	
Often	527 (17.2%)	57 (10.8%)		28 (5.3%)		79 (15.0%)		88 (16.7%)	
Mother's exposure to secondhand smoke from family members during pregnancy			0.015		0.464		0.187		0.366
No	2609 (85.2%)	367 (14.1%)		214 (8.2%)		482 (18.5%)		514 (19.7%)	
Yes	455 (14.8%)	84 (18.5%)		42 (9.2%)		96 (21.1%)		98 (21.5%)	
Mother smoking ☐			0.984		0.006		0.263		0.941
No	3010 (98.2%)	443 (14.7%)		246 (8.2%)		571 (19.0%)		601 (20.0%)	
Yes	54 (1.8%)	8 (14.8%)		10 (18.5%)		7 (13.0%)		11 (20.4%)	
Data were presented with frequency and percentage; p-value was calculated by Pearson's chi-squared (χ^2) test;									

Analysis revealed frequent co-occurrence among FA, AD, and AR, a significant increase in prevalence was observed in children aged 3–6 years ($P < 0.001$). Specifically, the prevalence rates of children suffering from FA and AD simultaneously, FA and AR, and AD and AR were 5.2%, 5.9%, and 5.8% respectively. (Fig. 2 and Supplementary file 1: Table S1)

Multiple factors were associated with elevated prevalence rates across several conditions. Preterm birth was associated with higher prevalence of FA and AR ($P = 0.001$ and $P < 0.001$). Higher socioeconomic status (indicated by parental education), being an only child, and postnatal renovation of the child's room were significantly associated with increased prevalence of FA, asthma, and AR ($P < 0.001$). A family history of allergy, history of antibiotic treatment, otitis media, pneumonia, average nightly sleep duration of less than 10 hours, and lack of the habit of opening windows for ventilation in winter were all significantly associated with an elevated prevalence of allergic diseases ($P < 0.001$).

When considering each disease separately, higher prevalence of FA was observed among ethnic minorities and children whose mothers were exposed to secondhand smoke during pregnancy ($P = 0.027$ and $P = 0.015$, respectively). Maternal smoking and non-use of fresh air systems were linked to a higher prevalence of asthma ($P = 0.006$ and $P = 0.034$). Vaginal section delivery was associated with a significantly increased prevalence of AD ($P = 0.031$). The use of seaweed mud as a decorative material in the child's room, residence near rivers, lakes, parks, or greenways, and living on the 4th to 6th floors were associated with a significantly increased prevalence of AR ($P = 0.002$, 0.002 and 0.016 , respectively).

3.2 Influencing factors of allergies in children

Univariable and multivariable logistic regression analyses indicated that certain factors exhibited consistent effects on various conditions, a family history of allergies, longer annual duration of air conditioner use, a history of antibiotic

treatment, and a history of pneumonia were associated with higher OR of asthma and allergic diseases. For instance, the AORs for children had a family history of allergies were 2.29 (95%CI: 1.81–2.90) for FA, 2.17 (95%CI: 1.58–2.98) for asthma, 2.32 (95%CI: 1.88–2.85) for AD, and 2.83 (95%CI: 2.27–3.51) for AR. In contrast, having siblings (particularly one sibling) and an average sleep duration of > 12 hours per day were associated with lower OR. The AORs for children have an average sleep duration of > 12 hours were FA (AOR = 0.58, 95%CI: 0.38–0.88), asthma (AOR = 0.46, 95%CI: 0.25–0.88), and AR (AOR = 0.38, 95%CI: 0.23–0.60). Similarly, the AORs for those with one sibling were FA (AOR = 0.79, 95%CI: 0.62–0.99), AD (AOR = 0.81, 95%CI: 0.65–0.99), and AR (AOR = 0.67, 95%CI: 0.54–0.84). (Table 2)

Table 2
Results of univariate and multivariate logistics regression analyses between childhood allergy and independent variables

Variable	Food allergy		Asthma		Atopic dermatitis		Allergic rhinitis	
	COR	AOR	COR	AOR	COR	AOR	COR	AOR
Age	1.14 (1.09–1.20)	1.02 (0.94–1.10)	1.24 (1.16–1.33)	1.02 (0.92–1.14)	0.91 (0.87–0.95)	0.85 (0.80–0.92)	1.38 (1.31–1.45)	1.23 (1.14–1.32)
Birth weight	1.01 (0.98–1.04)	1.00 (0.97–1.03)	1.03 (1.00–1.06)	1.03 (1.00–1.06)	1.01 (0.99–1.04)	1.02 (0.99–1.04)	1.01 (0.99–1.03)	0.99 (0.96–1.02)
The number of months using air conditioners (within one year)	1.12 (1.07–1.17)	1.07 (1.02–1.13)	1.14 (1.07–1.21)	1.09 (1.02–1.18)	1.10 (1.06–1.15)	1.06 (1.01–1.11)	1.11 (1.06–1.16)	1.07 (1.02–1.13)
Gender (girls)								
Boys	0.95 (0.77–1.16)	0.95 (0.76–1.17)	1.84 (1.40–2.40)	1.97 (1.47–2.64)	0.99 (0.83–1.19)	0.99 (0.82–1.20)	1.05 (0.88–1.26)	1.06 (0.87–1.29)
Race (Han ethnicity)								
Others	1.70 (1.06–2.74)	1.67 (1.00–2.79)	1.33 (0.70–2.51)	1.09 (0.53–2.24)	1.04 (0.63–1.71)	1.07 (0.63–1.80)	0.62 (0.35–1.10)	0.57 (0.31–1.06)
Number of children (1)								
2	0.78 (0.63–0.98)	0.79 (0.62–0.99)	1.08 (0.82–1.41)	1.09 (0.80–1.47)	0.72 (0.59–0.89)	0.81 (0.65–0.99)	0.78 (0.64–0.94)	0.67 (0.54–0.84)
3	0.80 (0.45–1.42)	1.11 (0.60–2.05)	1.30 (0.68–2.48)	1.39 (0.65–2.94)	1.00 (0.62–1.62)	1.08 (0.65–1.82)	0.90 (0.55–1.46)	1.25 (0.71–2.20)
≥ 4	0.44 (0.06–3.41)	0.82 (0.09–7.19)	0.95 (0.12–7.33)	1.20 (0.12–11.80)	0.32 (0.04–2.49)	0.37 (0.05–3.04)	0.31 (0.04–2.36)	0.39 (0.04–3.95)
Degree of mother (Junior high school and below)								
High school/vocational high school	1.29 (0.48–3.42)	1.18 (0.41–3.41)	2.26 (0.74–6.89)	1.62 (0.46–5.71)	0.75 (0.43–1.31)	0.59 (0.31–1.12)	1.46 (0.68–3.13)	0.84 (0.35–1.97)
Undergraduate	4.03 (1.76–9.22)	2.99 (1.12–7.99)	3.12 (1.14–8.54)	1.75 (0.52–5.91)	1.04 (0.66–1.62)	0.59 (0.33–1.06)	3.47 (1.81–6.67)	1.16 (0.52–2.59)
Postgraduate	4.58 (1.97–10.65)	3.26 (1.18–9.06)	3.41 (1.22–9.56)	2.18 (0.61–7.81)	1.15 (0.71–1.84)	0.62 (0.32–1.17)	3.38 (1.73–6.62)	1.12 (0.48–2.60)
Degree of Father (Junior high school and below)								
Data were presented with OR and 95% CI; COR crude odds ratio, AOR adjusted odds ratio, CI confidence interval								
The bold value indicates statistical significance ($P < 0.05$)								

Variable	Food allergy		Asthma		Atopic dermatitis		Allergic rhinitis	
	COR	AOR	COR	AOR	COR	AOR	COR	AOR
High school/vocational high school	0.88 (0.41–1.90)	0.62 (0.26–1.48)	1.24 (0.47–3.26)	0.88 (0.29–2.70)	0.91 (0.49–1.69)	1.30 (0.65–2.61)	1.39 (0.63–3.08)	1.45 (0.59–3.56)
Undergraduate	1.95 (1.04–3.66)	0.71 (0.32–1.57)	2.05 (0.89–4.71)	0.97 (0.34–2.78)	1.51 (0.90–2.51)	1.83 (0.95–3.53)	3.67 (1.85–7.29)	2.35 (1.01–5.48)
Postgraduate	2.24 (1.17–4.28)	0.74 (0.32–1.71)	1.85 (0.78–4.38)	0.69 (0.23–2.11)	1.59 (0.93–2.70)	1.83 (0.91–3.71)	3.85 (1.91–7.76)	2.55 (1.05–6.18)
Premature birth (No)								
Yes	1.70 (1.17–2.49)	1.48 (0.99–2.22)	1.26 (0.81–1.96)	1.15 (0.70–1.90)	0.95 (0.72–1.27)	1.04 (0.76–1.42)	2.00 (1.42–2.83)	1.61 (1.09–2.37)
Birth mode (Vaginal delivery)								
Cesarean section	1.16 (0.95–1.42)	1.09 (0.88–1.35)	0.96 (0.74–1.24)	0.89 (0.67–1.18)	0.82 (0.68–0.98)	0.85 (0.70–1.03)	1.07 (0.90–1.28)	0.94 (0.77–1.15)
Breastfeeding duration (< 6months)								
≥ 6 months	1.07 (0.86–1.33)	1.03 (0.82–1.30)	0.82 (0.62–1.07)	0.79 (0.58–1.06)	1.00 (0.82–1.21)	0.94 (0.76–1.16)	0.97 (0.80–1.17)	0.93 (0.75–1.15)
Has the child ever had pneumonia (No)								
Yes	2.27 (1.84–2.80)	1.63 (1.28–2.06)	5.77 (4.42–7.54)	3.66 (2.72–4.95)	1.21 (0.99–1.49)	1.08 (0.86–1.37)	2.68 (2.22–3.23)	1.55 (1.25–1.92)
Has the child ever had Pediatric inflammation (No)								
Yes	1.60 (1.11–2.30)	1.21 (0.82–1.79)	1.91 (1.25–2.94)	1.18 (0.74–1.91)	1.54 (1.10–2.16)	1.65 (1.15–2.38)	2.45 (1.80–3.34)	1.32 (0.94–1.87)
Has the child ever received antibiotic treatment (No)								
Yes	2.33 (1.86–2.92)	1.38 (1.04–1.83)	5.99 (4.06–8.83)	2.59 (1.64–4.10)	1.21 (1.00–1.46)	1.32 (1.03–1.69)	3.87 (3.12–4.82)	1.69 (1.30–2.19)
Family history of allergy (No)								
Yes	2.93 (2.35–3.65)	2.30 (1.82–2.90)	2.93 (2.19–3.91)	2.15 (1.57–2.95)	2.46 (2.02–2.98)	2.35 (1.91–2.89)	3.44 (2.82–4.20)	2.84 (2.28–3.52)
Keep pets (No)								
Yes	0.87 (0.65–)	0.75 (0.56–)	1.20 (0.86–)	1.02 (0.70–)	0.87 (0.68–)	0.80 (0.61–)	1.10 (0.86–)	1.00 (0.76–)
Data were presented with OR and 95% CI; COR crude odds ratio, AOR adjusted odds ratio, CI confidence interval								
The bold value indicates statistical significance ($P < 0.05$)								

Variable	Food allergy		Asthma		Atopic dermatitis		Allergic rhinitis	
	COR	AOR	COR	AOR	COR	AOR	COR	AOR
	1.15)	1.02)	1.67)	1.48)	1.12)	1.05)	1.39)	1.30)
Raising plants (No)								
Yes	1.20 (0.98– 1.46)	0.99 (0.79– 1.23)	1.22 (0.94– 1.57)	0.96 (0.72– 1.29)	0.94 (0.79– 1.13)	0.94 (0.77– 1.15)	1.29 (1.08– 1.54)	0.96 (0.79– 1.18)
Fresh air systems usage frequency (No)								
Sometimes	0.88 (0.63– 1.23)	0.86 (0.60– 1.25)	1.04 (0.69– 1.56)	1.22 (0.77– 1.93)	0.75 (0.55– 1.03)	0.86 (0.61– 1.20)	0.69 (0.51– 0.95)	0.69 (0.48– 0.98)
Often	1.02 (0.67– 1.55)	1.19 (0.75– 1.89)	0.35 (0.16– 0.81)	0.34 (0.14– 0.82)	0.70 (0.46– 1.07)	0.66 (0.42– 1.05)	0.68 (0.45– 1.02)	0.76 (0.48– 1.23)
Mosquito repellents/mosquito repellents usage frequency (No)								
Sometimes	1.21 (0.99– 1.49)	1.04 (0.83– 1.31)	1.17 (0.90– 1.52)	0.87 (0.64– 1.17)	0.99 (0.82– 1.20)	1.00 (0.81– 1.24)	1.23 (1.03– 1.48)	0.93 (0.76– 1.15)
Often	0.71 (0.46– 1.10)	0.72 (0.44– 1.15)	0.76 (0.44– 1.32)	0.72 (0.38– 1.33)	1.24 (0.89– 1.72)	1.37 (0.96– 1.96)	0.78 (0.53– 1.13)	0.84 (0.55– 1.29)
Air purifiers usage frequency (No)								
Sometimes	1.36 (1.08– 1.71)	1.14 (0.89– 1.46)	0.96 (0.70– 1.31)	0.74 (0.52– 1.04)	1.01 (0.81– 1.25)	1.03 (0.81– 1.30)	1.21 (0.98– 1.48)	0.93 (0.73– 1.17)
Often	1.01 (0.75– 1.35)	0.97 (0.70– 1.34)	1.10 (0.77– 1.57)	1.25 (0.83– 1.88)	1.06 (0.82– 1.37)	1.03 (0.77– 1.36)	0.98 (0.76– 1.27)	0.95 (0.70– 1.29)
Incense/air fresheners usage frequency (No)								
Sometimes	1.09 (0.83– 1.44)	0.90 (0.67– 1.23)	1.16 (0.82– 1.65)	0.98 (0.66– 1.45)	0.86 (0.66– 1.12)	0.93 (0.70– 1.25)	1.40 (1.10– 1.77)	1.12 (0.85– 1.47)
Often	0.81 (0.45– 1.45)	0.97 (0.51– 1.84)	0.78 (0.36– 1.70)	0.74 (0.31– 1.77)	0.68 (0.39– 1.18)	0.85 (0.47– 1.54)	1.52 (0.98– 2.37)	1.98 (1.17– 3.36)
Open the windows for ventilation within one day (0 times)								
1	0.64 (0.21– 1.99)	0.45 (0.14– 1.49)	0.44 (0.14– 1.37)	0.17 (0.05– 0.61)	0.40 (0.15– 1.06)	0.34 (0.12– 0.95)	0.77 (0.25– 2.38)	0.31 (0.09– 1.11)
2	0.63 (0.20– 1.95)	0.56 (0.17– 1.85)	0.31 (0.10– 0.98)	0.15 (0.04– 0.54)	0.37 (0.14– 0.99)	0.33 (0.12– 0.93)	0.75 (0.24– 2.32)	0.40 (0.11– 1.39)
Data were presented with OR and 95% CI; COR crude odds ratio, AOR adjusted odds ratio, CI confidence interval								
The bold value indicates statistical significance ($P < 0.05$)								

Variable	Food allergy		Asthma		Atopic dermatitis		Allergic rhinitis	
	COR	AOR	COR	AOR	COR	AOR	COR	AOR
≥ 3	0.58 (0.19– 1.78)	0.47 (0.14– 1.53)	0.28 (0.09– 0.88)	0.10 (0.03– 0.37)	0.35 (0.13– 0.90)	0.34 (0.12– 0.95)	0.95 (0.31– 2.91)	0.39 (0.11– 1.37)
Daily exercise time for children (< 2 hours) 2 hours)								
≥ 2h	1.09 (0.89– 1.34)	1.08 (0.86– 1.34)	0.94 (0.72– 1.22)	0.90 (0.67– 1.21)	0.94 (0.78– 1.13)	1.01 (0.83– 1.24)	0.95 (0.79– 1.14)	0.83 (0.67– 1.01)
Daily sleep time of children (< 10 hours)								
10–12 h	0.96 (0.77– 1.20)	0.96 (0.74– 1.24)	0.86 (0.65– 1.15)	0.92 (0.66– 1.28)	1.42 (1.15– 1.75)	1.11 (0.88– 1.41)	0.89 (0.74– 1.09)	1.17 (0.93– 1.47)
≥ 12 h	0.41 (0.30– 0.56)	0.58 (0.38– 0.87)	0.23 (0.14– 0.38)	0.47 (0.25– 0.88)	1.31 (1.04– 1.65)	0.92 (0.67– 1.27)	0.14 (0.09– 0.20)	0.38 (0.24– 0.61)
Are environment near the residence close to rivers, lakes, parks and green spaces (No)								
Yes	0.85 (0.58– 1.24)	1.16 (0.78– 1.74)	0.93 (0.58– 1.49)	1.36 (0.80– 2.31)	0.81 (0.57– 1.15)	0.90 (0.62– 1.29)	0.55 (0.38– 0.81)	0.80 (0.52– 1.20)
Residential floor (1–3 floors)								
4–6 floors	1.14 (0.90– 1.45)	1.04 (0.80– 1.34)	1.00 (0.74– 1.35)	0.92 (0.66– 1.29)	1.29 (1.04– 1.61)	1.27 (1.01– 1.60)	1.28 (1.04– 1.58)	1.16 (0.92– 1.47)
≥ 7 floors	1.26 (0.98– 1.62)	1.24 (0.95– 1.62)	0.89 (0.64– 1.23)	0.85 (0.59– 1.22)	1.24 (0.99– 1.56)	1.17 (0.92– 1.49)	0.96 (0.76– 1.20)	1.00 (0.66– 1.50)
Decoration situation of the permanent residence (Never)								
Before pregnancy	1.68 (1.15– 2.45)	1.35 (0.90– 2.01)	1.11 (0.64– 1.92)	0.84 (0.46– 1.54)	0.81 (0.54– 1.22)	0.65 (0.42– 0.99)	1.22 (0.85– 1.76)	0.51 (0.25– 1.04)
during pregnancy	1.81 (1.06– 3.10)	1.79 (1.01– 3.16)	1.54 (0.76– 3.13)	1.27 (0.56– 2.85)	1.05 (0.60– 1.83)	0.95 (0.53– 1.71)	0.61 (0.31– 1.19)	1.13 (0.87– 1.48)
after birth	1.43 (1.09– 1.89)	1.11 (0.82– 1.51)	1.92 (1.39– 2.65)	1.42 (0.98– 2.05)	1.12 (0.86– 1.45)	1.27 (0.96– 1.68)	1.80 (1.42– 2.28)	1.01 (0.81– 1.27)
Wall materials for children's rooms (Others)								
Wall painting	1.92 (0.74– 1.14)	1.06 (0.84– 1.35)	0.83 (0.63– 1.12)	1.00 (0.72– 1.38)	1.20 (0.99– 1.46)	1.31 (1.06– 1.61)	0.84 (0.69– 1.03)	0.93 (0.61– 1.41)
Habit of keeping windows open in spring (No)								
Data were presented with OR and 95% CI; COR crude odds ratio, AOR adjusted odds ratio, CI confidence interval								
The bold value indicates statistical significance ($P < 0.05$)								

Variable	Food allergy		Asthma		Atopic dermatitis		Allergic rhinitis	
	COR	AOR	COR	AOR	COR	AOR	COR	AOR
Sometimes	0.86 (0.68– 1.09)	1.07 (0.67– 1.68)	1.02 (0.75– 1.39)	1.25 (0.69– 2.26)	0.82 (0.66– 1.03)	0.91 (0.59– 1.38)	0.97 (0.78– 1.20)	1.00 (0.56– 1.79)
Often	0.69 (0.54– 0.88)	1.04 (0.55– 1.96)	0.85 (0.62– 1.17)	1.51 (0.68– 3.36)	0.86 (0.69– 1.07)	1.33 (0.76– 2.33)	0.92 (0.74– 1.15)	1.07 (0.81– 1.42)
Habit of keeping windows open in summer (No)								
Sometimes	0.84 (0.66– 1.07)	0.92 (0.68– 1.24)	0.99 (0.73– 1.34)	1.16 (0.79– 1.71)	0.85 (0.68– 1.05)	0.94 (0.72– 1.23)	1.03 (0.83– 1.28)	0.96 (0.69– 1.34)
Often	0.74 (0.58– 0.94)	0.89 (0.62– 1.28)	0.84 (0.61– 1.15)	0.88 (0.55– 1.40)	0.61 (0.49– 0.77)	0.70 (0.50– 0.98)	1.06 (0.85– 1.31)	1.09 (0.71– 1.67)
Habit of keeping windows open in fall (No)								
Sometimes	0.84 (0.66– 1.06)	0.83 (0.52– 1.31)	0.96 (0.71– 1.31)	0.91 (0.51– 1.65)	0.85 (0.68– 1.06)	1.04 (0.68– 1.59)	0.98 (0.79– 1.22)	1.17 (0.65– 2.11)
Often	0.68 (0.53– 0.87)	0.78 (0.41– 1.48)	0.82 (0.60– 1.13)	1.12 (0.50– 2.49)	0.80 (0.64– 1.00)	0.83 (0.47– 1.48)	0.95 (0.76– 1.18)	0.98 (0.73– 1.32)
Habit of keeping windows open in winter (No)								
Sometimes	0.80 (0.63– 1.02)	1.14 (0.83– 1.57)	0.65 (0.47– 0.90)	0.64 (0.42– 0.98)	0.98 (0.79– 1.21)	1.07 (0.80– 1.42)	0.82 (0.66– 1.02)	0.80 (0.54– 1.20)
Often	0.62 (0.46– 0.84)	1.01 (0.64– 1.60)	0.51 (0.34– 0.77)	0.53 (0.29– 0.97)	0.72 (0.55– 0.93)	0.91 (0.61– 1.36)	0.73 (0.56– 0.94)	1.06 (0.80– 1.41)
Mother's exposure to secondhand smoke from family members during pregnancy (No)								
Yes	1.38 (1.07– 1.80)	1.37 (1.03– 1.83)	1.14 (0.80– 1.61)	0.91 (0.61– 1.34)	1.18 (0.92– 1.51)	1.18 (0.90– 1.54)	1.12 (0.88– 1.43)	0.78 (0.37– 1.63)
Mother smoking (No)								
Yes	1.01 (0.47– 2.15)	0.74 (0.32– 1.69)	2.55 (1.27– 5.14)	1.77 (0.78– 3.98)	0.64 (0.29– 1.41)	0.52 (0.22– 1.21)	1.03 (0.53– 2.00)	0.96 (0.67– 1.38)
Data were presented with OR and 95% CI; COR crude odds ratio, AOR adjusted odds ratio, CI confidence interval								
The bold value indicates statistical significance ($P < 0.05$)								

In terms of sociodemographic characteristics, boys are associated with increased OR of asthma ($AOR = 1.97$, 95% CI: 1.47–2.64). Besides, increasing age, treated as a continuous variable, was associated with lower OR of AD ($AOR = 0.85$, 95%CI: 0.80–0.92) but higher OR of AR ($AOR = 1.23$, 95%CI: 1.14–1.32). Higher socioeconomic status was associated with increased OR of FA ($AOR = 3.33$, 95%CI: 1.19–9.27) and AR ($AOR = 2.49$, 95%CI: 1.02–6.05).

Regarding the maternal exposure during pregnancy and living environment, maternal exposure to secondhand smoke from family members during pregnancy ($AOR = 1.38$, $95\%CI: 1.03-1.84$) and residence in a newly renovated room during pregnancy ($AOR = 1.78$, $95\%CI: 1.01-3.16$) were associated with higher OR of FA. Window ventilation at least once per day, often use of fresh air ventilation systems, and leaving windows open for ventilation during winter were associated with reduced OR of Asthma with AORs of 0.17 ($95\% CI: 0.05-0.61$), 0.34 ($95\% CI: 0.14-0.82$), and 0.64 ($95\% CI: 0.42-0.98$), respectively. While, residing on floors 4–6 was associated with a reduction in the OR for asthma ($AOR = 1.27$, $95\% CI: 1.01-1.60$). Frequent window ventilation during summer and often use of fresh air ventilation systems was associated with a reduced OR for AR, $AOR = 0.70$ ($95\% CI: 0.50-0.98$) and 0.34 ($95\% CI: 0.14-0.82$).

3.3 Subgroup and sensitivity analyses

We performed a sensitivity analysis using a multivariable logistic regression model that was additionally adjusted for birth weight and the number of children in the household, the results of this analysis remained largely unchanged from those presented in Table 2. (Supplementary File 1: Table S2)

Furthermore, we explored potential effect modification by age and sex through tests of interaction. Two significant interactions were identified: first between sex and window ventilation (≥ 1 time/day) for asthma ($P = 0.022$); and second, between age (as a continuous variable) and average sleep duration for AR ($P = 0.001$).

Stratified analyses revealed that the association between window ventilation (≥ 1 time/day) and reduced OR of Asthma was significant only among boys. For AR, the association of longer sleep duration (> 12 hours) with reduced odds was observed exclusively in children under 3 years of age with $AOR = 0.25$ ($95\% CI: 0.13-0.48$). (Supplementary file 1: Table S3 and S4)

3.4 Scale Development and Validation

The CACSQ demonstrated high sensitivity ($0.89-0.93$), specificity ($0.71-0.97$), split-half reliability ($0.83-0.91$), and substantial agreement ($Kappa = 0.68-0.88$) across all four allergic conditions. These results confirm the CACSQ as a highly valid and reliable screening instrument for allergic diseases in young children. (Fig. 3, Table 3, and Table 4)

Table 3 Authenticity evaluation of CACSQ				
Disease condition	Sensitivity (95% CI)	Specificity (95% CI)	LR+	LR-
Food allergy	0.89 (0.72–0.96)	0.83 (0.74–0.89)	5.12	0.19
Asthma	0.93 (0.77–0.99)	0.97 (0.91–0.99)	30.34	0.03
Atopic dermatitis	0.92 (0.72–0.96)	0.71 (0.63–0.79)	3.23	0.11
Allergic rhinitis	0.80 (0.69–0.87)	0.96 (0.90–0.98)	19.54	0.21
Combined allergy	0.92 (0.85–0.96)	0.76 (0.66–0.83)	3.75	0.67

Table 4. Consistency evaluation of CACSQ

Disease condition	N of Items	Cronbach's Alpha	Spearman-Brown Coefficient	Kappa coefficient
Food allergy	6	0.882	0.910	0.821
Asthma	6	0.853	0.828	0.884
Atopic dermatitis	7	0.889	0.828	0.752
Allergic rhinitis	5	0.845	0.887	0.684
Questionnaire	24	0.869	0.660	0.698

4. Discussion

This population-based cross-sectional study delineates the complex epidemiology of allergic diseases in young urban Chinese children, revealing a high burden of food allergy, atopic dermatitis, and allergic rhinitis. We identified a core set of universal risk factors—notably family allergy history and antibiotic use. Furthermore, we delineated both shared and distinct environmental and lifestyle determinants for each allergic outcome, demonstrating a nuanced relationship between higher socioeconomic status and increased risk for certain allergies that challenges simplistic interpretations of the hygiene hypothesis. The development and validation of the CACSQ provide a critical tool for future screening and research.

Our findings are consistent with most previous studies in which CS delivery, only one child in the household and exposure to second-hand smoke were associated with an increased risk of allergic diseases among children (10, 13–15). The observed association between higher SES (proxied by parental education) and increased allergy risk resonates with global patterns often described as the allergy epidemic associated with economic development (16, 17). This phenomenon may be mediated by a constellation of factors linked to improved living conditions, including increased time spent indoors, dietary changes, and the characteristics of the gut microbiota in the early stage of life (18, 19). Our detailed exposure assessment allowed us to probe specific elements of this complex picture. For instance, the protective association of frequent window ventilation and fresh air system use against Asthma and AR provides tangible support for the role of improved indoor air quality and dilution of airborne allergens or volatile organic compounds. As reviewed by Eguluz-Gracia et al, indoor and outdoor air pollution, along with the ensuing climate change, significantly influence the development and severity of allergic rhinitis and asthma in both children and adults (20). In parallel, Huang et al. identified indoor air quality and specific household environmental characteristics as potential factors associated with the development and exacerbation of allergic diseases among preschool children (21).

The robustness of a family history of allergy as a paramount risk factor (AORs ranging from 2.17 to 2.83) is consistent with the well-established genetic predisposition to atopy (13). The finding that longer nocturnal sleep duration (> 12 hours) was a consistent protective factor against FA, Asthma, and AR aligns with growing evidence on the immunomodulatory role of sleep. Sleep and the immune system maintain a bidirectional relationship, where immune activation can alter sleep patterns, adequate sleep enhances immune defense by reducing infection risk and improving response to vaccines, conversely, chronic sleep deficiency disrupts this balance, promoting systemic low-grade inflammation and increasing susceptibility to various inflammatory diseases (22–24). The findings are consistent with those of Esteban et al, who suggested that more positive allergy test results in urban school-age children with asthma are associated with objectively measured poorer sleep outcomes (25).

The intricate patterns of comorbidity among FA, AD, and AR, coupled with their partially overlapping yet distinct environmental triggers, reflect the concept of the "atopic march" (26). Our data suggest that early-life exposures may program the immune system towards a Th2-skewed phenotype (27), which then manifests as different conditions along

a developmental trajectory (28). The identification of condition-specific risk factors is a key contribution. For instance, cesarean section shows a specific association with AD, a linkage potentially mediated by its impact on the infant gut microbiome. Supporting evidence comes from a large cohort study by Mubanga et al., which indicated a higher risk of early-onset atopic dermatitis in children delivered by cesarean section or instrumental vaginal delivery (29). Further mechanistic insight is provided by an RCT from Marrs et al., which analyzed breastfed infants at three months of age and identified distinct gut microbiota profiles associated with cesarean delivery, including an increased abundance of *Clostridium perfringens*—a bacterium implicated in atopic dermatitis pathogenesis (30).

There are four important strengths in this study. First, the rigorous multistage, multilevel random sampling method ensured a highly representative sample. Second, the high response rate (> 95%) minimized potential selection bias. Third, the investigation encompassed multiple childhood allergic conditions—including asthma, allergic rhinitis, food allergy, and atopic dermatitis—enabling a comprehensive assessment of the effects of perinatal factors, living environment, family background, and dietary patterns on these diseases. Finally, we developed and validated the CACSQ, which demonstrates comparable or superior performance to established tools (11, 12, 31, 32). It provides a standardized, low-cost, and efficient tool for large-scale epidemiological studies and initial community-based screening in resource-limited settings.

The study has several limitations. First, all information was obtained from questionnaires, which inevitably introduces some degree of bias (e.g., recall bias and measurement bias). While we adjusted for a wide array of confounders, residual confounding by unmeasured factors, such as precise outdoor air pollution exposure, remains possible. The cross-sectional design precludes causal inference, and the possibility of reverse causality cannot be ruled out. Nevertheless, factors such as the child's age, being an only child, and family history of allergies were already significantly present before the diagnosis of allergic diseases, thus establishing a temporal sequence.

5. Conclusion

In conclusion, allergic diseases affect a strikingly high proportions of preschool children in urban China. Genetic susceptibility interacts with modifiable modern environmental and lifestyle factors—particularly indoor air quality, sleep duration, and dietary patterns—to drive risk. The protective associations identified here are immediately translatable into preventive recommendations. The validated CACSQ provides a robust new tool to facilitate early detection and future longitudinal research needed to clarify temporal relationships and track the atopic march from infancy onward.

Abbreviations

FA

food allergy

AD

atopic dermatitis

AR

allergic rhinitis

CACSQ

Childhood Allergy and Asthma Comprehensive Screening Questionnaire

ISAAC

International Study of Asthma and Allergies in Childhood

CECAQ

Comprehensive Early Childhood Allergy Questionnaire

AUC

area under the receiver operating characteristic curve
ROC
receiver operating characteristic curve
AOR
adjusted odds ratio
CIs
confidence intervals.

Declarations

Declarations

Ethics approval and consent to participate

This study involving human participants was reviewed and approved by the Medical Ethics Committee of Shanghai Fifth People's Hospital, Fudan University (2024177). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Written informed consent was obtained from participants' their parent/legal guardian prior to the study.

Consent for publication

Consent for publication was obtained from participants' their parent/legal guardian prior to the study.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

JY designed the study, performed the statistical analysis, and drafted the manuscript. NM, AG, CS, YZ , YW and LW contributed to manuscript revision and participant recruitment. FT, SH, YL, YC, CS and other authors conceived the study, supervised its implementation, and revised the manuscript. All authors read and approved the final manuscript.

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Data Availability

Due to privacy concerns for research participants, the data generated in this study is not publicly available. Data are only available on an approved request to the corresponding author.

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Figures

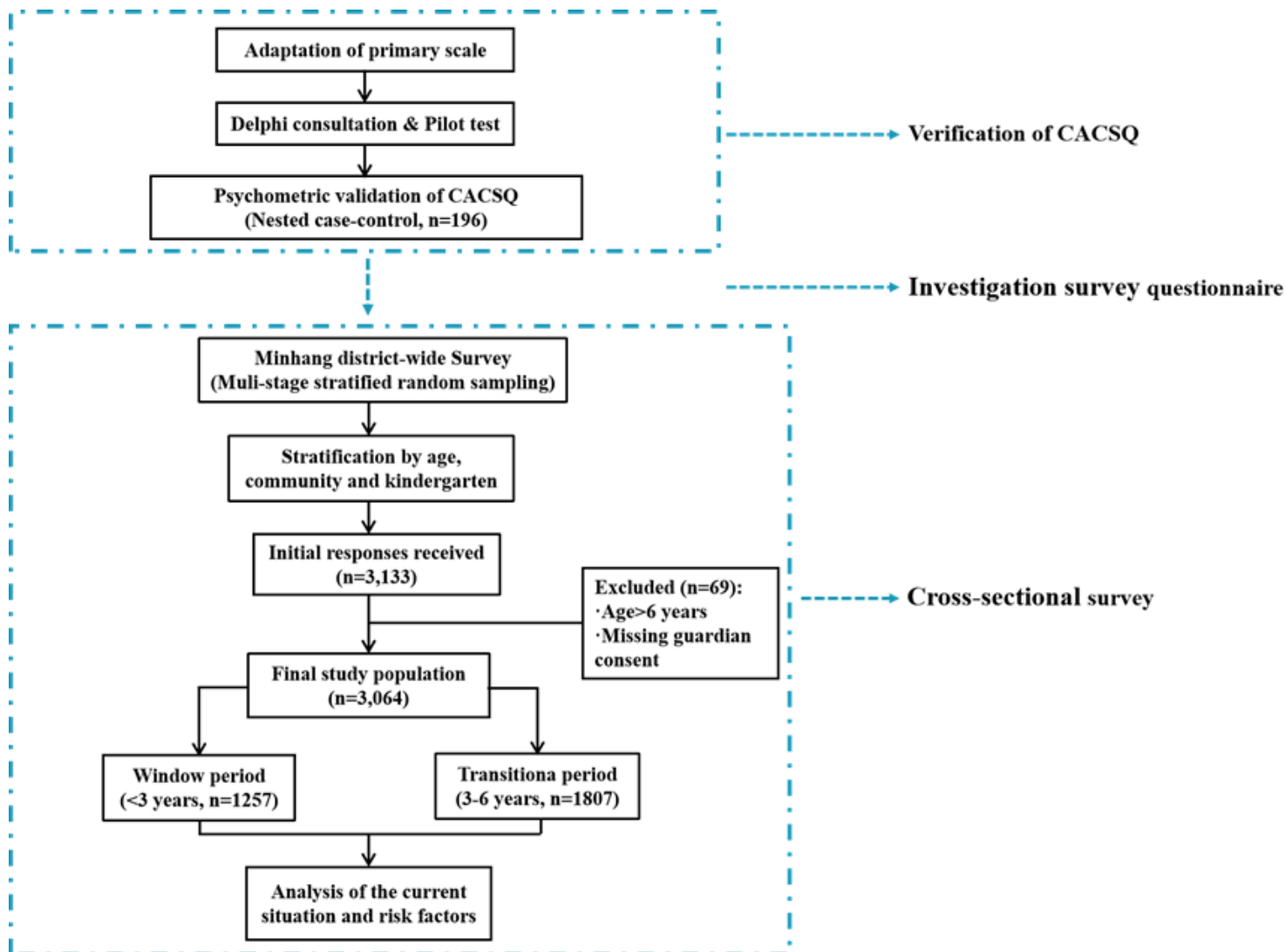


Figure 1

Recruitment process. CACSQ, Childhood Allergy and Asthma Comprehensive Screening Questionnaire.

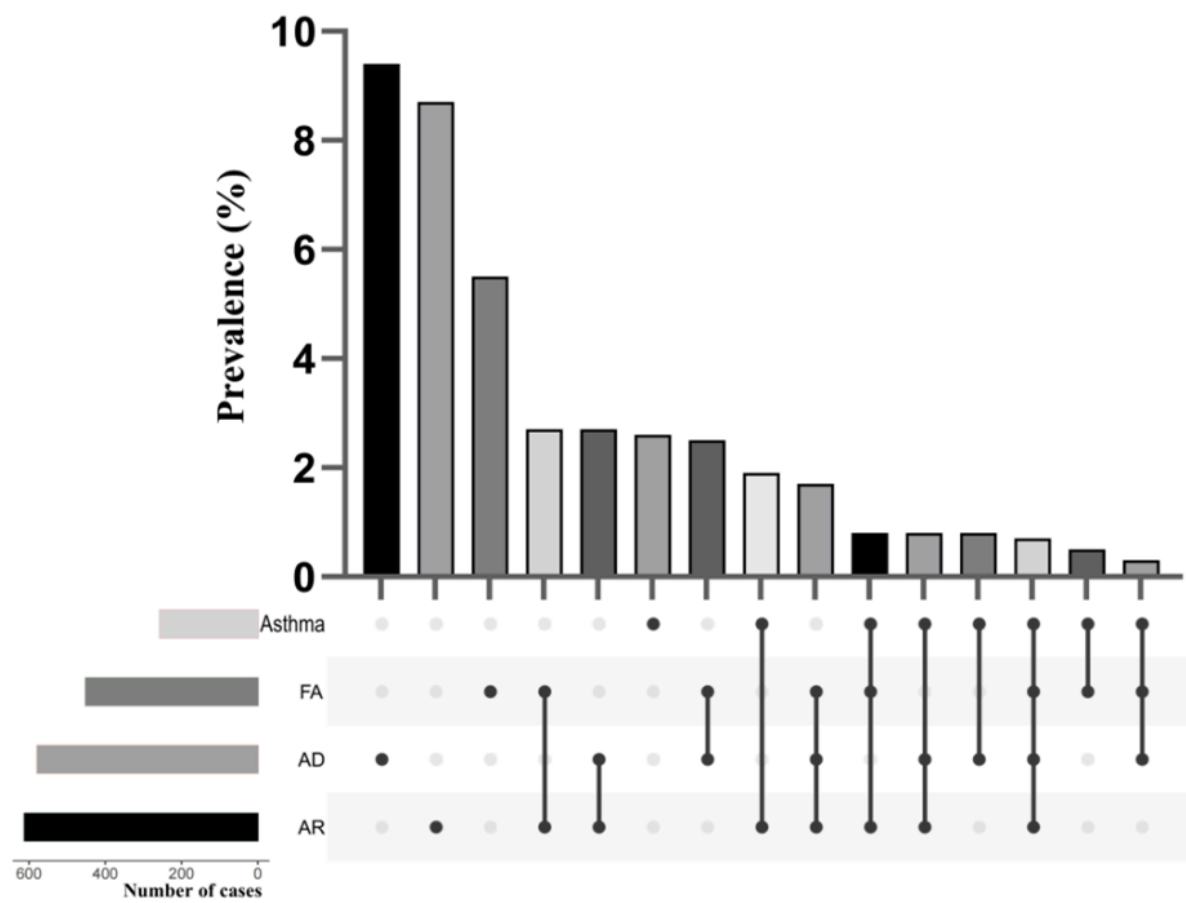


Figure 2

The comorbidity of allergic diseases in children. The incidence rate on the vertical coordinate is an exact set of each classification. AR, allergic rhinitis. AD, atopic dermatitis. FA, food allergies.

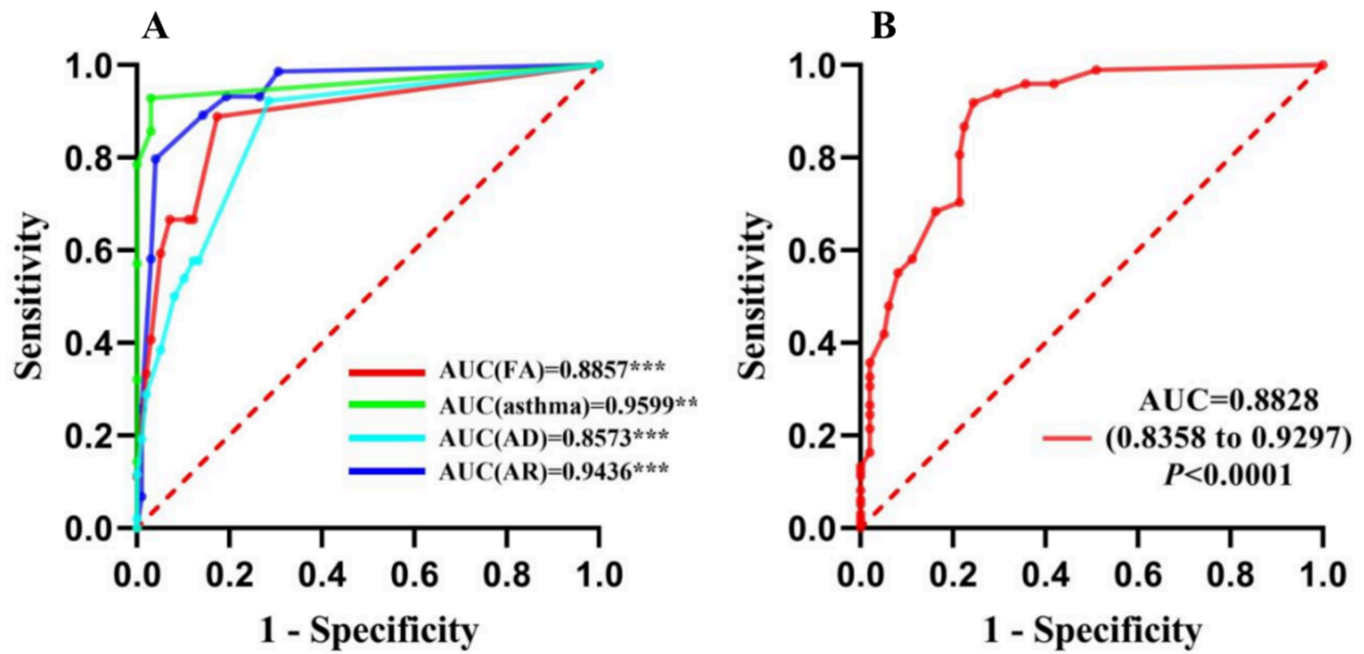


Figure 3

ROC analysis of the CACSQ, *** indicates $P < 0.001$

Supplementary Files

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