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Allergic rhinitis co-morbidity on asthma outcomes in city school children

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ABSTRACT

Background: School based asthma programs have demonstrated that preventive asthma therapy administered in school reduces asthma morbidity. The burden of co-morbid allergic disease on asthma outcomes in a large school based asthma cohort has been unexplored.

Objective: Evaluate the prevalence of allergic rhinitis (AR) in historically minoritized school children with persistent asthma, and determine if AR is an independent risk factor for asthma morbidity.

Methods: We evaluated the prevalence of AR in children enrolled in 3 NIH funded school based asthma programs in Rochester, NY. We used linear regression and multivariate analyses to compare asthma outcomes for children whose caregivers did and did not report AR.

Results: We used data from 1,029 children with asthma (mean age 7.4, 60.4% Black, 29.5% Hispanic, 72.8% insured with Medicaid). 63% of children reported AR. Children with AR had significantly fewer symptom free days over 2 weeks compared to children without AR (7.2 vs. 8.3, $p < 0.001$). Children with AR also had more daytime symptoms, (4.7 vs. 3.7, $p < 0.001$), more rescue medication use (4.5 vs. 3.4, $p < 0.01$), and more activity limitation due to asthma (3.6 vs. 2.5, $p < 0.001$). Only 44% of children with AR reported allergy medication use.

Conclusions: Among a large school-based cohort of minoritized children with asthma, we found that the majority of children have comorbid allergic rhinitis, which was associated with increased asthma morbidity. Inadequate recognition and treatment for allergic rhinitis likely represents substantial preventable morbidity for this group.

Abbreviations: FEV1: forced expiratory volume in one second; FeNO: fractional exhaled nitric oxide; AR: Allergic Rhinitis

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Introduction

Allergic rhinitis (AR) and asthma are the two of the most common chronic disorders in childhood. AR is an inflammatory chronic disease with significant burden, yet is often underdiagnosed and undertreated (1). AR is a risk factor for the development of asthma and if not well controlled, can exacerbate asthma symptoms (2). In fact, it has been postulated that AR and asthma represent one disease in two parts of the airway (3). Previous surveys have shown that approximately 60–80% of children with asthma have symptoms of AR (1) and AR symptoms are worse in those with difficult-to-control asthma. Specifically, perennial AR with seasonal exacerbation was highlighted to be the most severe phenotype, and it is most likely to be associated with difficult-to-control asthma.

Low income, minoritized children have disproportionately high rates of morbidity and mortality from

asthma compared to white children (4). The causes for this disparity are multifold, but indoor allergens (dust mite, cat, cockroach, and mouse) are major contributors to asthma morbidity in this population, (5,6) and allergic sensitization is often underdiagnosed in Puerto Rican and Black children with asthma and AR (7). In a cluster analysis of participants enrolled in nine inner city asthma centers, the most severe asthma phenotype was highly atopic with high total serum IgE, serum eosinophilia and allergic sensitizations (8). Importantly, relevant allergen levels vary across and within cities (9–12). For example, in a study of low income, minoritized children with asthma living in Baltimore city, despite high levels of both mouse and cockroach allergen, mouse allergen was more strongly and consistently associated with poor asthma outcomes (6). In follow up studies of this population, mouse sensitization and exposure

remained associated with asthma severity (13). Importantly, reduction in mouse allergen was associated with greater increase in pre-bronchodilator FEV1 and pre-bronchodilator and post bronchodilator FEF₂₅₋₇₅ over 1 year, suggesting improvement in lung function growth (14). There are also disparities in treatment of AR; only 1/3rd of a cohort of school children with AR and asthma were using appropriate treatments based on guidelines (15).

The objectives of this study were to: (1) determine the prevalence of reported co-morbid AR in children with persistent asthma participating in three school-based asthma clinical trials in Rochester, NY, (2) determine if there is increased asthma morbidity among the cohort of children with reported AR and asthma, and (3) assess whether the children with reported AR are receiving appropriate treatment. We hypothesized that similar to other cohorts, rhinitis symptoms would be common, and AR would be an independent risk factor for asthma morbidity. We also hypothesized that AR would be undertreated in this population. These factors may contribute to the persistence of asthma symptoms and increased asthma morbidity in this population.

Methods

Settings and participants

In Rochester, NY, 1 in 10 children have asthma, making it the most common pediatric illness in this community. For more than 15 years, the Preventive Care Program for Children with Asthma has partnered with the Rochester City School District (RCSD) and implemented several studies to enhance access to care and treatment for children with asthma in this community. The majority of Rochester city students are Black and Latinx (90%), and 85% live in poverty. In this study we analyzed baseline data for children enrolled as participants in one of three school-based asthma clinical trials, including the School-Based Telemedicine Enhanced Asthma Management Team (SB-TEAM) trial, the School-Based Asthma Therapy (SBAT) trial, and the School-Based Preventive Asthma Care Technology (SB-PACT) trial. The details of the SB-TEAM, SBAT, and SB-PACT study designs have been previously published (16–18). All three studies had consistent enrollment criteria. Through collaboration with the Rochester City School District (RCSD), eligible school children 3–10 years old were identified for initial eligibility screening through school medical alert forms. Inclusion criteria were physician-diagnosed asthma with persistent symptoms or poor control

according to National Heart, Lung and Blood Institute (NHLBI) guidelines and primary care physician agreement. Children were excluded if they had a significant medical condition that could interfere with assessment of asthma related measures (e.g. congenital heart disease, cystic fibrosis), if the family had no access to a working telephone, and if there was an inability to speak or understand English.

Secondary analyses were performed using baseline data from the three studies, which enrolled 400, 530, and 100 children, respectively. All trials were approved by the University of Rochester Institutional Review Board, and written informed consent was obtained from primary caregivers.

Data collection

After inclusion screening and informed consent were completed, a baseline survey assessment was performed. Baseline assessments included questions about asthma symptoms, health care utilization, family and health history variables, environmental exposures, and presence of reported nasal symptoms, AR or hay fever. The prevalence of AR was assessed by the question, ‘does your child have hay fever or allergic rhinitis.’ Caregivers were also asked, ‘has a doctor ever diagnosed your child with hay fever, nasal allergies, or allergic rhinitis.’ Demographic variables known to influence asthma outcomes were also collected. These include child age, sex, race, ethnicity, insurance status, atopic dermatitis, and environmental tobacco smoke exposure. Caregiver’s also self-reported their age, marital status, and educational attainment.

Asthma symptoms

The primary outcome for all three trials was the mean number of asthma symptom-free days over two weeks. This outcome measure is used commonly for symptom monitoring in asthma clinical trials.

We used structured interviews to collect information about the number of days with no asthma symptoms (including no coughing, wheezing, or shortness of breath) over the past two weeks. Caregivers were also asked to identify the number of days the child had any nighttime asthma symptoms, daytime symptoms, and rescue medication use to relieve symptoms over the previous two weeks.

We also measured the fractional exhaled nitric oxide (FeNO) at baseline. FeNO reflects the presence of eosinophilic airway inflammation; FeNO levels >20 ppb were considered elevated.

Health care utilization and school absenteeism

Caregivers reported general and asthma related health care utilization over the past year including the number of doctor's visits, emergency department visits, hospital visits and urgent care visits. Caregivers also reported missed school days due to asthma.

Statistical analysis

Using STATA, we conducted frequency analyses to provide descriptive data and determine the prevalence of AR in the sample. Unadjusted parametric tests assessed differences between those with and without allergic rhinitis. Multivariate linear and logistic regression analyses estimated the association between participant demographics and asthma symptoms and AR status. These models were adjusted for child characteristics: race, ethnicity, sex, age, smoke exposure and insurance status and caregiver characteristics: age, educational attainment, and marital status. A p values <0.05 was considered statistically significant.

Results

Descriptive statistics of the study participants and caregiver characteristics are presented in Table 1. Overall, the three combined clinical trials included 1,029 3–10 year old children with persistent asthma. The average age of children was 7 years, 40.4% were female, 60.4% Black, 72.8% used Medicaid as their primary insurance, and 52.1% lived in a home with a smoker. Approximately one-third of the

participants were Hispanic and 60.0% had a caregiver with a high school education or greater. The average age of caregivers was 34 and the majority were not married.

Allergic rhinitis was reported among the majority of children (63%). Among participants with reported AR, 41% experienced allergy symptoms around animals, 57% around dust, and 63% around pollen; only 46% reported that AR was diagnosed by a doctor. In comparing children with and without reported AR, children with AR were slightly older (7.6 vs. 7.1 years) and had older caregivers (34.8 vs. 33.5 years). Among children with AR, 55.6% also reported a history of atopic dermatitis compared with 39.2% of those without AR ($p < 0.001$). We found that 26 of the 1,029 children participated in more than one of the trials; when we repeated analyses with data from these children excluded, the findings were unchanged.

Allergic rhinitis and asthma morbidity

Table 2 shows the primary outcome measures of children with asthma and AR compared with those without AR. We found that children with AR had significantly fewer symptom free days over 2 weeks compared to children without AR (7.20 vs. 8.4, $p < 0.001$). Children with AR also had more daytime symptoms in the prior two weeks, (4.7 vs. 3.7, $p < 0.001$), more rescue medication use (4.5 vs. 3.4, $p < 0.01$), and more days with activity limitation due to asthma (3.6 vs. 2.5, $p < 0.001$). Among children with AR, 42.1% had elevated FeNO (> 20 ppb). In

Table 1. Sample descriptive statistics.

Independent variables	Analytic sample $N=1029$	Allergic rhinitis $N=646$	No Allergic rhinitis $N=383$	p -value
Adolescent characteristics				
Sex				0.11
Female	416 (40.4%)	249 (38.5%)	167 (43.6%)	
Age (years), mean (SD)	7.4 (1.9)	7.6 (1.8)	7.1 (1.9)	<0.001
Race				0.52
White	81 (7.9%)	52 (8.1%)	29 (7.6%)	
Black	621 (60.4%)	397 (61.5%)	224 (58.5%)	
Other	327 (31.8%)	197 (30.5%)	130 (33.9%)	
Ethnicity				0.41
Hispanic	304 (29.5%)	185 (28.6%)	119 (31.1%)	
Medicaid coverage				0.69
Is on Medicaid	749 (72.8%)	473 (73.2%)	276 (72.1%)	
Atopic dermatitis (AD)				<0.001
Yes AD	509 (49.5%)	359 (55.6%)	150 (39.2%)	
Caregiver characteristics				
Age (years), mean (SD)	34.3 (8.6)	34.8 (8.6)	33.5 (8.6)	0.03
Marital status				0.06
Married	226 (22.0%)	130 (20.1%)	96 (25.1%)	
Educational attainment				0.07
High school graduate or less	412 (40.0%)	245 (37.9%)	167 (43.6%)	
More than high school graduate	617 (60.0%)	401 (62.1%)	216 (56.4%)	
Cigarette smoke exposure at home				0.85
Smoker at home	536 (52.1%)	335 (51.9%)	201 (52.5%)	

Table 2. Asthma outcomes by allergic rhinitis status.

Dependent variables	Analytic sample N = 1030	Allergic rhinitis N = 646	No Allergic rhinitis N = 383	p-value	Beta, 95% CI, p
Continuous variables					
Number of symptom-free days in past 2 weeks, mean (SD)	7.6 (4.9)	7.2 (4.9)	8.4 (4.9)	<0.001	−1.27 (−1.90, −0.64), $p < 0.001$
Number of days with daytime asthma symptoms in past 2 weeks, mean (SD)	4.3 (4.5)	4.7 (4.6)	3.7 (4.3)	<0.001	1.06 (0.50, 1.63), $p < 0.001$
Number of days with nighttime asthma symptoms in past 2 weeks, mean (SD)	3.7 (4.3)	3.9 (4.3)	3.4 (4.3)	0.07	0.68 (0.13, 1.23), $p = 0.02$
Number of days in past 2 weeks on which rescue medication was used, mean (SD)	4.1 (4.7)	4.5 (4.7)	3.4 (4.5)	<0.001	1.07 (0.49, 1.65), $p < 0.001$
Number of days in past 2 weeks on which activity was limited, mean (SD)	3.2 (4.0)	3.6 (4.2)	2.5 (3.6)	<0.001	1.07 (0.58, 1.56), $p < 0.001$
FeNO ppb, mean (SD)	22.9 (25.4)	26.0 (28.1)	17.6 (18.9)	<0.001	6.06 (2.64, 9.49), $p = 0.001$
Dichotomous variables					
				AOR, 95% CI, p	
Missed school due to asthma*				0.04	1.63 (1.03, 2.53), $p = 0.03$
Did not miss any school due to asthma	499 (80.7%)	296 (78.1%)	203 (84.9%)		
Missed ≥ 1 school day due to asthma	119 (19.3%)	83 (21.9%)	36 (15.1%)		
ED visit due to asthma				0.20	1.34 (1.03, 1.74), $p = 0.03$
No ED visits due to asthma	710 (69.1%)	437 (67.7%)	273 (71.5%)		
At least 1 ED visit due to asthma	318 (30.9%)	209 (32.4%)	109 (28.5%)		
Hospitalization due to asthma				0.01	2.72 (1.22, 6.04), $p = 0.01$
No hospitalization due to asthma	985 (95.8%)	610 (94.6%)	375 (97.9%)		
At least 1 hospitalization due to asthma	43 (4.2%)	35 (5.4%)	8 (2.1%)		
Urgent care visit due to asthma				0.35	1.22 (0.93, 1.58), $p = 0.15$
No urgent care visit due to asthma	428 (41.6%)	261 (40.5%)	167 (43.6%)		
At least 1 urgent care visit due to asthma	599 (58.2%)	383 (59.5%)	216 (56.4%)		
Elevated FeNO				<0.001	1.59 (1.14, 2.23), $p = 0.006$
Normal FeNO (<20)	458 (62.9%)	265 (57.9%)	193 (71.5%)		
Elevated FeNO (≥ 20)	270 (37.0%)	193 (42.1%)	77 (28.5%)		

Multivariate linear and logistic regression models adjusted for child characteristics: race, ethnicity, sex, age, smoke exposure and insurance and caregiver characteristics: age, educational attainment, and marital status.

*SB-TEAM excluded from sample.

linear regression analysis controlling for child race, ethnicity, sex, age, insurance status and smoke exposure, and caregiver age, educational attainment and marital status, all of these findings remained statistically significant.

Table 2 also shows school absenteeism and health care utilization for children with and without AR. In multivariate analyses, children with AR had a 63% increase in the relative odds of missing school due to asthma compared to children without AR (OR 1.6, 95% CI 1.0–2.5). Children with AR also had 2.7 greater odds of being hospitalized due to asthma (OR 2.7, 95% CI 1.2–6.0) in the prior year. Children with AR did not have significantly more emergency department or doctor visits for asthma than children without AR.

Medication use

Among the 1,029 children, 67% reported using a preventive asthma medications at baseline, and only 31% reported allergy medication use. Even among the group of children with AR, only 44% reported using

allergy medications. The most common allergy medications were second generation anti-histamines (68%), followed by corticosteroid nasal spray (28%), and first generation anti-histamines (3.8%).

Discussion

As hypothesized, we found that the majority of children participating in these school-based asthma trials have comorbid AR, and the children with reported AR had increased asthma morbidity compared to children without AR. Among multiple asthma outcome measures, including symptom free days, daytime asthma symptoms, and missed school days due to asthma, there was greater symptom severity among children with AR compared to children without AR. The objective measure of FeNO was also elevated in children with AR compared to children without AR, consistent with the higher FeNO levels seen in allergic asthma compared to non-allergic asthma (19). Importantly, the majority of caregivers reporting their child had AR did not report any treatment for AR.

The relationship between AR and asthma has been evaluated in previous studies, and AR has been shown to be a risk factor for the development of asthma in both children in adults (20). Similar to our findings that children with AR had more days with asthma symptoms, in a prospective study, a history of AR in children with recurrent wheezing was associated with significantly increased odds of persistent asthma symptoms (21). Severity of rhinitis symptoms has also been correlated with asthma symptoms. In one study, patients with persistent and severe rhinitis symptoms had a significantly increased odds of having uncontrolled asthma compared to patients without AR (22).

Children with AR and asthma in this analysis also had increased odds of missing school due to asthma and greater odds of hospitalization due to asthma compared to children without AR. This is consistent with previous studies that have shown that children with comorbid AR and asthma have greater asthma severity and health care utilization compared to those without AR (23).

Importantly, in our analysis the majority of children with comorbid AR and asthma were not receiving any treatment for AR (55%), which is even higher than seen in previous studies and likely represents preventable morbidity. In addition, most children who did report treatment were not using the first line treatment of intranasal corticosteroids. Under-treatment may be related to under recognition of AR in children with asthma among both caregivers and clinicians, since many caregivers reported AR without a physician diagnosis. One possibility is that implicit bias contributes to the under-recognition of the relevance of the comorbidity of AR in patients with asthma, which could also lead to bias in referral patterns to specialists. In a similar school-based asthma study, among 166 children with asthma, 72% had rhinitis symptoms, yet AR was undiagnosed in 53%. In a study of under diagnosis of AR in underserved children, Jacobs et al. report that primary care physicians correctly diagnosed AR in only 15.3% of children with asthma and 3.5% of children without asthma. We do not have data about whether the children in this study received allergen immunotherapy, but based on our finding that the majority of AR was not physician diagnosed and only 6% had seen an asthma specialist, we expect that rates are very low.

There are several important clinical implications of the high prevalence of comorbid, undertreated, and potentially underdiagnosed comorbid AR in Rochester city school children with asthma. While the trials of supervised asthma therapy in schools consistently demonstrate improvement in asthma outcomes for

participating children, there is a subset of children that do not improve. The comorbidity of allergic disease, especially if unrecognized and untreated, may contribute to this gap. The school-based studies also have not intervened to improve conditions in the home or school environment, which may contain triggers for allergy and asthma symptoms. Further, the majority of children in these previous studies were not in the care of asthma or allergy specialists, which may account for under treatment of AR. Current studies in Rochester school-based cohorts have been designed to ensure evaluation for potential allergic disease and increase availability to specialty care via telemedicine.

Strengths of this study include the very large, community-based, diverse sample of children with asthma and the availability of a rich dataset including demographic and medical variables as well as health-care utilization. Limitations include the use of caregiver report of AR, which could lead to over or underestimation of this diagnosis. There is also no confirmatory sensitization data, including skin prick test results or serum IgE for children reported to have AR. While this could lead to misclassification, other studies have found that caregiver report of rhinitis symptoms are concordant with confirmatory sensitization data (15). In addition, multiple studies have found that AR is underdiagnosed by physicians, especially in Black and Latinx children with asthma. This may account for the difference seen in this study between AR reported by caregivers and caregiver's report of physician diagnosed AR. This suggests that there may be a knowledge gap regarding the effect of AR on asthma, and is an opportunity for improvement. In addition, under diagnosis of AR by primary care physicians in this population may highlight difficulty in accessing specialty clinicians such as allergists/immunologists. The possibility of bias in referral to a specialist for AR should also be explored in this and similar cohorts.

Conclusion

Among a large school-based cohort of children with asthma, we found that the majority of children have comorbid AR, which was associated with increased asthma morbidity. This may contribute to the disparities in outcomes for asthma morbidity among minoritized children with asthma in the Rochester area. Inadequate treatment for AR likely represents substantial preventable morbidity for this group. The results of this study may be used to support improved public policy in this region, emphasizing the need to

improve health and reduce inequities in asthma outcomes. Future studies will include understanding the sensitization patterns as contributors to the burden of disease and use of a multi-disciplinary, comprehensive, community-based approach to address not only mechanism of disease, but also systemic improvements on barriers to care.

Authorship

Dr. Stern made substantial contribution to the design, acquisition, analysis and interpretation of the data, drafted and approved the manuscript, and agrees to be accountable for the work related to its accuracy and integrity. Dr. Chen contributed to the analysis and interpretation of the data, writing and approval of the manuscript, and agrees to be accountable for the work. Maria Fagnano made significant contribution to the design of the study and acquisition of the data, reviewed the manuscript critically, gave approval for the final version and agrees to be accountable for all aspects of the work related to accuracy. Dr. Halterman made substantial contribution and design of the study, acquisition, analysis and interpretation of the data, reviewed the manuscript for important intellectual content, approved the final version of the manuscript and agrees to be accountable for the work.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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References

- de Groot EP, Nijkamp A, Duiverman EJ, Brand PL. Allergic rhinitis is associated with poor asthma control in children with asthma. *Thorax*. 2012;67(7):582–587. Epub 2012/01/04. doi:10.1136/thoraxjnl-2011-201168.
- Brożek JL, Bousquet J, Agache I, Agarwal A, Bachert C, Bosnic-Anticevich S, Brignardello-Petersen R, Canonica GW, Casale T, Chavannes NH, et al. Allergic Rhinitis and its Impact on Asthma (ARIA) guidelines-2016 revision. *J Allergy Clin Immunol*. 2017;140(4):950–958. Epub 2017/06/13. doi:10.1016/j.jaci.2017.03.050.
- Togias A, Gergen PJ, Hu JW, Babineau DC, Wood RA, Cohen RT, et al. Rhinitis in children and adolescents with asthma: Ubiquitous, difficult to control, and associated with asthma outcomes. *J Allergy Clin Immunol*. 2018; Epub 2018/09/15. doi:10.1016/j.jaci.2018.07.041.
- Jacobs TS, Forno E, Brehm JM, Acosta-Pérez E, Han Y-Y, Blatter J, Colón-Semidey A, Alvarez M, Canino G, Celedón JC, et al. Underdiagnosis of allergic rhinitis in underserved children. *J Allergy Clin Immunol*. 2014;134(3):737–739 e6. Epub 2014/05/07. doi:10.1016/j.jaci.2014.03.028.
- Ahluwalia SK, Matsui EC. Indoor environmental interventions for furry pet allergens, pest allergens, and mold: looking to the future. *J Allergy Clin Immunol Pract*. 2018;6(1):9–19. Epub 2018/01/10. doi:10.1016/j.jaip.2017.10.009. PubMed PMID: 29310769; PubMed Central PMCID: PMC5763515.
- Ahluwalia SK, Peng RD, Breyse PN, Diette GB, Curtin-Brosnan J, Aloe C, Matsui EC. Mouse allergen is the major allergen of public health relevance in Baltimore City. *J Allergy Clin Immunol*. 2013;132(4):830–835. e1–2. Epub 2013/07/03. doi:10.1016/j.jaci.2013.05.005. PubMed PMID: 23810154; PubMed Central PMCID: PMC3800085.
- Celedón JC, Sredl D, Weiss ST, Pisarski M, Wakefield D, Cloutier M. Ethnicity and skin test reactivity to aeroallergens among asthmatic children in Connecticut. *Chest*. 2004;125(1):85–92. doi:10.1378/chest.125.1.85. PubMed PMID: WOS:000188217700018.
- Zoratti EM, Krouse RZ, Babineau DC, Pongracic JA, O'Connor GT, Wood RA, Khurana Hershey GK, Kercsmar CM, Gruchalla RS, Kattan M, et al. Asthma phenotypes in inner-city children. *J Allergy Clin Immunol*. 2016;138(4):1016–1029. Epub 2016/10/11. doi:10.1016/j.jaci.2016.06.061. PubMed PMID: 27720016; PubMed Central PMCID: PMC5104222.
- Olmedo O, Goldstein IF, Acosta L, Divjan A, Rundel AG, Chew GL, Mellins RB, Hoepner L, Andrews H, Lopez-Pintado S, et al. Neighborhood differences in exposure and sensitization to cockroach, mouse, dust mite, cat, and dog allergens in New York City. *J Allergy Clin Immunol*. 2011;128(2):284–292.e7. Epub 2011/05/04. PubMed PMID: 21536321; PubMed Central PMCID: PMC3271316. doi:10.1016/j.jaci.2011.02.044.
- Pomes A, Arruda LK. Investigating cockroach allergens: aiming to improve diagnosis and treatment of cockroach allergic patients. *Methods*. 2014;66(1):75–85. Epub 2013/08/07. doi:10.1016/j.ymeth.2013.07.036. PubMed PMID: 23916425; PubMed Central PMCID: PMC3909726.
- Pomes A, Glesner J, Calatroni A, Visness CM, Wood RA, O'Connor GT, et al. Cockroach allergen component analysis of children with or without asthma and rhinitis in an inner-city birth cohort. *J Allergy Clin Immunol*. 2019; Epub 2019/06/16. doi:10.1016/j.jaci.2019.05.036.
- Pomes A, Mueller GA, Randall TA, Chapman MD, Arruda LK. New insights into cockroach allergens. *Curr Allergy Asthma Rep*. 2017;17(4):25. Epub 2017/04/20. doi:10.1007/s11882-017-0694-1. PubMed PMID: 28421512; PubMed Central PMCID: PMC5575827.

13. Grant T, Aloe C, Perzanowski M, Phipatanakul W, Bollinger ME, Miller R, Matsui EC. Mouse sensitization and exposure are associated with asthma severity in urban children. *J Allergy Clin Immunol Pract*. 2017;5(4):1008–1014.e1. Epub 2016/12/08. PubMed PMID: 27923647; PubMed Central PMCID: PMC5457718. doi:[10.1016/j.jaip.2016.10.020](https://doi.org/10.1016/j.jaip.2016.10.020).
14. Grant T, Phipatanakul W, Perzanowski M, Balcer-Whaley S, Peng RD, Curtin-Brosnan J, et al. Reduction in mouse allergen exposure is associated with greater lung function growth. *J Allergy Clin Immunol*. 2019; Epub 2019/12/24. doi:[10.1016/j.jaci.2019.08.043](https://doi.org/10.1016/j.jaci.2019.08.043).
15. Esteban CA, Klein RB, Kopel SJ, McQuaid EL, Fritz GK, Seifer R, York D, Golova N, Jandasek B, Koinis-Mitchell D, et al. Underdiagnosed and undertreated allergic rhinitis in urban school-aged children with asthma. *Pediatr Allergy Immunol Pulmonol*. 2014;27(2):75–81. Epub 2014/06/26. doi:[10.1089/ped.2014.0344](https://doi.org/10.1089/ped.2014.0344). PubMed PMID: 24963455; PubMed Central PMCID: PMC4062104.
16. Halterman JS, Szilagyi PG, Fisher SG, Fagnano M, Tremblay P, Conn KM, Wang H, Borrelli B. Randomized controlled trial to improve care for urban children with asthma: results of the School-Based Asthma Therapy trial. *Arch Pediatr Adolesc Med*. 2011;165(3):262–268. PubMed PMID: 21383275; PubMed Central PMCID: PMC3600609. doi:[10.1001/archpediatrics.2011.1](https://doi.org/10.1001/archpediatrics.2011.1).
17. Halterman JS, Fagnano M, Tajon RS, Tremblay P, Wang H, Butz A, Perry TT, McConnochie KM. Effect of the school-based telemedicine enhanced asthma management (SB-TEAM) program on asthma morbidity: A randomized clinical trial. *JAMA Pediatr*. 2018;172(3):e174938. Epub 2018/01/09. doi:[10.1001/jamapediatrics.2017.4938](https://doi.org/10.1001/jamapediatrics.2017.4938). PubMed PMID: 29309483; PubMed Central PMCID: PMC585835.
18. Halterman JS, Sauer J, Fagnano M, Montes G, Fisher S, Tremblay P, Tajon R, Butz A. Working toward a sustainable system of asthma care: development of the School-Based Preventive Asthma Care Technology (SB-PACT) trial. *J Asthma*. 2012;49(4):395–400. doi:[10.3109/02770903.2012.669441](https://doi.org/10.3109/02770903.2012.669441). PubMed PMID: 22455402; PubMed Central PMCID: PMC3381057.
19. Elmasri M, Romero KM, Gilman RH, Hansel NN, Robinson CL, Baumann LM, Cabrera L, Hamilton RG, Checkley W, PURA Study Investigators. Longitudinal assessment of high versus low levels of fractional exhaled nitric oxide among children with asthma and atopy. *Lung*. 2014;192(2):305–312. Epub 2014/01/15. PubMed PMID: 24414739; PubMed Central PMCID: PMC35526602. doi:[10.1007/s00408-013-9551-8](https://doi.org/10.1007/s00408-013-9551-8).
20. Guerra S, Sherrill DL, Martinez FD, Barbee RA. Rhinitis as an independent risk factor for adult-onset asthma. *J Allergy Clin Immunol*. 2002;109(3):419–425. Epub 2002/03/19. doi:[10.1067/mai.2002.121701](https://doi.org/10.1067/mai.2002.121701).
21. Morais-Almeida M, Gaspar A, Pires G, Prates S, Rosado-Pinto J. Risk factors for asthma symptoms at school age: an 8-year prospective study. *Allergy Asthma Proc*. 2007;28(2):183–189. Epub 2007/05/08. doi:[10.2500/aap.2007.28.2953](https://doi.org/10.2500/aap.2007.28.2953).
22. Ponte EV, Franco R, Nascimento HF, Souza-Machado A, Cunha S, Barreto ML, Nasipitz C, Cruz AA. Lack of control of severe asthma is associated with co-existence of moderate-to-severe rhinitis. *Allergy*. 2008;63(5):564–569. Epub 2008/04/09. doi:[10.1111/j.1398-9995.2007.01624.x](https://doi.org/10.1111/j.1398-9995.2007.01624.x).
23. Thomas M. Allergic rhinitis: evidence for impact on asthma. *BMC Pulm Med*. 2006;6 Suppl 1(Suppl 1):S4. Epub 2006/12/05. doi:[10.1186/1471-2466-6-s1-s4](https://doi.org/10.1186/1471-2466-6-s1-s4). PubMed PMID: 17140422; PubMed Central PMCID: PMC1698497.