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BRIEF RESEARCH REPORT

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Pollen exposures in pregnancy and early life are associated with childhood asthma incidence

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ABSTRACT

Background: Pollen exposure is an environmental risk factor for asthma symptoms and allergic reactions in children. The extent to which pollen exposure in pregnancy and the first year of life influences the development of childhood asthma and rhinitis is not fully understood.

Objective: We aimed to investigate early life exposures to pollen with childhood asthma and rhinitis at age 6 in a longitudinal birth cohort of the United Kingdom.

Methods: In this retrospective cohort study, via logistic regressions, we analyzed the associations between pollen exposures in pregnancy and the first year of life with childhood asthma and rhinitis.

Results: Higher pollen exposure accumulated during pregnancy and during the first year of life both associated with an increased odds of asthma at age 6 (OR = 1.14, 95% CI 1.03–1.26, p = 0.01; OR = 1.15, 95% CI 1.03–1.29, p = 0.02, respectively). We did not observe statistically significant associations between early life pollen exposures and the odds of rhinitis at the same age.

Conclusion: High pollen exposure during early life (prenatal and postnatal) associated with an increased risk of asthma incidence at age 6. Further studies are desired to validate these findings and to elucidate the mechanisms of early life exposures to pollen on asthma etiology.

Keywords: Pollen, Pregnancy, Early life, Childhood asthma, Rhinitis

INTRODUCTION

Childhood asthma is a major non-communicable disease of the lungs that commonly presents with cough, shortness of breath, and wheezing. Evidence indicates that acute exposure to pollen can trigger and exacerbate allergic and asthmatic symptoms in asthmatic and non-asthmatic children.[1] Some studies also demonstrate associations between birth in a pollen season and risk of asthma and allergic rhinitis.[2–4] Other studies note that high

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levels of pollen exposure during pregnancy may increase the risk of allergic sensitization or asthma hospitalizations.[5,6]

However, none of these studies examine the individual and joint impacts of early life pollen exposures (prenatal and postnatal) on asthma development in children. The primary aim of this study was to examine the association between pollen exposures during these critical periods and the risk of childhood asthma at age 6 years. Given that pollen exposure is a well-accepted risk factor of rhinitis, as a secondary aim, we also evaluated its association with such exposures.

MATERIALS AND METHODS

Population cohort and data collection

The Isle of Wight birth cohort (IOWBC) consists of 3 generations (F0, F1, and F2), all studied for the past 3 decades on the natural history, prevalence, and risk and protective factors for allergic diseases and asthma. This report is based on offspring born from 2010-present (F2-generation, N = 611) who were followed at ages 3 and 6 months and 1, 2, 3, and 6 years. Standardized questionnaires were used to collect information on demographics, clinical outcomes such as asthma and rhinitis, and related risk factors. Additional details on data collection are available in Supplemental File 1.1.

Pollen exposures

Measurements of daily pollen counts of 12 tree/plant genera (*Corylus*, *Alnus*, *Salix*, *Betula*, *Fraxinus*, *Ulmus*, *Quercus*, *Platanus*, *Gramineae*, *Urtica*, *Artemisia*, and *Ambrosia*) occurred between March 1, 1992, and August 27, 2012. A Burkard Volumetric Spore Trap was used to collect airborne particles of pollen. Two definitions of pollen exposure measurement are used in our study: 1) sum of pollen counts and 2) number of days with high pollen counts $\geq$31 g/m^3. More related details are in Supplemental File 1.2.

Statistical analyses

Descriptive statistics are displayed for study variables, stratified by sex. Differences between sex are examined using Chi-square tests (Table 1). The means of cumulative pollen counts in pregnancy and in the first year of life are compared by sex using two-sample t tests (Supplemental Table 1). We investigated associations between prenatal and postnatal pollen exposures and asthma at age 6 using logistic regressions from the SAS procedure PROC LOGISTIC. For rhinitis, generalized linear mixed models with repeated measures were applied with parameters estimated using generalized estimating equations. The SAS procedure PROC GENMOD was applied for this purpose with link function glogit, which estimated odds ratios of rhinitis at ages 2, 3, and 6 years from pollen exposures with no rhinitis as the reference group. The joint impact of prenatal and postnatal pollen exposures was further analyzed to determine the odds of developing asthma or rhinitis, separately. Details on evaluating the joint impacts of pollen exposures and adjusted models are presented in Supplemental File 1.3.

RESULTS

Overall characteristics of study subjects

Characteristics of study subjects (N = 443) are summarized in Table 1. A small fraction of mothers reported a physician diagnosis of asthma or wheezing (14.95%) and smoked during pregnancy (20.77%). Such proportions were not statistically different between sexes ($p > 0.05$). The prevalence of asthma diagnosed at age 6 was 7.45%, consistent with established findings on childhood asthma prevalence.[7]

Turning to rhinitis, a large proportion of mothers had a history of rhinitis during pregnancy (45.67%). Overall, the prevalence of children to ever having rhinitis increased from 15.14% at age 2–20.16% at age 6. Boys accounted for a larger proportion of rhinitis diagnoses at such years, consistent with the predominance of allergic rhinitis in boys.[8]

Sum of pollen counts and high pollen days ($\geq$31 g/m^3)

Though statistically insignificant, more days (prenatal and postnatal) of high pollen exposure were observed among girls, consistent with the statistics for the sum of pollen counts (Supplemental Table 1, $p > 0.05$). A weak correlation was observed between sum of pollen

Variable	Description	Overall (N = 443)	Boys (N = 235)	Girls (N = 208)	*p*-value[a]
		n (%)	n (%)	n (%)	
Covariates					
Maternal asthma/wheeze	Yes	58 (14.95)	32 (15.31)	26 (14.53)	0.83
	No	330 (85.05)	177 (84.69)	153 (85.47)	
Paternal asthma	Yes	98 (31.82)	53 (32.12)	45 (31.47)	0.90
	No	210 (68.18)	112 (67.88)	98 (68.53)	
Maternal rhinitis	Yes	190 (45.67)	91 (41.36)	99 (50.51)	0.06
	No	226 (54.33)	129 (58.64)	97 (49.49)	
Smoking[b]	Prenatal	65 (20.77)	37 (22.16)	28 (19.18)	0.56
	Postnatal	26 (8.31)	12 (7.19)	14 (9.59)	
	Pre&Postnatal	27 (8.63)	17 (10.18)	10 (6.85)	
	Neither	195 (62.30)	101 (60.48)	94 (64.38)	
Animal exposure	Yes	293(80.72)	156 (80.83)	137 (80.59)	0.95
	No	70 (19.28)	37 (19.17)	33 (19.41)	
Birth order	1st child	211 (48.28)	112 (48.28)	99 (48.29)	0.42
	2nd child	152 (34.78)	76 (32.76)	76 (37.07)	
	3rd child	55 (12.59)	30 (12.93)	25 (12.20)	
	4th child	15 (3.43)	11 (4.74)	4 (1.95)	
	5th child	4 (0.92)	3 (1.29)	1 (0.49)	
Clinical Outcomes					
Childhood asthma (6 years)	Yes	33 (7.45)	20 (8.51)	13 (6.25)	0.37
	No	410 (92.55)	215 (91.49)	195 (93.75)	
Rhinitis (2 years)	Yes	38 (15.14)	22 (16.67)	16 (13.45)	0.48
	No	213 (84.86)	110 (83.33)	103 (86.55)	
Rhinitis (3 years)	Yes	37 (15.55)	21 (17.07)	16 (13.91)	0.50
	No	201 (84.45)	102 (82.93)	99 (86.09)	
Rhinitis (6 years)	Yes	26 (20.16)	14 (22.22)	12 (18.18)	0.57
	No	103 (79.84)	49 (77.78)	54 (81.82)	

Table 1. Demographics, clinical data, and potential covariates for study cohort (N = 443). *[a]p-values are for comparisons between boys and girls. [b]Smoking: "Prenatal" denotes exposure to maternal smoking during pregnancy, "Postnatal" denotes exposure of second-hand smoking in the first year of life, "Pre&Postnatal" means exposure to smoke during both periods, prenatal and postnatal*

counts in the prenatal and postnatal periods (Supplemental Fig. 1, $R^2 = 0.1446$, $p < 0.0001$).

Pollen exposures of childhood asthma and rhinitis

We examined associations of pollen exposures assessed by sum of pollen counts and number of days with high pollen counts ≥ 31 g/m^3 with the status of childhood asthma and rhinitis, respectively, adjusted for maternal risk factors (smoking asthma/wheeze status, and rhinitis status), infant exposures (passive smoke and animal exposures), and characteristics of F2-offspring (gender and birth order). Exposure to cumulative pollen counts during pregnancy and during the first year of life significantly increased the odds of childhood asthma at age 6 (OR = 1.14, 95% CI 1.03–1.26, $p = 0.01$; OR = 1.15, 95% CI 1.03–1.29, $p = 0.02$, respectively, Fig. 1).

When examining the joint impact of pollen exposures, we found that high cumulative pollen exposures in both life periods contributed to a substantially elevated risk of asthma (OR = 8.30, 95% CI 1.68–40.94, $p = 0.01$, Fig. 1), but not high exposures in 1 period only. When measuring pollen exposure using the number of days with high pollen counts, we did not identify statistically significant associations with asthma, adjusting for maternal asthma and other confounders ($p > 0.05$; Supplemental Table 2).

We further performed a sensitivity analysis to assess the impact of paternal asthma on the

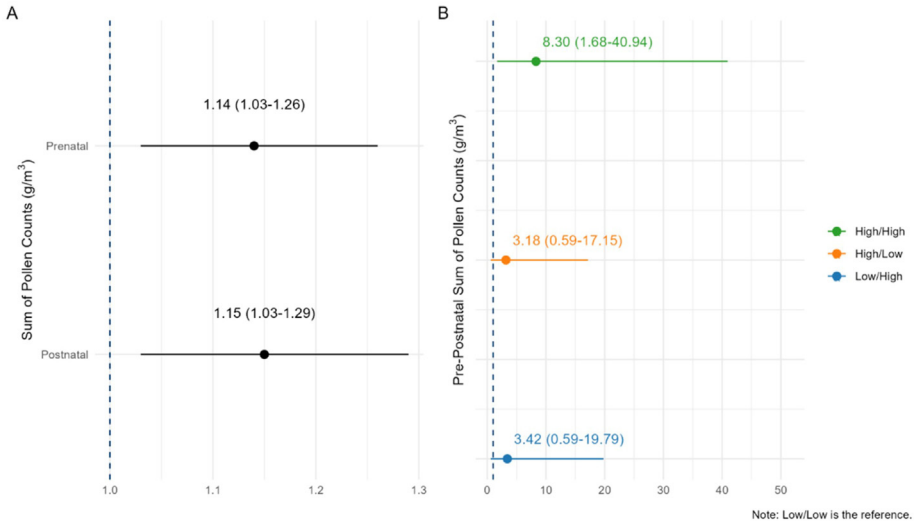

Fig. 1 Odds ratios of childhood asthma at age 6.

association of pollen exposures and childhood asthma incidence. Including paternal asthma in the models did not impact the effect of pollen sum exposures (prenatal and postnatal) on asthma at age 6 by more than 10% (OR = 1.18, 95% CI 1.05–1.32, p = 0.004; OR = 1.16, 95% CI 1.02–1.31, p = 0.02, respectively). Similarly, the effect of the joint impact of pollen sum exposures on asthma risk was not impacted with the inclusion of paternal asthma (OR = 8.20, 95% CI 1.57–42.84, p = 0.01). For the number of days with high pollen counts, we only detected a significant increased odds of asthma from high pollen exposure in the first year of life, adjusting for paternal asthma and the aforementioned infant exposures and F2 characteristics (OR = 1.02, 95% CI 1.00–1.03, p = 0.04).

As for rhinitis, there was no significant risk of rhinitis at ages 2, 3, and 6 years from high prenatal and postnatal pollen exposures and their associated joint impacts, using either measure of pollen exposure, although the trends were overall consistent with those for asthma (Supplemental Tables 3 and 4). In addition, maternal rhinitis and birth order was found to be significantly associated with rhinitis status at ages 2, 3, and 6 years (Supplemental Tables 3 and 4).

DISCUSSION

We investigated the role of pollen exposure during pregnancy, the first year of life, as well as joint exposure during both periods on childhood asthma and rhinitis in the IOWBC. We also found that the impact of cumulative pollen exposures during these life periods were similar for childhood rhinitis, although the effects were statistically insignificant. Adjusting for maternal risk factors and environmental exposures did not change the statistical significance of associations between pollen exposure and rhinitis, although it is possible that we might have missed some other potentially important perinatal factors such as maternal age at delivery and assisted reproductive technology.[9] It is worth noting that the present study focuses on asthma incidence rather than asthma exacerbation associated with pollen exposure as in existing studies.[1,10]

In our study, we observed similar effects of pollen exposure between prenatal and postnatal periods, with exposure evaluated based on the sum of pollen counts. During pregnancy, the fetus is not directly exposed to pollen. One explanation of such an observed impact from prenatal pollen exposure is the existence of strong confounders. Because of meteorological conditions (ie, sunlight and wind), pollen concentrations are correlated with the concentration of air pollutants such as $PM_{2.5}$,[11] which may consequently alter the environment that the fetus is exposed to during pregnancy. As a result, there is higher pollen exposure among pregnant mothers who may likely spend time outdoors in warmer weather, thereby imposing a greater risk of asthma in early childhood. However, the comparable effects of pollen exposures between the 2 life

periods do not fully support the confounding effects due to air pollutants, and subsequent studies that thoroughly address potential confounders to tease out the contribution of pollen exposure are in great need. Overall, the strength of this study exists in its time-lagged longitudinal analysis design to avoid reverse causation and the informative findings with respect to the varying impact of pollen exposure during different periods on childhood asthma and rhinitis, although with pollen exposure at the population level, the findings were possibly attenuated. More detailed discussions are in Supplemental File 2.

CONCLUSION

Asthma development at age 6 is associated with cumulative pollen exposure during pregnancy and in the first year of life. The joint impact of pollen exposures in these life periods contributed to a much higher risk of asthma in early childhood. Findings from this study are helpful to our understanding about the impact of such exposures on the risk of childhood asthma later in life, which in turn will benefit health practitioners' efforts on asthma prevention in early childhood. In addition, we laid out several areas that warrant future studies to confirm these findings such as addressing potential confounding and improving exposure measurements of pollen. Elucidating the mechanisms of prenatal and postnatal exposures to pollen on the etiology of childhood asthma is ultimately desired.

Abbreviations

IOWBC: Isle of Wight birth cohort; ISAAC: International Study of Asthma and Allergy in Childhood

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Availability of data and materials

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Authors' contributions

H.Z. designed the study; R.M. analyzed the data; J.A. assisted in pollen exposure measurement; R.M. and H.Z. drafted the manuscript; R.M., H.Z., and D.E.W. interpreted the findings; and S.P. and H.A. supervised the study.

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of The Isle of Wight Local Research Ethics Committee (protocol code 18/98 and date of approval 07/20/1998). We have received ethics approval from the Isle of Wight, Portsmouth, and National Research Ethics Service (NRES) Committee South Central – Southampton B (09/H0504/129), Berkshire (14/SC/0133), and Hampshire B(14/SC/1191). The NERS Committee East Midlands – Leicester Central (17/EM/0083) also provided ethics approval for the study. Informed consent was obtained from all participants via in-person visits or phone interviews.

Authors' consent for publication

All authors approve this manuscript to be submitted to the World Allergy Organization Journal.

Declaration of competing interest

The authors declare that they have no competing interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.waojou.2024.100976.

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