He et al. BMC Public Health (2024) 24:3088
https://doi.org/10.1186/s12889-024-20561-2

BMC Public Health

RESEARCH

Open Access

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

Wenjun He[1†], Junyang Li[1†], Lanye Hu[1], Yabin Hu[2], Jing Li[3*] and Youjin Li[1,4*]

Abstract

Background Establishing the interaction between aeroallergens and air pollution in children with house dust mite induced allergic rhinitis (HDM-AR) remains challenging, especially in urban areas. The coronavirus disease 2019 (COVID-19) pandemic and the subsequent lockdown measures provided a valuable opportunity.

Methods We analyzed the clinical data of HDM-AR children between March and August in 2018–2020, and classified the children according to the type and the degree of HDM sensitization. The records of patients' hospital visits, allergic rhinitis symptoms assessments, and air pollution measurements in Shanghai were used to assess the differences before (2018–2019) and during the pandemic (2020), as well as during lockdown (March-June) and unlockdown (July-August) period in 2020.

Results The study included 1570 HDM-AR children aged 2 to 8 years old, 815 (51.9%) were monosensitized to HDM (mono-HDM-AR), and 755 (48.1%) were polysensitized to HDM (poly-HDM-AR). There was a significant increase in the rate of clinical visits among children with HDM-AR during the COVID-19 pandemic compared to pre-pandemic ($P<0.001$), particularly among older children aged 7–8 years ($P=0.01$). During the unlockdown period, there was a notable decrease in clinical visits for children with poly-HDM-AR ($P<0.001$). Children with high levels of HDM sensitization exhibited significant symptom improvement in unlockdown period ($P<0.001$). Although the air pollutants concentration had improved during the study, there was no effect on the improvement of HDM-AR children as expected.

Conclusions The COVID-19 pandemic and its associated lockdown measures provided a unique context to observe the dynamics of management in children with HDM-AR. The findings underscore the complexity of managing allergic conditions in pediatric populations, highlighting the influence of environmental and lifestyle changes on disease presentation and the need for tailored approaches to treatment during periods of societal disruption.

Keywords Allergic rhinitis, House dust mite, COVID-19, Lockdown, Children

†Wenjun He and Junyang Li contributed equally to this work.

*Correspondence:
Jing Li
zzhlq3@qq.com
Youjin Li
kevinliyoujin@outlook.com
Full list of author information is available at the end of the article

Background

Allergic rhinitis (AR) is a non-infectious inflammatory disease of the nasal mucosa, primarily mediated by immunoglobulin E (IgE) in atopic individuals exposed to allergens [1]. Symptoms of AR include nasal congestion, runny nose, sneezing, and nasal itching, impacting the quality of life in this population [2, 3]. It has increasingly become a worldwide health concern affecting people of all ages, with a notable surge in its prevalence among children in recent years [4]. AR adversely affects social life and school performance, particularly in children with severe symptoms, imposing substantial time and economic burdens on their families [5].

The rising prevalence of AR appears to be closely linked to environmental factors [6]. While exposure to indoor and outdoor allergens constitutes a recognized risk factor for AR development, indoor allergens could induce more severe airway allergic phenotypes [7]. House dust mite (HDM) is the most common aeroallergen in Shanghai. The predominant species are *Dermatophagoides pteronyssinus* (67.86%) and *Dermatophagoides farina* (68.75%) [8]. The ARIA (Allergic Rhinitis and its Impact on Asthma) guideline recommends allergen avoidance as a key treatment principle, although implementing this approach can be challenging [9].

Although the use of face masks and low air pollution emissions resulting due to COVID-19 lockdowns have been proposed as having the potential benefit of decreasing symptom severity in patients with AR, the prevalence of AR children still increased [10, 11]. Recent epidemiological studies show that the COVID-19 pandemic has had a negative influence on the clinical symptoms of patients sensitized to HDM, which supports the important pathogenic role of indoor aeroallergens in AR development [12–14]. During the initial wave of the pandemic, the social distancing measures were implemented for a period of 4 months, from March to June 2020, to mitigate the frequency of upper respiratory tract infections. This time frame provided a valuable opportunity to investigate the impact of air quality and lifestyle factors on pediatric populations with allergies.

Methods

Study population

Clinical data of patients with nasal complaints who visited the otolaryngology outpatient department at Shanghai Children's Medical Center from March to August 2018–2020 were systematically collected. We retrospectively analyzed the clinical data and recruited children between the ages of 2 and 8 with a diagnosis of AR and sensitized to HDM (HDM-AR). The principal diagnostic classification of HDM-AR was made based on Allergic Rhinitis and its Impact on Asthma (ARIA) guideline [15].

The medical records of the patients comprised their age, gender, visit data, and blood allergy tests, were used to assess the differences before (2018–2019) and during the pandemic (2020), as well as during lockdown (March-June) and unlockdown (July-August) period in 2020. The types of aeroallergens, including HDM, molds, cat/dog dander, pollens, and cockroaches, were identified through ImmunoCAP IgE assays (Thermo Fisher Scientific/Phadia, Shanghai, China). Based on the quantified serum-specific IgE (sIgE) levels, sensitization to HDM was categorized as low-level when HDM sIgE level < 50 kUA/L and high-level when HDM sIgE level ≥ 50 kUA/L.

Monosensitiezed to house dust mite was categorized as mono-HDM-AR and polysensitized to HDM and other allergens was categorized as poly-HDM-AR. Specifically, poly-HDM-AR was characterized by the presence of HDM-specific IgE in conjunction with other allergen-specific IgE.

We conducted telephone follow-up with the parents of children with HDM-AR. We limited the recall period to less than three months before the interview, as shorter recall periods have been shown to reduce bias. The primary criterion for selection was the representation of diverse HDM sensitization profiles (mono-HDM-AR vs. poly-HDM-AR) to a balanced representation of children with different symptom severities and varying levels of HDM sensitization. We excluded children with other chronic respiratory diseases (e.g., asthma) to minimize confounding factors that could influence symptom assessment. Additionally, children with incomplete medical records or those who did not participate in any follow-up activities during the study period were excluded from the analysis. To control for potential biases, we accounted for socioeconomic status, living conditions (e.g., ventilation at home), and any concurrent medication use that could affect symptom reporting. A questionnaire of 14 inquiries was administered during the follow-up process, with a focus on evaluating allergies in the children during two separate periods: the period of lockdown (March-June) and the subsequent period of unlockdown (July-August) in 2020. Parents responded to the questions based on Rhinitis Control Assessment Test (RCAT) and Visual Analog Scale (VAS), which were employed to assess nasal symptoms and the subjective severity of those symptoms.

Assessment of AR severity

Subjective severity of HDM-AR was evaluated utilizing a pre-defined VAS ranging from 0 to 10. The evaluation of nasal symptom severity was conducted using the RCAT with scores ranging from 0 (no symptoms) to 5 (very frequent). The assessment comprised six items that surveyed the children's impairment during the previous seven days, including symptoms of nasal congestion, sneezing, watery eyes, sleep disorders, avoiding exposure to allergens, and allergic symptom control. In this way, we obtained RCAT and VAS scores from primary caregivers of children via phone survey, recorded from March to August 2020.

Collection of air pollution data

Air pollution data for Shanghai between 2018 and 2020 were collected from the China National Environmental Monitoring Centre website (http://www.cnemc.cn/). The accumulated data included hourly concentrations of fine particulate matter, categorized by diameters equal to or less than 2.5 μm ($PM_{2.5}$) and 10 μm or less (PM_{10}), along with data on sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and ozone (O_3), obtained from a monitoring station. Subsequently, we computed daily and monthly concentrations for these pollutants using valid measurements for at least 18–24 h per day.

Statistical analysis

Chi-square (χ^2) tests were used to evaluate the differences between categorical variables, such as clinical visit rates before and during the pandemic, with the null hypothesis being that there is no significant difference between the groups. Wilcoxon rank-sum tests were applied to continuous variables (e.g., symptom scores), under the null hypothesis that there is no significant difference in the distribution of these variables across different groups. For the analysis of clinical visit frequency, the Poisson regression model was employed, as the daily number of clinic visits followed a Poisson distribution. The null hypothesis for this model was that the regression coefficients for predictors (e.g., time periods, age, type of sensitization) were equal to zero, meaning they did not affect the clinical visit rate. This method provided more robust and convergent coefficients due to the nature of the data distribution [16]. We introduced the Distributed Lag Nonlinear Model (DLNM) to account for the potential lagged effects of air pollutants on HDM-AR symptoms. This model included a lag term to capture the delayed impact of air pollution on clinical symptoms. The null hypothesis in the significance testing of regression coefficients was that air pollutants had no delayed effect on the clinical symptoms of HDM-AR children [17]. The t-test was used for hypothesis testing of these coefficients. The final multivariable model was as follows:

log E(Yt) = α + as.factor(dow) + as.factor(holiday) + ns(time, df/year) + cb(Tmean) + cb(air pollutant).

The model was developed according to previous studies [18]. All analyses were conducted using IBM SPSS version 25 (IBM Corp., Armonk, NY, USA), GraphPad Prism software version 9 (GraphPad Software, San Diego, CA, USA), and R version 3.6.3 (The R Project for Statistical Computing, Vienna, Austria). The statistical significance level was set at P-value < 0.05 (two-tailed).

Results

Clinical visits characteristics of children with HDM-AR: a pre- and during COVID-19 pandemic analysis

Our study focused on a cohort of 1570 children with HDM-AR aged 2–8 years. Of these, 1031 (65.7%) were male and 539 (34.3%) were female. Among these AR children, 815 (51.9%) were monosensitiezed to HDM (mono-HDM-AR), and 755 (48.1%) were polysensitized to HDM (poly-HDM-AR). As shown in Table 1, we analyzed the disparities in clinical visits among children with HDM-AR, taking into consideration variables such as gender, age, and the degree of sensitization. No significant difference was observed based on gender for children with HDM-AR before and during the pandemic. However, there was a marked increase in monthly clinical visits for older children aged 7–8 years during the pandemic (P = 0.01). Compared to children with poly-HDM-AR, the clinical visit rate increased significantly during the pandemic in children with mono-HDM-AR (P = 0.001). The clinical visit rate showed no marked difference in the low- and

Table 1 Clinical characteristics of HDM-AR patients before (2018–2019) and during (2020) the COVID-19 pandemic in the Otolaryngology outpatient department

Variables	2018–2019 group (N = 957, n/N%)	2020 group (N = 613, n/N%)	P	P_1
Gender, n (n/N%)				
Boy	624 (65.2%)	407 (66.4%)	0.598	
Girl	333 (34.8%)	206 (33.6%)		
Age, n (n/N%)				
2 ≤ age < 7	695 (72.6%)	408 (66.6%)	**0.01**	
7 ≤ age ≤ 8	262 (27.4%)	205 (33.4%)		
Type and degree of HDM sensitization, n (n/N%)				**0.001**
mono-HDM	479 (50.1%)	336 (59.7%)		
Low-level	423 (88.3%)	293 (87.2%)	0.634	
High-level	56 (11.7%)	43 (12.8%)		
poly-HDM	478 (49.9%)	277 (40.3%)		
Low-level	441 (92.3%)	233 (84.1%)	**0.001**	
High-level	37 (7.7%)	44(15.9%)		

Bold indicates P < 0.05, *HDM-AR* allergic rhinitis induced by house dust mite (HDM), *mono-HDM*, allergic rhinitis induced only by house dust mite, *poly-HDM* allergic rhinitis induced by house dust mite and other coexisting inhaled allergens, *Low-level* HDM sIgE < 50 kUA/L, *High-level* HDM sIgE ≥ 50 kUA/L, P comparison between 2018–2019 group and 2020 group, P_1-value, comparison between mono-HDM and poly-HDM high- level subgroups of children with mono-HDM-AR. However, among children with poly-HDM-AR, the clinical visit rate significantly increased during the pandemic in the high-level subgroup compared to low-level subgroup ($P=0.001$). Thus, the effect of the pandemic seemed to be more pronounced in children with high-level poly-HDM-AR.

Difference in monthly clinical visit rate for HDM-AR children before and during pandemic periods

We further analyzed the monthly clinical visit records for these children in two distinct time frames: before the COVID-19 pandemic (2018–2019) and during the COVID-19 pandemic (2020). As shown in Fig. 1, among children presenting nasal complaints at the otolaryngology outpatient department, there was a significant increase ($P<0.005$) in the clinical visits rate of HDM-AR children during the pandemic compared to the period before the COVID-19 pandemic. The increased clinical visit rate was evident both during the periods with (March-June) and without (July-August) lockdown measures in 2020. Interestingly, during the unlockdown period, a sudden, notable decline in the proportion of clinical visits among children with HDM-AR was observed.

Difference in monthly clinical visit rate for mono- and poly-HDM-AR children before and during pandemic periods

In addition, Fig. 1 also display the results of subgroup analyses on the monthly visit rate among children with HDM-AR. Analysis of each group individually revealed that, the proportion of clinical visit significantly increased among children with mono-HDM-AR during the period without lockdown ($P<0.001$, $P=0.031$) compared to the corresponding months in 2018–2019. Conversely, clinical visit rate decreased significantly during the same period in children with poly-HDM-AR. Children with poly-HDM-AR seems to be the key factor responsible for the downward trend in clinical visits among all children with HDM-AR. Tables S1 present the monthly clinical visits for children with mono- and poly- HDM-AR in detail.

Subgroup analyses of HDM-AR children by phone survey during periods with and without lockdown

The follow-up phone interviews included a smaller subsample of 100 children to gather in-depth qualitative insights and assess their experiences during the lockdown period. Analysis of nasal symptoms in children with low-level ($n=50$) and high-level ($n=50$) HDM-AR revealed significant differences between periods with and without lockdown. As shown in Fig. 2a and b, when compared to children with low-level HDM-AR, those with high-level HDM-AR exhibited more

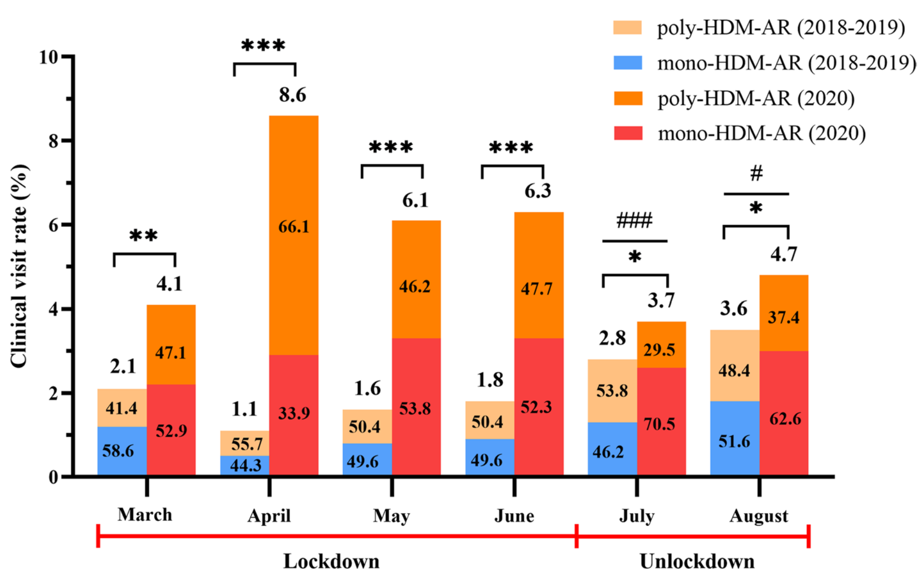

Fig. 1 Clinical visits rate of mono- and poly- HDM-AR children before (2018–2019) and during (2020) the COVID-19 pandemic. Note:* indicates the comparison of HDM-AR between before (2018-2019) and during (2020) the COVID-19 pandemic; *$P<0.05$, **$P<0.01$, ***$P<0.001$. # manifests the comparison of poly-HDM-AR between before (2018-2019) and during (2020) the COVID-19 pandemic; #$P<0.05$, ###$P<0.001$. HDM-AR, allergic rhinitis induced by house dust mite; poly-HDM-AR, allergic rhinitis induced by house dust mite and other coexisting inhaled allergens; mono-HDM-AR, allergic rhinitis induced only by house dust mite. clinical visit rate, proportion of HDM-AR children among patients presenting nasal complaints in the outpatient

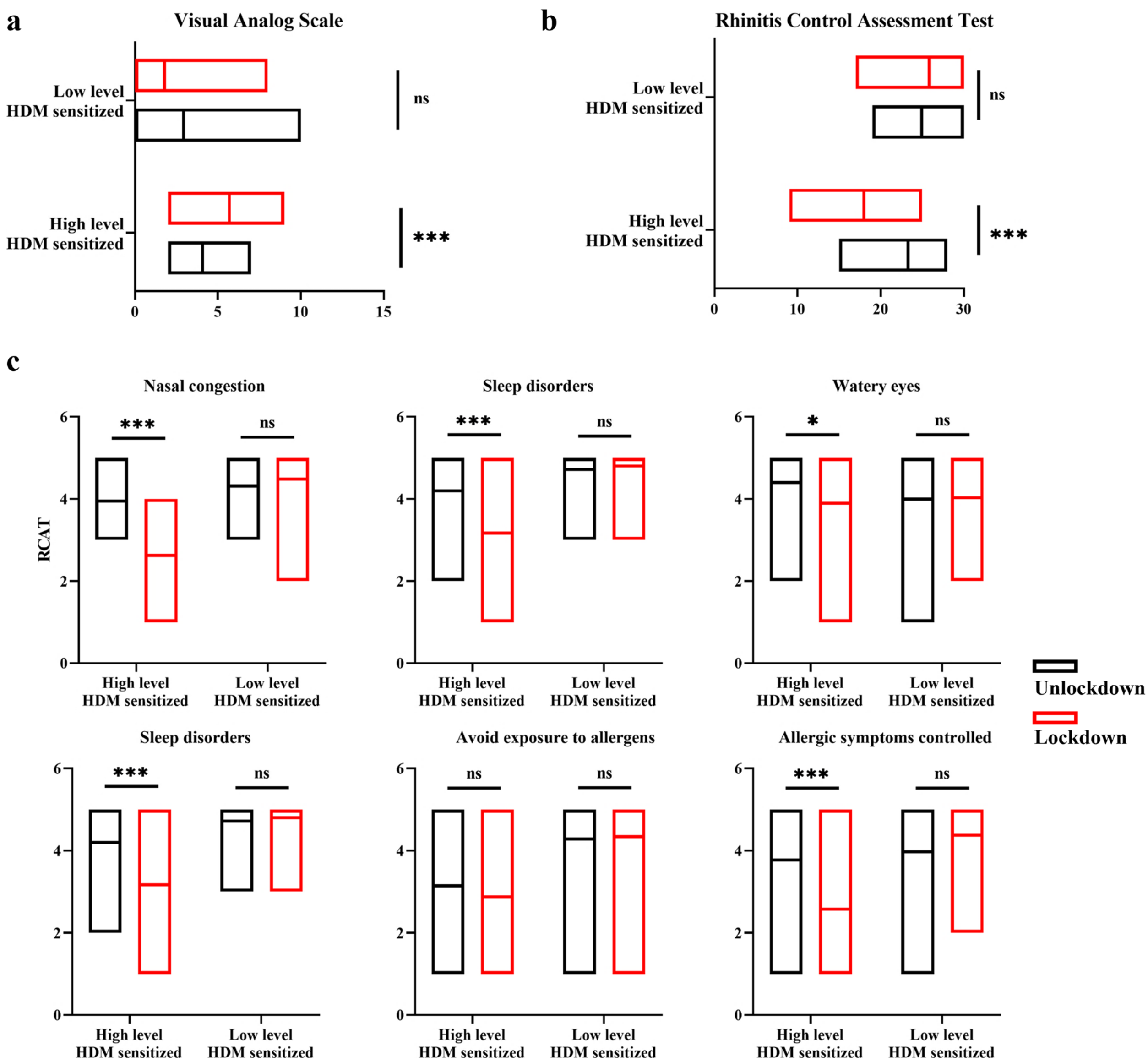

Fig. 2 Comparison of nasal symptoms assessments between low-level and high-level HDM-AR children during lockdown and unlockdown in 2020. Note Asterisk indicates statistical significance. * $P<0.05$. *** $P<0.001$. HDM, house dust mite; RCAT, Rhinitis control assessment test

severe symptoms, as indicated by increased VAS and decreased total RCAT scores during the lockdown ($P<0.001$). We evaluated the impact of lockdown on the severity of each nasal symptom (nasal congestion, sneezing, watery eyes, sleep disorders, avoid exposure to allergens, and allergy symptoms control) using RCAT (Fig. 3c). Each symptom was significantly worse in children with high-level HDM-AR during the lockdown ($P<0.001$, $P<0.001$, $P=0.02$, $P<0.001$, not significant, $P<0.001$, respectively). There was no significant difference between children with low- and high-level HDM-AR avoiding exposure to allergens, which may be attributed to the mandatory lockdown measures.

Figure S1a illustrates a comparison of VAS and total RCAT between 100 follow-up children with mono-sensitization (42%) and poly-sensitization (58%) to HDM during lockdown and unlockdown period in 2020. Compared to poly-HDM-AR children, mono-HDM-AR children did not exhibit significant improvement in VAS scores or RCAT total scores during and after the lockdown period. However, mono-HDM-AR children had significantly higher VAS scores and significantly lower RCAT scores than those with multiple allergies. According to

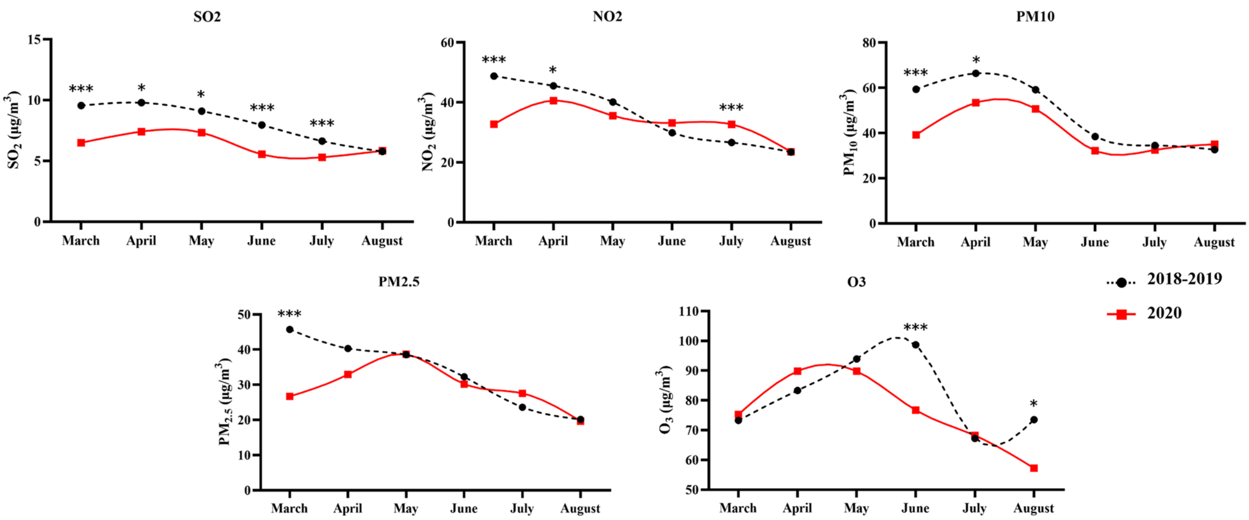

Fig. 3 Monthly outdoor air quality values of Shanghai between the same periods of 2018–2019 and 2020. Note Asterisk indicates statistical significance. * $P<0.05$. *** $P<0.001$. Abbreviations: SO 2 , sulfur dioxide; NO 2 , nitrogen dioxide; PM 10 , coarse particulate matter measuring 2.5 to 10 µm; PM 2.5 , particulate matter measuring under 2.5 µm; O 3 , ozone

each nasal symptom score (Figure S1b), mono-HDM-AR children significantly improved in nasal congestion, sneezing, and sleep disorders during unlockdown period ($P<0.05$, $P<0.01$, $P<0.01$), while poly-HDM-AR children significantly improved in nasal congestion and sleep disorders ($P<0.05$, $P<0.05$).

Difference in monthly outdoor air quality values in Shanghai before and during the COVID-19 pandemic

Overall, a noteworthy enhancement in the quality of outdoor air was observed during the pandemic in Shanghai, as compared to the corresponding periods in 2018–2019. As shown in Fig. 3, it is apparent that the average monthly SO_2 values were markedly lower during the pandemic (from March to August 2020) in comparison to the corresponding months in 2018–2019 ($P<0.001$, $P=0.032$, $P=0.013$, $P<0.001$, $P<0.001$, not significant, respectively). Likewise, for NO_2 and PM10 concentrations, the average monthly levels in March and April 2020 were significantly reduced in contrast to the same months in 2018–2019 (NO_2: $P<0.001$, $P=0.021$; PM10: $P<0.001$, $P=0.042$, respectively). Furthermore, PM2.5 concentrations in March ($P<0.001$) and O_3 concentrations ($P<0.001$) in June exhibited substantial improvements. Tables S2 present the monthly air pollutants values in detail.

Spearman correlation and relative risk between outdoor air quality and HDM-AR during the COVID-19 pandemic in 2020

Analysis of correlation between air pollutants and childhood HDM-AR in 2020 is thoroughly outlined in Table S3. A Spearman correlation coefficient of 0.07 ($P<0.05$) was found between HDM-AR and PM_{10}, but no significant association was discovered between HDM-AR and the other air pollutants. A subgroup analysis for air pollutants was conducted among children with HDM-AR from March to August 2020, aiming to assess the effects of SO_2, NO_2, PM_{10}, $PM_{2.5}$, and O_3 on daily clinical visits of children with HDM-AR (Figure S2). The results indicated that none of these pollutants exhibited a statistically association with an increased risk of clinical visits among HDM-AR children. The daily distribution of air pollutants from March to August in 2018–2020 is illustrated in Figure S3.

Discussion

AR is the most common chronic inflammatory disease and is affected by complex interactions among genetic, environmental, and lifestyle factors [19]. In recent years, AR has become more prevalent in childhood and adolescence, with substantial health impacts on the quality of life as it is associated with numerous complications and comorbidities [20]. Comprehensive management of AR encompasses education, environmental control, immunotherapy, and pharmacologic treatment. Pharmacotherapy is an effective treatment of choice for moderate to severe disease, and immunotherapy is an appropriate choice when AR symptoms are driven by specific allergens [21]. Despite these strategies, the first step in managing AR is avoiding or minimizing exposure to allergens, which may effectively reduce symptoms of AR. However, avoidance strategies are often challenging for polysensitized patients as it is difficult to eliminate all possible allergens or triggers [22]. During the first wave of the COVID-19 pandemic, lockdown measures (from March to June 2020) implemented by the Shanghai government effectively reduced the frequency of upper respiratory tract infections. However, children were required to stay at home for long periods, with continued exposure to indoor allergens during lockdown periods because HDM is the primary source of indoor allergens [23].

Our results showed that the monthly rate of clinical visits for childhood HDM-AR significantly increased during the pandemic. Consistent with our findings, other studies have proposed that continuous indoor allergen exposure markedly worsens rhinitis symptoms in asthmatic HDM-sensitized patients with AR [14]. It is noteworthy that the rate of clinical visits primarily increased among older children (aged 7–8 years) as opposed to younger children (aged 2–6 years). The exact reason for this difference is unclear, but we speculate that it might be attributable to the rapid development of the immune system in the former age group [24]. Kulig et al. reported that early symptoms of allergic rhinitis are non-specific, and the increased prevalence in older children may be linked to longer exposure to allergens [25]. Childhood AR is usually a persistent and progressive disease, and the prevalence of AR increases from 5.4% at age 4 years to 14% at age 8 years [26]. Once an allergy develops, symptoms usually persist into adulthood, and symptoms of AR develop before the age of 20 years in 80% of patients [27]. In addition, most children with HDM-AR (61.0%) are boys; but the sex ratio of clinical visit had no statistically significant difference before versus during the COVID-19 pandemic. According to David P, boys with AR outnumber girls in childhood, but the affected numbers are equal during adulthood [28].

When lockdown measures were implemented, children were forced to spend all their time at home, which would increase exposure to indoor allergens such as HDM, molds, and pet al.lergens. According to our caseload, during the period with no lockdown measures, the visit rate among patients with poly-HDM-AR decreased significantly, whereas this rate among patients with mono-HDM-AR increased significantly. Our telephone follow-up results revealed that children with mono-HDM-AR experienced significantly higher nasal symptom scores during the lockdown period compared to those with poly-HDM-AR. We hypothesize that children with mono-HDM-AR may have been more severely affected by indoor dust mite allergens due to their single allergen sensitivity. In contrast, children with poly-HDM-AR might have been less affected due to their sensitization to multiple allergens, potentially benefitting more from reduced exposure to outdoor allergens during lockdowns. According to a report by Miller, inflammation and Th2 polarization caused by HDM can lead to a cascade of spreading sensitization to other allergens and aggravation of polysensitized airway inflammation [29]. It is noteworthy that the visit rate of children with high-level poly-HDM-AR was significantly higher than that in the low-level group. This means that the additional impact of HDM may aggravate airway inflammation in polysensitization, which is consistent with the conclusions of Bousquet et al. that compared with monosensitization, polysensitization may increase the risk of allergic comorbidity and may be associated with more severe symptoms [30].

To diagnose allergic diseases and assess the severity of symptoms, it is important to use the combination of the patient's medical history, clinical findings, and testing for relevant allergens [31]. In our study, compared with low-level HDM-AR, the nasal symptoms of children with high-level HDM-AR were significantly worse during the lockdown period. Allergic symptoms in patients with HDM are associated with HDM allergen levels in their homes [32]. However, a limitation of the present study was that we could not measure the concentration of indoor allergens and indoor pollutants in the homes of participating children with HDM-AR owing to the pandemic. In urban areas, indoor pollution may have increased correspondingly with the increase in indoor activities during lockdown, such as smoking and cooking.

In addition to indoor allergens, outdoor air pollutants also negatively affect respiratory health [33]. Although, wearing masks not only effectively reduces the concentration of inhaled airborne allergens but also increases the temperature and humidity of the breathed air to improve AR symptoms [34]. However, breathing "cleaner" air with fewer pollutants may paradoxically worsen symptoms in allergic individuals. This could be due to an increased exposure to purified allergens in the absence of airborne pollutants that typically reduce allergen bioavailability [35]. This may be the reason why the clinical visit rate for HDM-AR still increased even though air quality had improved obviously in 2020.

This study has several limitations. First, the cases were selected from a single hospital, and our study focused on younger children (aged 2–8 years) since AR often begins in early childhood, and this age range may not fully represent the broader spectrum of children affected by HDM-AR, particularly older children. Future research should aim to include a more diverse age range to better capture the full spectrum of AR presentation and management across different developmental stages. Second, we were unable to measure HDM allergen levels within the homes of the children in this study. Due to significant variability in family living environments—such as differences in ventilation, cleaning practices, and housing conditions—it was challenging to standardize data collection on indoor allergen exposure. This limitation underscores the need for future studies to incorporate real-time indoor allergen monitoring, which could provide more accurate insights into the relationship between allergen exposure and clinical symptoms. Third, measurement bias may have occurred, as the observed reduction in outdoor air pollution during the study period does not necessarily reflect individual-level exposure. Indoor air can contain various pollutants, including tobacco smoke, cooking fumes, and emissions from solid fuels used for heating, all of which may influence AR symptoms but was not directly accounted for in our analysis [36]. A more comprehensive assessment of both outdoor and indoor air quality would be beneficial for future research. Finally, psychological and environmental factors, such as increased parental anxiety during the COVID-19 pandemic or changes in household conditions (e.g., prolonged indoor exposure to HDM allergens), may have contributed to the rise in clinical visits. While our study did not explicitly focus on these factors, they likely played a role in the observed patterns of healthcare utilization. Future studies should consider incorporating psychological assessments and more detailed environmental analyses to better understand their impact on AR management during periods of societal disruption.

Conclusion

In summary, persistent exposure to indoor allergens may have worsened the symptoms of HDM-AR among children during the COVID-19 pandemic, especially in older children (aged 7–8 years). In HDM-AR, rhinitis symptoms were markedly worsened in children with high-level sensitization during lockdown whereas patients with poly-HDM-AR improved significantly during the period with no lockdown. Compared with outdoor air pollutants, indoor allergy interventions and activities outside of the home are important.

Abbreviations

AR	Allergic rhinitis
HDM	House dust mite
HDM-AR	Allergic rhinitis induced by house dust mite
COVID-19	The coronavirus disease 2019
mono-HDM-AR	Allergic rhinitis induced only by house dust mite
poly-HDM-AR	Allergic rhinitis induced by house dust mite and other coexisting inhaled allergens
RCAT	Rhinitis Control Assessment Test
VAS	Visual Analog Scale
sIgE	Specific IgE
SO_2	Sulfur dioxide
NO_2	Nitrogen dioxide
PM_{10}	Coarse particulate matter measuring 2.5 to 10 µm
$PM_{2.5}$	Particulate matter measuring under 2.5 µm
O_3	Ozone

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-024-20561-2.

Supplementary Material 1.

Acknowledgements

We would like to thank Shanghai Children's Medical Center, China National Environmental Monitoring Centre for providing hospital and environmental data.

Authors' contributions

YL and JL were responsible for the conception and design of the study. JL carried out the statistical analysis. WH wrote the initial draft of the manuscript. LH and YH performed bioinformatics analysis. All authors (1) provided substantial contributions to the conception or design of the work, or the acquisition, analyzing and interpreting of the data for the work, (2) revised the manuscript critically for important intellectual content and (3) approved the final version for submission.

Funding

This study was supported by a grant from Chinese National Natural Science Foundation [82071015], the Science and Technology Commission of Shanghai Municipality [21Y11900200], and a grant from Shanghai Pudong New Area Health Commission [PW2022D-07].

Data availability

The data that support the findings in this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

Ethical approval for this study was obtained from the Ethics Committee of Shanghai Children's Medical Center (approval number: SCMCIRB-Y2020100) prior to data collection. Given that the clinical data were de-identified and aggregated, written informed consent was not required. No personal identifying information was collected at any point during the study, ensuring full compliance with ethical guidelines for patient privacy and data protection.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Otolaryngology, Shanghai Children's Medical Center, School of Medicine, Shanghai Jiao Tong University, Shanghai, China. [2]Key Laboratory of Public Health Safety, Ministry of Education, School of Public Health, Fudan University, Shanghai 200032, China. [3]Department of Neonatology, Shanghai First Maternity and Infant Hospital, School of Medicine, Tongji University, Shanghai 200092, China. [4]Department of Otolaryngology, Hainan Branch, Shanghai Children's Medical Center, School of Medicine, Shanghai Jiao Tong University, Sanya, China.

Received: 10 July 2024 Accepted: 29 October 2024
Published online: 08 November 2024

References

1. Bousquet J, Khaltaev N, Cruz AA, et al. Allergic Rhinitis and its impact on Asthma (ARIA) 2008 update (in collaboration with the World Health Organization, GA(2)LEN and AllerGen). Allergy. 2008;63(Suppl 86):8–160.
2. Barr JG, AL-Reefy H, Fox A T, et al. Allergic rhinitis in children [J]. BMJ, 2014, 349: g4153.

3. Greiner AN, Hellings PW, Rotiroti G, et al. Allergic Rhinitis. Lancet. 2011;378(9809):2112–22.
4. Schuler IVCF, Montejo JM. Allergic rhinitis in children and adolescents. Pediatr Clin North Am. 2019;66(5):981–93.
5. Bousquet J, Schunemann HJ, Samolinski B, et al. Allergic Rhinitis and its impact on Asthma (ARIA): achievements in 10 years and future needs. J Allergy Clin Immunol. 2012;130(5):1049–62.
6. Zhang Y, Lan F. Advances and highlights in allergic rhinitis. Allergy. 2021;76(11):3383–9.
7. Eguiluz-Gracia I, Mathioudakis AG, Bartel S, et al. The need for clean air: the way air pollution and climate change affect allergic rhinitis and asthma. Allergy. 2020;75(9):2170–84.
8. Zheng M, Wang X, Wang M, et al. Clinical characteristics of allergic rhinitis patients in 13 metropolitan cities of China. Allergy. 2020;76(2):577–81.
9. Brozek JL, Bousquet J, Baena-Cagnani C E, et al. Allergic Rhinitis and its impact on Asthma (ARIA) guidelines: 2010 revision. J Allergy Clin Immunol. 2010;126(3):466–76.
10. Dror AAEN, Marshak T, Layous E, Zigron A, Shivatzki S, Morozov NG, Taiber S, Alon EE, Ronen O, Zusman E, Srouji S, Sela E. Reduction of allergic rhinitis symptoms with face mask usage during the COVID-19 pandemic. J Allergy Clin Immunol Pract. 2020;8(10):3590–3. https://doi.org/10.1016/j.jaip.2020.08.035. Epub 2020 Sep 2. PMID: 32889221; PMCID: PMC7467086.
11. Dayal AK, Sinha V. Trend of allergic rhinitis post COVID-19 pandemic: a retrospective observational study. Indian J Otolaryngol Head Neck Surg. 2022;74(1):50–2.
12. Brindisi G, De Vittori V, De Nola R et al. Updates on children with allergic Rhinitis and Asthma during the COVID-19 outbreak. J Clin Med, 2021, 10(11):2278.
13. Perez-Herrera LC, Ordonez-Ceron S, Moreno-Lopez S, et al. Impact of the COVID-19 national lockdown in the allergic rhinitis symptoms in patients treated with immunotherapy at two allergy referral centers in Bogota, Colombia. Laryngoscope Investig Otolaryngol. 2022;7(2):305–15.
14. Yucel E, Suleyman A, Hizli Demirkale Z, et al. Stay at home': is it good or not for house dust mite sensitized children with respiratory allergies? Pediatr Allergy Immunol. 2021;32(5):963–70.
15. Lee C H, Jang J H, Lee HJ et al. Clinical characteristics of allergic Rhinitis according to allergic Rhinitis and its impact on Asthma guidelines. Clin Exp Otorhinolaryngol. 2008;1(4):196–200.
16. Zheng JYL, Wang B, Li Y, Zhang L, Xue B, Tian X, Lei R, Luo B. Seasonal characteristics of ambient temperature variation (DTR, TCN, and TV0-t) and air pollutants on childhood asthma attack in a dry and cold city in China. Environ Res. 2023;217:114872.https://doi.org/10.1016/j.envres.2022.114872. Epub 2022 Nov 23. PMID: 36435499
17. Zhang Y, Ni H, Bai L, Cheng Q, Zhang H, Wang S, Xie M, Zhao D. The short-term association between air pollution and childhood asthma hospital admissions in urban areas of Hefei City in China: a time-series study. Environ Res. 2019;169:510–6. https://doi.org/10.1016/j.envres.2018.11.043 Epub 2018 Dec 1. PMID: 30544078.
18. Li J, Hu Y, Li H, et al. Assessing the impact of air pollutants on clinical visits for childhood allergic respiratory disease induced by house dust mite in Shanghai, China. Respir Res. 2022;23(1):48.
19. Anto JM, Bousquet J, Akdis M, et al. Mechanisms of the development of Allergy (MeDALL): introducing novel concepts in allergy phenotypes [J]. J Allergy Clin Immunol. 2017;139(2):388–99.
20. We B. Allergic rhinitis in children : diagnosis and management strategies. Paediatr Drugs. 2004;6(4):233–50.
21. Scadding GK, Kariyawasam HH, Scadding G, et al. BSACI guideline for the diagnosis and management of allergic and non-allergic rhinitis (Revised Edition 2017; First edition 2007). Clin Exp Allergy. 2017;47(7):856–89.
22. Bousquet J, Anto JM, Bachert C, et al. Allergic rhinitis. Nat Rev Dis Primers. 2020;6(1):95.
23. Gandhi VD, Davidson C, Asaduzzaman M, et al. House dust mite interactions with airway epithelium: role in allergic airway inflammation [J]. Curr Allergy Asthma Rep. 2013;13(3):262–70.
24. Wise SK, Lin SY, Toskala E, et al. International consensus statement on allergy and rhinology: allergic rhinitis. Int Forum Allergy Rhinol. 2018;8(2):108–352.
25. Kulig M, Klettke U. Development of seasonal allergic rhinitis during the first 7 years of life. J Allergy Clin Immunol. 2000;106(5):832–9.
26. Westman M, STJäRNE P, Asarnoj A, et al. Natural course and comorbidities of allergic and nonallergic rhinitis in children. J Allergy Clin Immunol. 2012;129(2):403–8.
27. Roditi RE, Shin JJ. The influence of age on the relationship between allergic rhinitis and otitis media. Curr Allergy Asthma Rep. 2018;18(12):68.
28. Skoner DP. Allergic rhinitis: definition, epidemiology, pathophysiology, detection, and diagnosis. J Allergy Clin Immunol. 2001;108(1 Suppl):S2–8.
29. Miller JD. The role of dust mites in allergy. Clin Rev Allergy Immunol. 2019;57(3):312–29.
30. Bousquet J, Anto JM, Wickman M, et al. Are allergic multimorbidities and IgE polysensitization associated with the persistence or re-occurrence of foetal type 2 signalling? The MeDALL hypothesis. Allergy. 2015;70(9):1062–78.
31. Ansotegui IJ, Melioli G, Canonica GW, et al. IgE allergy diagnostics and other relevant tests in allergy, a World Allergy Organization position paper. World Allergy Organ J. 2020;13(2):100080.
32. Zuiani C. Update on house dust mite allergen avoidance measures for asthma. Curr Allergy Asthma Rep. 2020;20(9):50.
33. Nordeide Kuiper I, Svanes C, Markevych I, et al. Lifelong exposure to air pollution and greenness in relation to asthma, rhinitis and lung function in adulthood. Environ Int. 2021;146:106219.
34. Dror AA, Eisenbach N, Marshak T, et al. Reduction of allergic rhinitis symptoms with face mask usage during the COVID-19 pandemic. J Allergy Clin Immunol Pract. 2020;8(10):3590–3.
35. Gallo O, Bruno C, Orlando P, et al. The impact of lockdown on allergic rhinitis: what is good and what is bad? Laryngoscope Investig Otolaryngol. 2020;5(5):807–8.
36. Gallo O, Bruno C. Global lockdown, pollution, and respiratory allergic diseases: are we in or are we out? J Allergy Clin Immunol. 2020;146(3):542–4.

Publisher's Note