

# Divergent Sensitization Kinetics to Indoor Allergens in Children: Early Dust Mite Surges vs Delayed Cat Dander Peaks During COVID-19 Lockdowns

Yi Zhang<sup>1</sup>, Xiaoying Fu<sup>1</sup>, Yang Chen<sup>2</sup>, Fanghua Yang<sup>1</sup>, Zhihao Xing<sup>3</sup>, Dongyan Li<sup>1</sup>, Zhangchi Ren<sup>4</sup>, Feng Ren<sup>2,\*</sup>, Yunsheng Chen<sup>1,\*</sup>

<sup>1</sup>Department of Laboratory Medicine, Shenzhen Children's Hospital, Shenzhen, Guangdong, People's Republic of China; <sup>2</sup>Department of Surgery, Shenzhen Children's Hospital, Shenzhen, Guangdong, People's Republic of China; <sup>3</sup>Biobank & Clinical Laboratory, Shenzhen Children's Hospital, Shenzhen, Guangdong, People's Republic of China; <sup>4</sup>Shenzhen Senior High School Chuangxin HighSchool, Shenzhen, People's Republic of China

\*These authors contributed equally to this work

Correspondence: Feng Ren, Department of Surgery, Shenzhen Children's Hospital, Shenzhen, Guangdong, 518000, People's Republic of China, Email 283311729@qq.com; Yunsheng Chen, Department of Laboratory Medicine, Shenzhen Children's Hospital, Shenzhen, Guangdong, 518000, People's Republic of China, Email chenyunshenglw@163.com

**Purpose:** The COVID-19 pandemic altered patterns of indoor allergen exposure. However, longitudinal dynamics of sensitization kinetics across allergens remain poorly characterized. This study delineated allergen-specific sensitization dynamics during 2019–2022, contrasting responses to dust mites and cat dander.

**Patients and Methods:** The retrospective cohort study of 43,314 children (0–17 years) in Shenzhen, China, analyzed specific IgE (sIgE) reactivity. Adjusted odds ratios (aORs) were calculated using logistic regression (adjusted for age/sex; 2019 baseline) and E-values assessed unmeasured confounding.

**Results:** Dust mite sensitization increased significantly in 2020 (Dermatophagoides pteronyssinus/farinae aOR = 1.29\1.42, 95% CI: 1.16–1.44\1.29–1.57, both  $P < 0.001$ ), declined in 2021, and partially rebounded in 2022. Conversely, cat dander sensitization exhibited a delayed peak, rising significantly only by 2022 (aOR = 1.83, 95% CI: 1.30–2.65,  $P < 0.001$ , E-value = 3.07). German cockroach sensitization decreased by 35% in 2022 (aOR = 0.65, 95% CI: 0.54–0.78,  $P < 0.001$ , E-value = 2.26). Adolescents (6–17 years) showed heightened cat dander sensitization (2022: aOR = 2.05,  $P = 0.001$ , E-value = 3.52), while males had steeper cockroach declines (2022: aOR = 0.61,  $P < 0.001$ ). Food sensitization remained stable except wheat (aOR = 0.80,  $P = 0.005$ ).

**Conclusion:** We identify distinct allergen-specific dynamics. Dust mites acted as early-response allergens linked to confinement intensity, while cat dander emerged as delayed-response allergens likely driven by cumulative behavioral and exposure changes. Targeted environmental interventions (eg, pest control) significantly reduced cockroach sensitization. These findings advocate for allergen-tailored, time-resolved prevention strategies during public health crises, with priority protection for adolescents.

**Clinical Trial Registration:** National Medical Research Registration Information System/MR-44-24-056093.

**Keywords:** COVID-19 pandemic, allergen sensitization kinetics, allergen-specific immunoglobulin E, pediatric allergy

## Introduction

The SARS-CoV-2 pandemic has profoundly disrupted global health systems and significantly altered environmental exposures through widespread behavioral changes and public health interventions.<sup>1–3</sup> Although the direct virological impacts of COVID-19 are well characterized,<sup>4,5</sup> the pandemic's indirect effects on allergen sensitization, particularly in pediatric populations, represent a critical knowledge gap. Studies suggest that pandemic-related lifestyle alterations, such

as prolonged indoor confinement and increased pet ownership, may significantly modify sensitization risks to indoor allergens like dust mites and pet dander.<sup>6,7</sup> However, significant limitations persist in current understanding.

First, existing studies predominantly capture short-term effects during initial lockdowns,<sup>8,9</sup> lacking longitudinal analysis across distinct pandemic phases to assess evolving or cumulative impacts on exposure-sensitization relationships. Second, the temporal kinetics of sensitization development remain inadequately characterized for different allergen types, obscuring potential mechanistic variations in immune response trajectories. These knowledge gaps impede the development of evidence-based strategies for allergy mitigation during public health crises.

Shenzhen—a hyper-urbanized metropolis with 17 million residents and homogeneous infrastructure—offers a unique setting to address these questions. The city’s well-documented pandemic responses created divergent allergen exposure landscapes between 2020 and 2022. Therefore, we conducted a four-year longitudinal analysis (2019–2022) of allergen-specific IgE sensitization among 43,314 pediatric patients in Shenzhen. Our study design advances the field by comparing annual sensitization trends across pandemic phases and elucidating time-dependent kinetics for distinct allergens, specifically contrasting dust mites and cat dander.

Through stratified analysis by age, sex, and pandemic year, this investigation systematically examines how exposure alterations during public health emergencies influence pediatric allergic susceptibility. The resulting evidence provides a framework for developing dual-purpose health policies that simultaneously optimize infection control and allergy prevention.

## Materials and Methods

### Study Design and Population

We conducted a retrospective cohort study at Shenzhen Children’s Hospital, a tertiary pediatric medical center. The study analyzed allergen sIgE test results from 43,314 children (including 9093, 9832, 12991 and 11398 from 2019 to 2020) aged 0–17 years who underwent testing between January 1, 2019 and December 31, 2022.

To ensure homogeneity of the study population, we excluded records with missing key demographic information (eg name, sex, age) and excluded children older than 17 years. In addition, we excluded children with autoimmune diseases or immunodeficiencies and those on immunosuppressive therapy to avoid confounding effects on allergen sensitization patterns.

### Data Collection

Trained researchers extracted data from the hospital’s electronic health record (EHR) system using standardized case report forms. For each patient, we collected the following information: age, sex, date of IgE testing, specific allergens tested, and corresponding IgE levels. The allergens included in the analysis were selected based on their relevance to allergic diseases in the pediatric population of Shenzhen. These allergens comprised both inhalant allergens (*Dermatophagoides pteronyssinus*, *Dermatophagoides farinae*, cockroach and cat dander) and food allergens (cow’s milk, egg white, wheat and shrimp).

### Allergen sIgE Testing

Serum allergen sIgE levels were quantified using the ImmunoCAP assay (Phadia 1000, Thermo Fisher Scientific), a widely validated and standardized method for measuring IgE antibodies. Venous blood samples were collected, processed, and analyzed by trained laboratory personnel following the manufacturer’s guidelines. IgE levels were expressed in kilounits per liter (kUA/L), and a threshold of  $\geq 0.35$  kUA/L was used to define sensitization,<sup>1</sup> consistent with established clinical guidelines.

### Public Health Context

During the study period (2020–2022), Shenzhen’s public health response strategies evolved dynamically in accordance with pandemic progression. As detailed in [Table 1](#), the initial outbreak year of 2020 witnessed the implementation of

**Table 1** Annual Pandemic Characteristics, Public Health Measures, and Cockroach Control Strategies in Shenzhen (2019–2022)

Year	Pandemic Context	Key Public Health Measures
2019	No SARS-CoV-2 circulation	
2020	First-wave emergence; naive immunity	<ul style="list-style-type: none"> <li>• Citywide Community Gated</li> <li>• School closures (<math>\geq 5</math> months)</li> <li>• Mandatory quarantine</li> <li>• Large-scale nucleic acid testing</li> </ul>
2021	Vaccination rollout; Delta variant sporadic	<ul style="list-style-type: none"> <li>• Resumed outdoor activities with mask mandates</li> <li>• Targeted containment for localized outbreaks</li> </ul>
2022	OmicronBA.1/BA.2 dominance; high transmission	<ul style="list-style-type: none"> <li>• Dynamic zoning controls</li> <li>• Mass testing campaigns</li> <li>• Temporary WFH/school closures</li> </ul>

**Abbreviations:** WFH, work from home; Omicron, SARS-CoV-2 Omicron virus.

stringent city-wide non-pharmaceutical interventions (NPIs), characterized by prolonged school closures exceeding five months and rigorous home confinement mandates.

The subsequent stabilization phase in 2021 marked a transition toward more localized containment approaches while maintaining fundamental protective measures. By 2022, with the emergence of the Omicron variant, public health strategies shifted to precision interventions featuring dynamic zoning controls alongside sustained environmental management measures as officially documented by the Shenzhen Municipal Health Commission (<http://wjw.sz.gov.cn/>).

## Statistical Analysis

To assess changes in allergen sensitization rates over time, we employed a two-step analytical approach. First, we used the chi-square test to evaluate annual differences in sensitization rates for each allergen. Second, we performed logistic regression analysis to calculate aORs and their 95% confidence intervals (CIs) for each year relative to the pre-pandemic baseline (2019). The logistic regression models were adjusted for potential confounders, including pandemic years, age and sex, to isolate the impact of the COVID-19 pandemic on allergen sensitization rates.

Subgroup analyses were conducted to explore gender- and age-specific patterns in allergen sensitization. Age groups were stratified as follows: 0–2 years, 3–5 years, and 6–17 years. Gender-specific patterns were similarly evaluated. All statistical tests were two-tailed, and a P-value of  $<0.05$  was considered statistically significant.

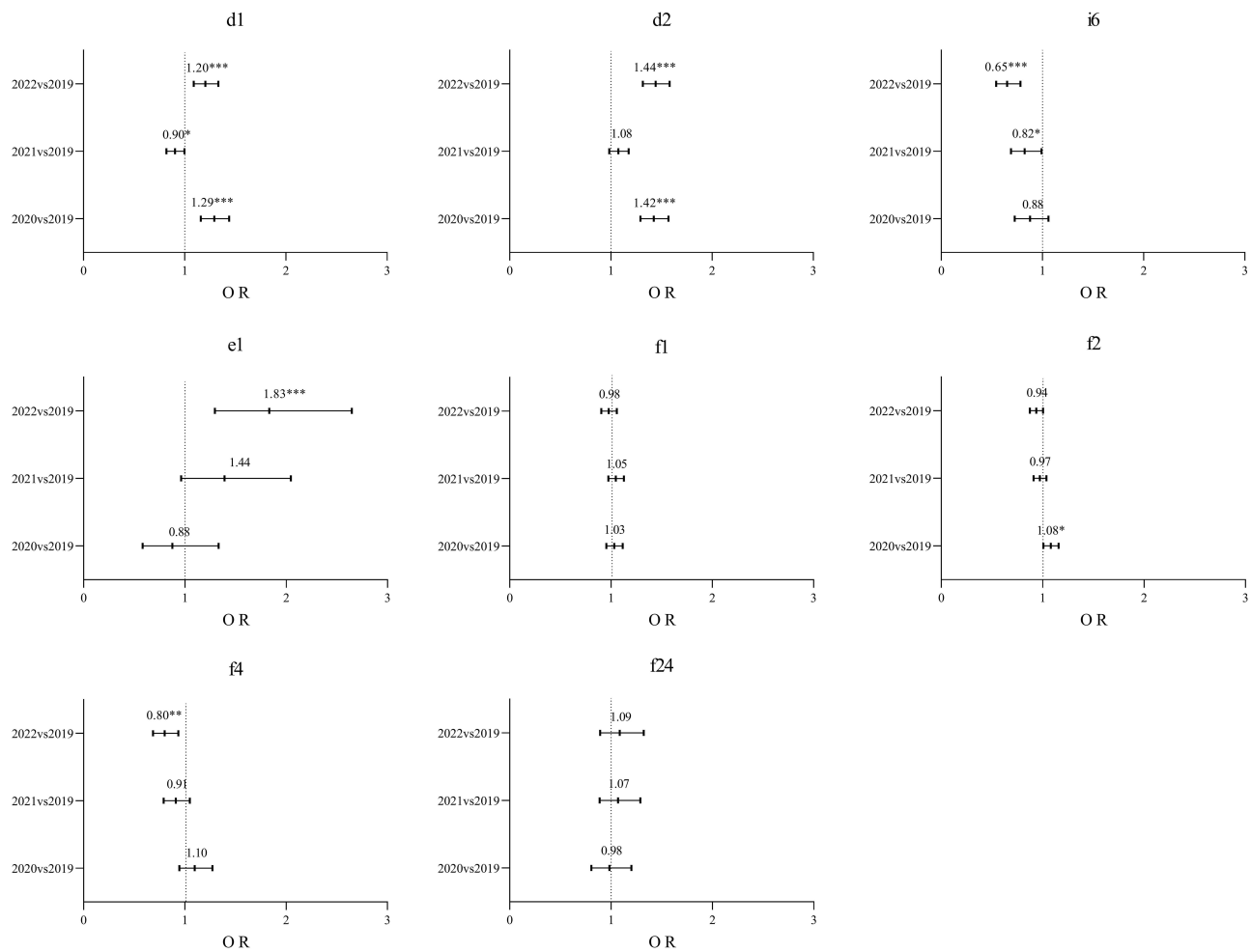
The handling of missing data was addressed as follows. Key variables in the primary analysis (age, sex, and diagnosis) were part of the standardized laboratory and demographic records. The missing rate for these fields is extremely low, below 0.5%. Given that missing data exhibits sporadic and non-systematic characteristics, any record with missing information in these key variables was excluded from the analysis.

Data processing and statistical analyses were performed using GraphPad Prism version 9.5 (GraphPad Software Inc., San Diego, CA).

E-values quantified the potential impact of unmeasured confounding on significant associations ( $P < 0.05$ ), with detailed methodology provided in [Table S1 \(Supplementary Material 1\)](#) for E-value calculation methods and formulas.<sup>10</sup>

## Ethical Considerations

The study protocol was approved by the Ethics Committee of Shenzhen Children's Hospital (Ethics Approval No. 2024092). All patient data were anonymized to protect privacy, and the study adhered to international ethical standards, including the World Medical Association's Declaration of Helsinki and relevant national regulations. Patient parental informed consent was waived by the Ethics Committee due to the retrospective nature of the study and the use of anonymized data.



**Figure 1** Adjusted Odds Ratios (aORs) for sIgE Reactivities to Allergens, Stratified by Sex and Age.

**Notes:** \* $P < 0.05$ , \*\* $P < 0.01$ , \*\*\* $P < 0.001$ .

**Abbreviations:** d1, Dermatophagoides pteronyssinus; d2, Dermatophagoides farina; i6, German cockroach; e1, cat dander; f1, egg white; f2, milk; f4, wheat; f24, shrimp; OR, odds ratios.

## Results

### Divergent Sensitization Kinetics: Dust Mites versus Cat Dander

Analysis revealed fundamentally distinct temporal patterns in sensitization to major inhalant allergens. House dust mites demonstrated early-response kinetics, while cat dander exhibited delayed escalation, as summarized in [Figure 1](#) and [Table 2](#).

**Table 2** Annual Distribution of Pediatric Patients and Allergen Sensitization Rates

	2019		2020		2021		2022	
	Total	(%)	Total	(%)	Total	(%)	Total	(%)
d1	2844	59.35	3859	66.52***	5730	56.95*	5457	66.36***
d2	3748	53.74	4397	62.68***	6158	55.85*	5638	66.50***

(Continued)

**Table 2** (Continued).

	2019		2020		2021		2022	
	Total	(%)	Total	(%)	Total	(%)	Total	(%)
i6	1401	16.00	2133	14.81	2851	13.22*	3030	11.75***
e1	630	6.51	1002	5.99	1346	8.02	1512	11.64***
f1	5262	34.93	5888	35.63	7843	36.07	6286	33.84
f2	6242	46.09	6916	48.06*	9133	45.38	7163	43.72**
f4	3347	11.11	3480	12.04	5015	10.27	3807	9.04**
f24	3246	6.28	3443	6.56	4297	7.33	3199	7.81*

Notes: \*P <0.05, \*\*P <0.01, \*\*\*P <0.001.

Abbreviations: d1, *Dermatophagoides pteronyssinus*; d2, *Dermatophagoides farinae*; i6, German cockroach; e1, cat dander; f1, egg white; f2, milk; f4, wheat; f24, shrimp.

Specifically, sensitization to *Dermatophagoides pteronyssinus* showed a significant increase in 2020 (aOR = 1.29, 95% CI: 1.16–1.44, P <0.001), followed by a decline in 2021 (aOR = 0.90, 95% CI: 0.82–1.00, P =0.044) and rebound in 2022 (aOR = 1.20, 95% CI: 1.09–1.33, P <0.001). A parallel but more pronounced trend was observed for *Dermatophagoides farinae*, which exhibited higher baseline susceptibility (2020: aOR = 1.42, 95% CI: 1.29–1.57, P <0.001), with similar annual fluctuations (Table 2). E-values for these associations ranged 1.22–1.60. In contrast, cat dander sensitization displayed minimal change during initial pandemic years (2020–2021), with significant escalation only in 2022 (aOR = 1.83, 95% CI: 1.30–2.65, P <0.001) with an E-value of 3.07, indicating that this association is robust and less likely to be explained by unmeasured confounding (see Table S1 for a complete set of E-values).

## Integrated Pest Control Efficacy

German cockroach sensitization demonstrated a progressive decline, culminating in a statistically significant 35% reduction by 2022 relative to pre-pandemic levels (aOR = 0.65, 95% CI: 0.54–0.78, P <0.001, E-value = 2.26) (Figure 1 and Table 2; the robustness of this association to potential confounding is further detailed in Table S1).

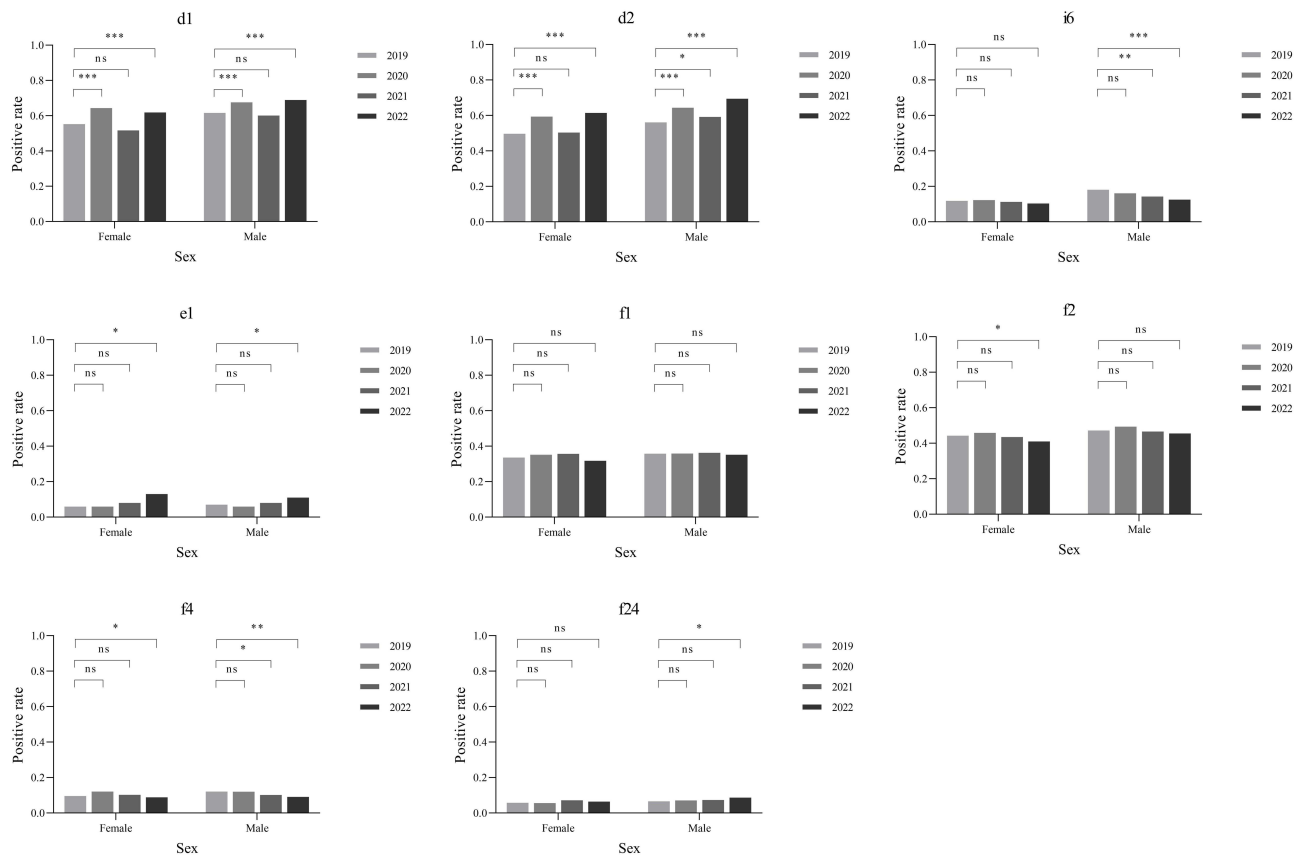
## Sex- and Age-Stratified Analyses

### Sex-Specific Patterns

Significant sex-based differentials emerged exclusively for cockroach sensitization. Males demonstrated a significant decline in 2022 (aOR = 0.61, 95% CI: 0.49–0.76, P <0.001, E-value = 2.42), whereas female rates remained stable (2022: aOR = 0.77, 95% CI: 0.55–1.09, P =0.14) (Figure 2 and Table 3; sex-stratified E-values supporting these differential associations are provided in Table S1).

### Age-Stratified Effects

Adolescents (6–17 years) demonstrated significantly heightened sensitization to inhalant allergens during the pandemic, with pronounced 2022 rebounds for both *Dermatophagoides pteronyssinus* (aOR = 1.30, 95% CI: 1.11–1.51; P =0.001, E-value = 1.33) and *Dermatophagoides farinae* (aOR = 1.43, 95% CI: 1.23–1.65; P <0.001, E-value = 1.39). Cat dander sensitization in this age group surged sharply (aOR = 2.05, 95% CI: 1.35–3.23; P =0.001, E-value = 3.52). Conversely, younger cohorts showed minimal perturbation. Infants aged 0–2 years and children aged 3–5 years exhibited stable cat dander reactivity (P >0.05), as documented in Figure 3 and Table 3, with corresponding age-stratified E-values available in Table S1.



**Figure 2** Sex-Stratified Positive Rates of sIgE Reactivities to Allergens.

**Notes:** \*P < 0.05, \*\*P < 0.01, \*\*\*P < 0.001, ns: P > 0.05.

**Abbreviations:** d1, Dermatophagoides pteronyssinus; d2, Dermatophagoides farina; i6, German cockroach; e1, cat dander; f1, egg white; f2, milk; f4, wheat; f24, shrimp.

### Food Allergens Sensitization

Sensitization to major food allergens demonstrated overall stability throughout the study period (2019–2022). However, wheat sensitization showed a statistically significant decline in 2022 (aOR = 0.80, 95% CI: 0.69–0.94, P = 0.005) relative to pre-pandemic baseline, as detailed in Figure 1 and Table 2.

**Table 3** Adjusted Odds Ratios for sIgE Reactivity to Allergens by Sex

	Year	d1			d2			i6			e1		
		OR	95% CI	P	OR	95% CI	P	OR	95% CI	P	OR	95% CI	P
Female	2020 vs 2019	1.34	1.12–1.60	0.001	1.44	1.23–1.69	<0.001	0.98	0.69–1.41	0.906	0.91	0.45–1.87	0.787
	2021 vs 2019	0.82	0.70–0.96	0.014	0.98	0.85–1.13	0.787	0.97	0.69–1.37	0.852	1.61	0.87–3.16	0.141
	2022 vs 2019	1.12	0.95–1.31	0.189	1.32	1.14–1.53	<0.001	0.77	0.55–1.09	0.140	2.06	1.16–3.90	0.019
Male	2020 vs 2019	1.27	1.11–1.46	<0.001	1.42	1.26–1.60	<0.001	0.84	0.67–1.05	0.124	0.86	0.52–1.44	0.556
	2021 vs 2019	0.96	0.85–1.09	0.546	1.14	1.02–1.23	0.025	0.77	0.62–0.96	0.020	1.28	0.81–2.07	0.298
	2022 vs 2019	1.27	1.11–1.44	<0.001	1.53	1.36–1.72	<0.001	0.61	0.49–0.76	<0.001	1.70	1.11–2.70	0.018

(Continued)

**Table 3** (Continued).

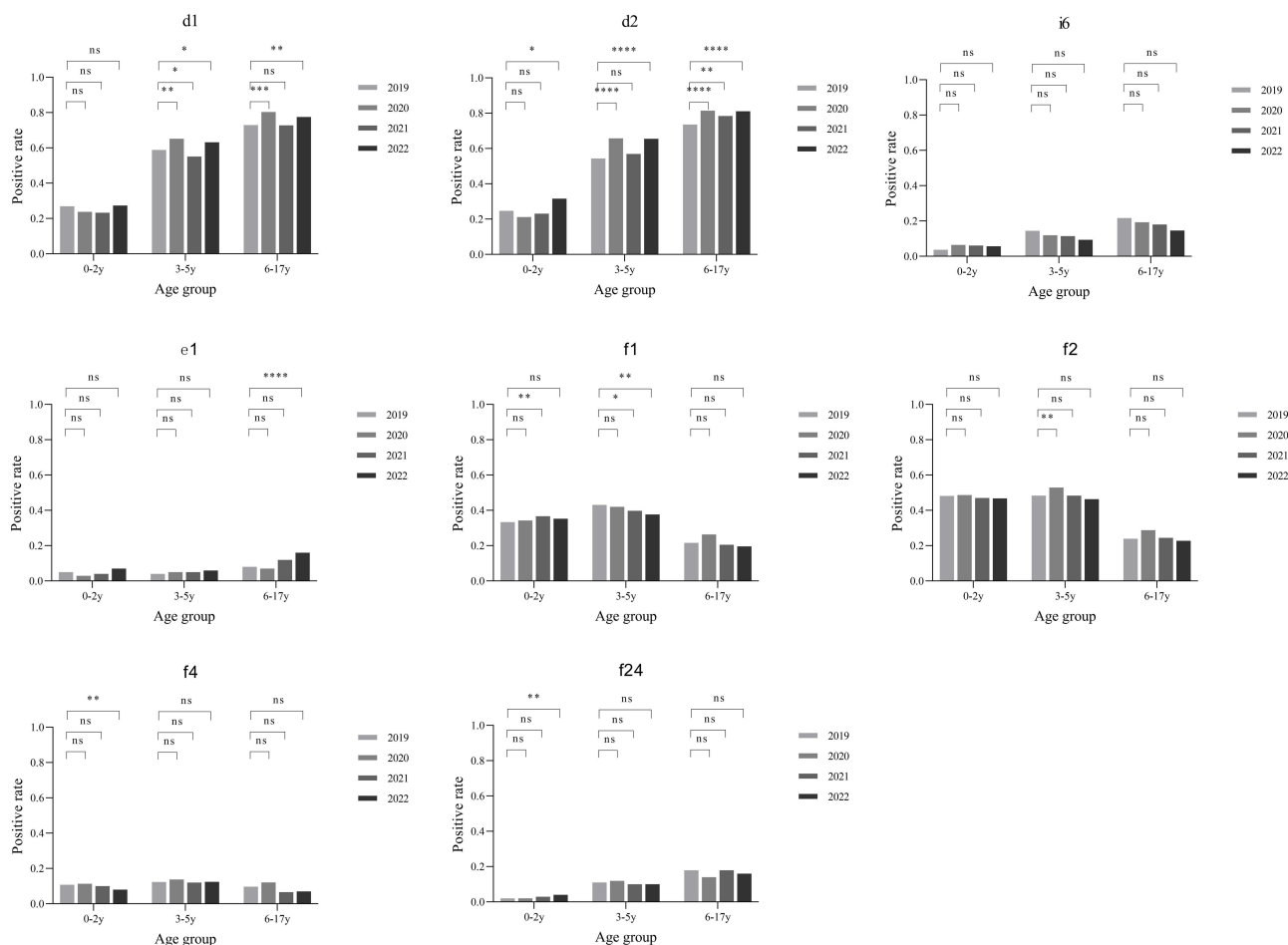
	Year	f1			f2			f4			f24		
		OR	95% CI	P	OR	95% CI	P	OR	95% CI	P	OR	95% CI	P
Female	2020 vs 2019	1.08	0.95–1.22	0.251	1.06	0.95–1.19	0.292	1.30	1.02–1.67	0.038	0.93	0.66–1.31	0.692
	2021 vs 2019	1.09	0.97–1.23	0.154	0.96	0.86–1.06	0.421	1.07	0.85–1.36	0.556	1.16	0.86–1.58	0.345
	2022 vs 2019	0.94	0.83–1.07	0.343	0.90	0.80–1.00	0.050	0.93	0.72–1.20	0.580	0.95	0.68–1.34	0.784
Male	2020 vs 2019	1.01	0.91–1.11	0.882	1.09	1.00–1.20	0.046	0.99	0.83–1.20	0.035	1.01	0.70–1.30	0.934
	2021 vs 2019	1.02	0.93–1.12	0.644	0.98	0.90–1.07	0.678	0.83	0.69–0.99	0.002	1.02	0.81–1.29	0.862
	2022 vs 2019	1.00	0.91–1.11	0.937	0.97	0.89–1.06	0.462	0.74	0.61–0.89	0.002	1.16	0.91–1.49	0.227

Notes: P for multivariate OR, adjusted for year and age. Significant differences: P <0.05.

Abbreviations: d1, *Dermatophagoides pteronyssinus*; d2, *Dermatophagoides farinae*; i6, German cockroach; e1, cat dander; f1, egg white; f2, milk; f4, wheat; f24, shrimp.

## Discussion

Our longitudinal cohort study provides the first reliable evidence of dynamic differences in allergic reactions to major indoor allergens across different stages of a major public health crisis. Key findings include a significant increase in dust



**Figure 3** Age-Specific Positive Rates of sIgE Reactivities to Allergens.

Notes: \*P <0.05, \*\*P <0.01, \*\*\*\*P <0.0001, ns: P >0.05.

Abbreviations: d1, *Dermatophagoides pteronyssinus*; d2, *Dermatophagoides farinae*; i6, German cockroach; e1, cat dander; f1, egg white; f2, milk; f4, wheat; f24, shrimp.

mite sensitization, a delayed peak in cat dander sensitization, and a significant reduction in cockroach sensitization through integrated pest management.

## Annual Variations in Indoor Allergen Sensitization

Our longitudinal analysis demonstrates that dust mite sensitization dynamics exhibited temporally concordant fluctuations with pandemic policy shifts. The 2020 sensitization surge reflects intense allergen exposure during stringent lockdowns, while the 2021 decline aligns with temporary restriction easing, demonstrating partial reversibility upon reduced exposure. This dose-dependent pattern culminated in the 2022 rebound during Omicron containment. These temporal patterns align with but extend beyond 2021 cross-sectional reports of increased dust mite sensitivity during lockdowns providing new insights into the dynamic nature of allergic sensitization across consecutive years of pandemic conditions.<sup>9</sup>

This pattern supports a dose-response relationship between indoor exposure duration and sensitization risk, potentially mediated through multiple pathways including increased allergen load in home environments and Der p 1-induced epithelial barrier disruption.<sup>11–13</sup> The partial reversibility observed in 2021 suggests that allergic responses maintain some plasticity when environmental exposures decrease.

Our study elucidates a dose-response pattern whereby public health interventions influence allergic disease risk by altering indoor environmental exposures. Notably, this indoor environment-mediated health effect mechanism may extend beyond allergic disease outcomes. A recent multicenter study indicates that under the same pandemic context, similar household factors—such as inadequate ventilation and indoor humidity—also significantly determine children’s risk of COVID-19 infection.<sup>14</sup> This convergence of evidence positions the indoor environment as a critical mediator of children’s health during epidemics, simultaneously influencing risk trajectories for both allergic and infectious diseases. Therefore, prioritizing indoor environmental quality as a core public health intervention target may emerge as an effective strategy for addressing future multidimensional health crises.

## Divergent Sensitization Kinetics and Their Public Health Implications

The COVID-19 pandemic revealed heterogeneity in cat dander sensitization patterns that challenge conventional exposure-response paradigms. Our longitudinal analysis identified a delayed sensitization peak in 2022 that contrasts with both the immediate dust mite response and existing literature reports.<sup>15–17</sup> This temporal dissociation from the documented 130% (the proportion of cat owners in Shenzhen increased from 2% in 2019 to 4.6% in 2020) surge in cat ownership during in 2020 (China Pet Industry White Paper) suggests a complex immunological mechanism modulated by exposure timing and dose.<sup>18,19</sup>

To reconcile these discrepancies, we propose a hypothesis regarding possible immunological mechanisms. Early high-dose exposure in pet-owning households may induce IgG4 antibody production, promoting tolerance (particularly in young children,  $P > 0.05$ ). This potential mechanism is consistent with the “modified Th2 response” to cat allergen exposure described by Platts-Mills et al, whereby high-dose exposure can lead to a distinct antibody profile (IgE<sup>+</sup>/IgG4<sup>+</sup>) associated with reduced clinical asthma risk.<sup>20,21</sup> Community-level low-dose dissemination post-lockdown likely sensitized previously unexposed children through shared spaces such as schools.

The robustness of these findings to unmeasured confounding is supported by high E-values ( $>2.50$ ; see [Table S1](#)), which makes residual bias an unlikely explanation. These findings carry important public health implications. The observed delayed sensitization suggests that early pet exposure during lockdowns may have been protective, while the gradual reopening of society potentially posed new risks. Targeted allergen reduction measures in shared spaces such as schools could help mitigate sensitization during pandemic recovery periods.

## Integrated Pest Control as a Model for Policy Synergy

The 35% reduction in German cockroach sensitization by 2022 contrasts markedly with global reports documenting increases of cockroach sensitization during the same period,<sup>9,22</sup> highlighting the uniqueness of our findings in the context of international trends. This decline demonstrates temporal and functional concordance with Shenzhen’s integrated pest management initiative (2021–2022).

Municipal documentation confirms program implementation (Shenzhen Municipal Health Commission, <https://wjw.sz.gov.cn/>). The robustness of this association is evidenced by its resistance to confounding (E-value = 2.26) and allergen specificity (no parallel declines in mite/cat dander sensitization) (Full E-value details are provided in [Table S1](#)). This exemplifies how policy-driven vector management may achieve population-level allergy prevention during public health crises.

## Demographic Tailoring of Allergy Prevention

Adolescents (6–17 years) exhibited significantly heightened sensitization to cat dander in 2022 possibly due to greater independent mobility post-lockdown and puberty-related immune changes.

A striking gender disparity emerged in cockroach sensitization: males demonstrated a 39% risk reduction by 2022, possibly linked to androgen-mediated IgE suppression.<sup>23</sup> Whereas females showed no significant change. This divergence underscores the necessity for demographically tailored prevention strategies-prioritizing adolescent pet allergen monitoring and gender-specific environmental interventions.

The demographic and allergen-specific dynamics described above resonate with and significantly expand upon a growing body of evidence. Our findings expand upon a growing body of evidence documenting the impact of pandemic-related behavioral and environmental changes on the trajectory of allergic diseases. For instance, several studies reported increased sensitization to house dust mites during strict lockdowns,<sup>6,9</sup> while sensitization to pets, particularly cats, has shown complex and evolving patterns.<sup>7,15</sup> Furthermore, clinical studies have observed significant shifts in the incidence and exacerbation of childhood allergic diseases.<sup>17</sup> Our study adds a critical layer of novelty and complexity to this evolving narrative by revealing divergent temporal kinetics across allergen types. We demonstrate an early surge for dust mites versus a delayed peak for cat dander, challenging simplistic assumptions about exposure-response relationships and pointing to distinct underlying immunological mechanisms.

Moreover, our observation that policy-driven integrated pest management was associated with a significant decline in cockroach sensitization adds a crucial positive dimension to this picture. It demonstrates that targeted environmental interventions can effectively modify allergy risk profiles even during a global health crisis, providing actionable insights for future public health policy. By situating our findings within this broader context, we underscore the urgency for adopting differentiated strategies. Future public health preparedness and response frameworks must concurrently consider infectious disease control and non-communicable disease prevention, devising precise interventions tailored to allergen type and local circumstances to avoid inadvertently exacerbating the long-term allergic burden while managing immediate infectious threats.

## Limitations and Future Directions

When interpreting our findings, three interrelated limitations warrant consideration. First, the urban-centric focus on Shenzhen, a hyper-urbanized metropolis with advanced public health infrastructure, limits generalizability to rural or socioeconomically diverse regions. This geographical bias, combined with single-center hospital-based recruitment, may overrepresent severe atopy cases while underrepresenting vulnerable populations (eg, low-income households), potentially compromising population-level inference validity. Second, methodological constraints in exposure assessment and temporal resolution persist, particularly the absence of quantitative environmental monitoring (eg, Fel d 1/Der p 1 quantification) and sub-annual data granularity. Third, despite adjustment for core demographics, residual confounding from unmeasured variables remains plausible, including household income gradients, building ventilation efficiency, flooring materials, and pet co-sleeping frequency-factors particularly relevant for complex pathways like community allergen transmission.

Future research should be conducted through multi-center collaborations across different geographical (urban and rural) and socioeconomic settings to enhance the generalizability of research findings. Standardized environmental monitoring methods should be integrated to comprehensively assess exposure levels, thereby establishing precise exposure indicators and dose-response relationships. Monitoring of the IgE/IgG4 ratio should be conducted to gain a deeper understanding of differences in sensitization kinetics.

These advancements will not only strengthen causal inference but also directly guide the development of public health strategies in future crises. Our findings, based on large sample sizes and robust E-values, have demonstrated the value of differentiated strategies: rapid intervention measures (such as HEPA filters and acaricides) for allergens like dust mites, and phased strategies for delayed-onset allergens like pet dander. Future emergency preparedness efforts should integrate these allergen-specific temporal patterns into dynamic guidelines, addressing both infection control and allergy prevention while adapting to local housing characteristics, pest management infrastructure, and pet ownership trends.

## Conclusion

Our longitudinal study has for the first time revealed heterogeneous sensitization dynamics driven by pandemic intervention measures. We identified distinct temporal pathways. Dust mites triggered an immediate sensitization peak during strict lockdowns, while cat dander exhibited a delayed peak associated with cumulative behavioral adaptation. Crucially, comprehensive environmental intervention measures significantly reduced sensitization levels for specific allergens. These findings establish a novel allergen differentiation framework for public health strategies: spatiotemporally resolved interventions targeting acute and delayed sensitization dynamics; population-based protection strategies prioritizing vulnerable groups; and policy coordination approaches combining environmental management with pandemic control. Based on the aforementioned research findings, we propose the following actionable clinical practice recommendations: Implement differentiated primary prevention strategies by providing households with allergen-specific risk guidance: Strengthen dust mite control during periods of indoor confinement (eg, using acaricides and HEPA filters), while advocating for early and sustained exposure to pets within the home to mitigate the risk of delayed-onset allergies among adolescents upon their return to community settings. This paradigm addresses a fundamental gap in pandemic preparedness-mitigating the incidence of both infectious and allergic diseases through precise exposure regulation.

## Declaration of Generative AI in Scientific Writing

In the process of writing this paper, AI (Deepseek-R1) tools were used solely to enhance readability and language expression. All content has been rigorously reviewed, edited, and verified by the authors.

## Acknowledgments

The authors would like to express their sincere gratitude to the clinical laboratory team at Shenzhen Children's Hospital for their meticulous work in sample processing and IgE testing. We would also like to extend our sincere thanks to all the children and families who participated in this study for their trust in us during this public health crisis.

## Funding

Guangdong High-Level Hospital Construction Fund.

## Disclosure

The author(s) report no conflicts of interest in this work.

## References

1. Han E, Tan MMJ, Turk E, et al. Lessons learnt from easing COVID-19 restrictions: an analysis of countries and regions in Asia Pacific and Europe. *Lancet*. 2020;396(10261):1525–1534. doi:10.1016/S0140-6736(20)32007-9
2. Witter S, Thomas S, Topp SM, et al. Health system resilience: a critical review and reconceptualisation. *Lancet Glob Health*. 2023;11(9):e1454–e1458. doi:10.1016/S2214-109X(23)00279-6
3. Herbstman JB, Romano ME, Li X, et al. Characterizing changes in behaviors associated with chemical exposures during the COVID-19 pandemic. *PLoS One*. 2023;18(1):e0277679. doi:10.1371/journal.pone.0277679
4. Proal AD, VanElzakker MB, Aleman S, et al. SARS-CoV-2 reservoir in post-acute sequelae of COVID-19 (PASC). *Nat Immunol*. 2023;24(10):1616–1627. doi:10.1038/s41590-023-01601-2
5. Carvajal JJ, Garcia-Castillo V, Cuellar SV, et al. New insights into the pathogenesis of SARS-CoV-2 during and after the COVID-19 pandemic. *Front Immunol*. 2024;15:1363572.
6. Karavaizoglu C, Suleyman A, Dolu KO, et al. Different aspects of COVID-19: “stay at home” increased cat and mite sensitivity in preschool children. *Pediatr Pulmonol*. 2025;60(1):e27422. doi:10.1002/ppul.27422

7. Evcen R, Çölkesen F, Yıldız E, et al. Increasing prevalence of sensitization to cat/dog allergens in the COVID-19 pandemic. *Int Arch Allergy Immunol.* 2024;185(2):133–141. doi:10.1159/000534173
8. He W, Li J, Hu L, Li J, Li Y, Li Y. Impact of the COVID-19 pandemic and lockdown measures on clinical visits and subjective symptoms in childhood allergic rhinitis induced by house dust mites in Shanghai. *BMC Public Health.* 2024;24(1):3088. doi:10.1186/s12889-024-20561-2
9. Li Y, Hu H, Zhang T, et al. Increase in indoor inhalant allergen sensitivity during the COVID-19 pandemic in South China: a cross-sectional study from 2017 to 2020. *J Asthma Allergy.* 2021;14:1185–1195. doi:10.2147/JAA.S322034
10. Trinquart L, Erlinger AL, Petersen JM, Fox M, Galea S. Applying the E value to assess the robustness of epidemiologic fields of inquiry to unmeasured confounding. *Am J Epidemiol.* 2019;188(6):1174–1180. doi:10.1093/aje/kwz063
11. Ogi K, Ramezanpour M, Liu S, et al. Der p 1 disrupts the epithelial barrier and induces IL-6 production in patients with house dust mite allergic rhinitis. *Front Allergy.* 2021;2:692049. doi:10.3389/falgy.2021.692049
12. Wan H, Winton HL, Soeller C, et al. Der p 1 facilitates transepithelial allergen delivery by disruption of tight junctions. *J Clin Invest.* 1999;104(1):123–133. doi:10.1172/JCI5844
13. Huss K, Adkinson NF, Eggleston PA, Dawson C, Van Natta ML, Hamilton RG. House dust mite and cockroach exposure are strong risk factors for positive allergy skin test responses in the childhood asthma management program. *J Allergy Clin Immunol.* 2001;107(1):48–54. doi:10.1067/mai.2001.111146
14. Lu C, Ma J, Qiao Z, et al. Early-life indoor environmental exposures and COVID-19 outcomes in Chinese preschool children: a secondary analysis of a multicenter study. *J Hazard Mater.* 2025;496:139445. doi:10.1016/j.jhazmat.2025.139445
15. Yildirim G, Gunes BN, Caliskan N, et al. The impact of the pandemic on cat and dog allergies. *Sisli Etfal Hastan Tip Bul.* 2024;58(2):159–164. doi:10.14744/SEMB.2024.93797
16. Li X, Li T, Chen N, Wang X, Yang J, Bi L. Influence of COVID-19 pandemic on inhaled allergens in children with allergic diseases, Henan, China. *J Med Virol.* 2023;95(1):e28409. doi:10.1002/jmv.28409
17. Ye Q, Wang B, Liu H. Influence of the COVID-19 pandemic on the incidence and exacerbation of childhood allergic diseases. *J Med Virol.* 2022;94(4):1655–1669. doi:10.1002/jmv.27536
18. 2019 China pet industry white paper (Consumption Report). 2019. Available from: [https://www.petdata.cn/reportdetail\\_31.html](https://www.petdata.cn/reportdetail_31.html). Accessed November 03, 2025.
19. 2020 China pet industry white paper (Consumption Report). 2020. Available from: [https://www.petdata.cn/login.html?redirect=reportdetail\\_25.html](https://www.petdata.cn/login.html?redirect=reportdetail_25.html). Accessed November 03, 2025.
20. Platts-Mills T, Vaughan J, Squillace S, Woodfolk J, Sporik R. Sensitisation, asthma, and a modified Th2 response in children exposed to cat allergen: a population-based cross-sectional study. *Lancet.* 2001;357(9258):752–756. doi:10.1016/S0140-6736(00)04168-4
21. Platts-Mills TA, Keshavarz B, Wilson JM, et al. High risk of asthma among early teens is associated with quantitative differences in mite and cat allergen specific IgE and IgG4: a modified Th2 related antibody response revisited. *EBioMedicine.* 2025;112:105556. doi:10.1016/j.ebiom.2024.105556
22. Evcen R, Çölkesen F, Yıldız E, Sadi Aykan F, Kılınc M, Arslan Ş. Impact of the COVID-19 pandemic on cockroach allergy: a 4-year retrospective study. *Int Arch Allergy Immunol.* 2024;185(11):1066–1073. doi:10.1159/000539321
23. Chen W, Mempel M, Schober W, Behrendt H, Ring J. Gender difference, sex hormones, and immediate type hypersensitivity reactions. *Allergy.* 2008;63(11):1418–1427. doi:10.1111/j.1398-9995.2008.01880.x

Journal of Asthma and Allergy

Publish your work in this journal

The Journal of Asthma and Allergy is an international, peer-reviewed open-access journal publishing original research, reports, editorials and commentaries on the following topics: Asthma; Pulmonary physiology; Asthma related clinical health; Clinical immunology and the immunological basis of disease; Pharmacological interventions and new therapies. The manuscript management system is completely online and includes a very quick and fair peer-review system, which is all easy to use. Visit <http://www.dovepress.com/testimonials.php> to read real quotes from published authors.

Submit your manuscript here: <https://www.dovepress.com/journal-of-asthma-and-allergy-journal>

**Dovepress**  
Taylor & Francis Group