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Exposure to agricultural pesticides and wheezing among 5–12-year-old children in the Imperial Valley, CA, USA

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Background: Exposure to pesticides has been linked to adverse respiratory health outcomes in children.
Methods: We leveraged the Children's Assessing Imperial Valley Respiratory Health and the Environment cohort located in the rural community of Imperial Valley near the US–Mexico border. We calculated the kilograms of total pesticides applied within 400 m of children's residential addresses for the years 2016–2020. Estimated pesticide usage near homes was categorized into three groups (none vs. low vs. high [split at the median]). All health variables (i.e., asthma status and wheezing) were derived from a parent-reported questionnaire on respiratory health. We used generalized linear models, controlling for child sex, the language of survey, health insurance, respondents' highest education, and exposure to environmental secondhand smoking, to calculate prevalence differences between none versus low and high exposure to agricultural pesticides.
Results: Approximately 62% of the 708 children (aged 5–12 years) lived within 400 m of at least one pesticide application within 12 months prior to survey administration. Exposure to pesticides within 400 m of children's residences was associated with 12-month prior wheeze. Those in the "high" exposure group had a prevalence of wheezing that was 10 (95% confidence interval: 2%, 17%) percentage points higher than among children not exposed to pesticide applications. Associations for high exposure to specific categories of pesticide applications, sulfur only, all pesticides except sulfur, chlorpyrifos, and glyphosate, also were observed with a higher prevalence of wheezing than among children not exposed to pesticide applications.
Conclusions: We observed associations between living near pesticide applications and more wheeze symptoms among children.

Keywords: Environmental justice; Pesticides; Wheezing; Asthma; Children's health

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Data are confidential but available upon reasonable request. The AIRE study Principal Investigators welcome new collaborations with other investigators and have actively engaged in collaborative data-sharing projects. Interested investigators should contact J.E.J. (jillj@usc.edu) and S.F.F. (sffarzan@usc.edu) to obtain additional information about the AIRE study, discuss collaborative opportunities, and request a project proposal form. Code available upon request. Interested investigators should contact Y.O.V.H (yov2000@cumc.columbia.edu).

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Introduction

The widespread application of agricultural pesticides disproportionally impacts rural communities living in close proximity to fields and may contribute to documented health disparities.[1] The health effects associated with pesticides are wide ranging.[2] Exposure to pesticides has been associated with preterm delivery,[3] an increased risk of autism spectrum disorder,[4,5] low APGAR scores (a marker of infant health at birth),[6] and respiratory effects.[7] Disparities in pesticide exposures by race/ethnicity also persist, with higher exposures concentrated in structurally marginalized communities.[8,9] In the United States, the agricultural sector accounts for nearly 90% of the total pesticide usage.[10] In California, from 2017 to 2020, total pesticide usage in industrial agriculture was approximately 200 million pounds annually.[11] These pesticide applications occur in agricultural fields in close proximity to schools and homes,[12] indicating that the pesticide drift exposure pathway is of particular concern for rural communities.[13,14]

What this study adds:
We leveraged data from the California Pesticide Use Registry to examine the association of agricultural pesticide use (i.e., sulfur only, all pesticides except sulfur, chlorpyrifos, and glyphosate) to parent-reported respiratory health symptoms in predominantly Latino school-aged children. Exposure to pesticide applications within 400 m of children's residences was associated with 12-month prior wheeze. These findings contribute to our understanding of pesticide exposures and their impact on children's health.

Pesticides can enter respiratory airways as small irritating molecules, aggravating the airways.[15] Children living in agricultural communities are exposed to multiple pesticides, which may vary by season, application, and crop type.[16] Previous studies have found that sulfur, a widely used fumigant, has been associated with an increase in respiratory symptoms and a decrease in pulmonary function in children.[17] The fumigants 1,3-dichloropropene and metam sodium have been reported to cause respiratory distress in adults in two separate case studies.[18,19] Results from adults in the Agricultural Health Study indicate that exposure to glyphosate is associated with atopic asthma,[20] while pendimethalin, trifluralin, and chlorpyrifos have been associated with wheezing in farmers.[21] The respiratory health of children, such as wheezing, can have long-term consequences for respiratory health into adulthood.[22–24] Established predictors of wheezing in children include age,[25] sex,[22] early-life sensitization,[26] and environmental exposures such as maternal smoking during pregnancy.[26–28] Despite prior research identifying adverse health impacts from exposure to pesticides,[5,6,29] there is a paucity of research focusing on their effects on children's health in rural communities across US populations.

There is a limited but growing number of studies that have identified an association between various types of pesticides and wheezing in children.[30,31] In the Infants' Environmental Health Study in Costa Rica, recent exposure to pyrethroids was associated with higher wheezing in children at age 5.[32] In Limpopo, South Africa, prenatal exposure to pyrethroids was also associated with an increased risk of wheezing in children at age 3.5 and 5.[33] In contrast, in a cohort in New York City, no association was found between prenatal exposure to organophosphate (OP) and pyrethroids and wheezing at age 5.[34] Additionally, among children of the Outcomes and Measures of the Environment (HOME) Study in Cincinnati, Ohio, prenatal exposure to OP and pyrethroids were not associated with wheeze at 8 years or from birth to 8 years.[35] Overall pooling of these studies in two different reviews suggests that exposure to pesticides increases the odds of developing wheezing among children.[30,31]

Residents of the Imperial Valley, located in the rural border county of Imperial County of southeastern California, experience a multitude of social and environmental issues that may impact their well-being.[36] Residents of this area are primarily Latino, 1 in 3 children live in poverty, and there is a 20% unemployment rate.[37] The county faces poor air quality and excess particulate matter levels (PM).[38] Further, one in five children is diagnosed with asthma and the rate of asthma-related pediatric emergency room visits and hospitalizations is two times the CA state average.[37,39] Industrial agriculture in the region results in one of the highest amounts of pesticide applications in the state, with Imperial County ranking in the top 12 (of 58 counties) since 2017[11,40–44] with approximately 5 million pounds of pesticides applied annually in this community. The purpose of this study was to assess the respiratory health impacts of pesticide usage in a rural, structurally marginalized population of school-aged children in Imperial Valley, CA.

Methods

Study setting and design

The Assessing Imperial Valley Respiratory Health and the Environment (AIRE) study was initiated as a direct response to address concerns about environmental pollution in Imperial Valley. In 2017, through a community-academic partnership with a local community organization, Comite Civico del Valle, a prospective cohort was initiated to understand the impacts of environmental exposures on children's respiratory health. Research protocols were approved by the University of Southern California Institutional Review Board (HS-17-00204). Written informed consent was obtained from a parent or legal guardian at enrollment.

Participants

From 2017 to 2019, the cohort enrolled 731 elementary school-aged children (aged 5–12 years) from five different schools across five communities in Imperial Valley.[45] Participation of the schools and study participants was voluntary. To recruit participants, study staff met with teachers, principals, superintendents, and parents from each school to answer questions. Staff visited 1st, 2nd, and 3rd grade classrooms to introduce the study and distribute packets containing materials to be taken home, including study information, a consent form and a child health survey to be completed by a caregiver. A total of 804 children were eligible for the study, of which 731 children enrolled, for a 91% acceptance rate. Parents (caregivers or guardians) of 731 children consented to their child's participation in the AIRE Study, however, only 708 (96%) completed and returned the accompanying questionnaire. The questionnaire included demographic and lifestyle questions that assessed the children's characteristics such as age, sex, race/ethnicity, and parent/guardian information including, educational attainment, insurance coverage, and tobacco usage (Table 1). In the questionnaire, we also asked parents/guardians their residential address and their children's residential history (i.e., if the child had lived in the same residence since birth and if the child had lived in the same residence the 12 months prior).

Wheezing

Parents were asked about the child's respiratory symptoms using questions adapted from the International Study of Asthma and Allergies in Childhood (ISAAC) questionnaire.[29,46–49] Children were categorized as asthmatic based on a positive response to the question, "has a doctor ever diagnosed your child as having asthma?" We defined wheezing as a binary outcome based on a positive response to the following during the previous 12 months: wheezing or whistling in the chest in the past 12 months.[17]

Geographic-based estimates of nearby pesticide applications

Using residential address information reported by the parent/guardian, we geocoded the location of the child's home at baseline. At enrollment, all children reported living at the same address for the previous 12 months. We estimated agricultural pesticide use near the child's residence using data from the California Department of Pesticide Regulation (CDPR).[11] Since 1990, California has required mandatory reporting of all agricultural pesticide applications, with data available through the Pesticide Use Report (PUR) Program. We used validated geospatial methods employed by other research teams and edited for outliers to assign exposures.[50,51] PURs include active ingredient, brand name, date/time applied, amount, and acreage within 1-square mile sections (~1.6 km × 1.6 km) defined by the Public Land Survey System. For each child, we computed the total pesticides applied within a 400-m buffer distance of their home, using a reported address from the questionnaire, for the 12 months before the date of the baseline survey using the following pesticide groups: all pesticides, all pesticides except sulfur, sulfur only, chlorpyrifos only, and glyphosate only. Analysis of all pesticides was chosen because of the concerns surrounding cumulative effects, given that many of the pesticides sprayed in Imperial County are classified as respiratory irritants (i.e., chlorpyrifos, glyphosate, and sulfur) and previous studies have also assessed

general proximity to fields sprayed near fields.[17,20,21,52,53] The 400 m buffer was selected based both on (1) previous studies identifying an association between a 500-m buffer correlation with pesticides measured in homes located near agricultural fields[17,54–56] and (2) a 2018 law in California that limits the application of pesticides within 402 m (1/4 mile) of schools. Thus 400 m represents a buffer with both scientific and policy implications.[12] For all pesticides, we weighted use near homes based on the proportion of each square mile that was within each buffer surrounding a residence centroid. Due to the large amount of residence centroids with zero pesticide applications within 400 m for chlorpyrifos, and to maintain consistency across pesticide groups, we categorized exposure based on three groupings: none, low, and high, with the low and high categories split at the group-specific median. The median used was 67 kg for all pesticide applications, 80 kg for sulfur, 34 kg for all minus sulfur, 2 kg for chlorpyrifos, and 7kg for glyphosate (Table 2).

Data analysis

We estimated respiratory symptoms associated with exposure to pesticides within 400 m by quantifying prevalence differences (rather than odds ratios) using generalized linear models, specifying identity links, Gaussian distribution, and sandwiched-based errors.[57] Based on prior literature and directed acyclic graphs

Table 1.

AIRE cohort study characteristics at baseline, N = 708

	All		Wheezing		No wheezing	
Characteristic	**N**	**%**	**n**	**%**	**n**	**%**
Age mean (years)	8.5 (1.1)		8.3 (0.9)		8.5 (1.0)	
Child sex						
Female	381	54	62	48	293	55
Male	327	46	68	52	236	45
Highest household education						
Less than 12th grade	137	19	29	22	102	19
Completed high school	197	28	27	21	167	32
Some college	236	33	55	42	174	33
Completed 4 years of college	60	8	14	11	31	6
Graduate or professional	50	7	3	2	29	5
Missing	28	4	2	2	26	5
Health insurance						
Private	134	19	3	2	88	17
Public	494	70	103	79	391	74
None	43	6	20	15	17	3
Missing	37	5	4	3	33	6
Secondhand smoke exposure						
Yes	47	7	5	4	14	3
No	566	80	112	86	454	86
Missing	95	13	12	9	61	12
Maternal smoking during pregnancy						
Yes	54	8	16	12	21	4
No	625	88	110	85	489	92
Do not know	29	4	4	3	19	4
Language of survey						
English	471	67	97	75	340	64
Spanish	237	33	32	25	189	36
Lived in the same residence since birth						
Yes	176	25	34	26	136	26
No	501	71	94	72	381	72
Missing	31	4	1	<1	12	2
Child's history of asthma						
Yes	166	23	90	69	65	12
No	539	76	39	30	463	88
Missing	3	<1	0	0	1	<1
Wheezing in past 12 months						
Yes	130	18				
No	527	74				
Missing	49	7				

Table 2.

Distributions of agricultural pesticide applications (kg) within 400 m of child's residence, N = 708

Pesticide use (kg)	Total	Mean	25th	50th	75th	90th	Max
All	56,824	77 (133)	0	20	109	209	1,379
Sulfur	28,060	38 (80)	0	0	49	147	975
All minus sulfur	28,763	39 (83)	0	14	53	99	404
Chlorpyrifos	523	1 (2)	0	0	0	1.3	18
Glyphosate	3,319	5 (9)	0	0	4	14	80

All includes the 150 active ingredients applied within 400 m. Median for analysis refers to the split of low vs. high for those in the exposed category.

Table 3.

Adjusted association for pesticide exposures (kg) within a 400-m radius of a child's residence and wheezing symptoms at baseline in the AIRE cohort, stratified by history of doctor-diagnosed asthma

		Wheezing prevalence (95% CI) Min[a]		Wheezing prevalence (95% CI) Full[b]		Wheezing prevalence (95% CI) Min		Wheezing prevalence (95% CI) Full
Exposure[c]	n	Asthmatic	n	Asthmatic	n	Nonasthmatic	n	Nonasthmatic
All								
None	40		36		154		143	
Low (<67 kg)	59	0.12 (–0.09, 0.32)	56	0.13 (–0.09, 0.35)	176	0.03 (–0.03, 0.09)	166	0.03 (–0.03, 0.09)
High (≥67 kg)	56	0.18 (–0.02, 0.38)	51	0.17 (–0.04, 0.39)	173	0.04 (–0.01, 0.10)	162	0.05 (–0.01, 0.11)
Sulfur								
None	78		70		319		299	
Low (<80 kg)	37	–0.05 (–0.24, 0.14)	36	–0.03 (–0.23, 0.17)	96	–0.003 (–0.07, 0.06)	89	–0.001 (–0.07, 0.07)
High (≥80 kg)	40	0.18 (–0.01, 0.37)	37	0.14 (–0.06, 0.35)	88	0.05 (–0.01, 0.11)	83	0.05 (–0.01, 0.12)
All minus sulfur								
None	41		37		156		145	
Low(<34 kg)	49	0.09 (–0.10, 0.28)	47	0.09 (–0.12, 0.30)	183	0.02 (–0.04, 0.07)	174	0.02 (–0.04, 0.08)
High (≥34 kg)	65	0.19 (–0.02, 0.40)	59	0.19 (–0.04, 0.42)	164	0.06 (0.002, 0.12)	152	0.06 (0.002, 0.12)
Chlorpyrifos								
None	123		112		407		380	
Low (<2 kg)	16	0.15 (–0.10, 0.41)	16	0.17 (–0.10, 0.43)	46	0.03 (–0.05, 0.11)	43	0.03 (–0.05, 0.11)
High (≥2 kg)	16	0.29 (0.03, 0.55)	15	0.24 (–0.02, 0.51)	50	0.09 (0.007, 0.17)	48	0.10 (0.008, 0.18)
Glyphosate								
None	79		69		277		260	
Low (<7 kg)	37	–0.06 (–0.25, 0.13)	35	–0.04 (–0.24, 0.16)	111	0.03 (–0.10, 0.41)	103	0.04 (–0.04, 0.09)
High (≥7 kg)	39	0.20 (0.01, 0.39)	39	0.19 (–0.008, 0.38)	111	0.02 (–0.03, 0.08)	105	0.03 (–0.03, 0.10)

[a]Minimally adjusted for sex and language of survey.

[b]Fully adjusted for sex, language of survey, health insurance, parent/guardian education, and exposure to environmental smoking.

[c]Low and high categories split at the median for those with pesticide exposures greater than 0 within a 400-m radius of the residence. None indicates no pesticide applications were applied within a 400-m radius of the child's residence. Generalized linear models, with Gaussian distribution, identity link function, and sandwiched errors.

(Figure S1; http://links.lww.com/EE/A296), we chose to minimally adjust models for child sex and language of survey (Spanish or English). We chose a priori to additionally evaluate models adjusted for health insurance (none, public, and private), respondents' highest education, and exposure to environmental secondhand smoke. Child exposure to environmental secondhand smoke at home was defined as living with a current smoker or the presence of any regular visitors who smoke inside the home, regardless of whether the child is also present or maternal smoking during pregnancy. In sensitivity analyses, we evaluated models by stratifying by asthma status (Table 3) and excluding participants with exposure to current environmental secondhand smoking from fully adjusted models (Table S1; http://links.lww.com/EE/A296), excluding participants whose biological mom smoked during pregnancy (Tables S2 and S3; http://links.lww.com/EE/A296) and further adjusting (Table S4; http://links.lww.com/EE/A296) and stratifying by time of residence in the same household (Tables S5 and S6; http://links.lww.com/EE/A296).

Results

The mean age of participants at enrollment in the AIRE cohort was 8.5, with a range of 7–9 years of age. A majority of children were female (n = 381, 54%), had a parent-completed survey in English (n = 471, 67%), and had public health insurance (n = 494, 69%) (Table 1). Less than 8% reported current exposure to environmental secondhand smoke. Most parents reported having attended some college (n = 236, 33%) or completing high school (n = 197, 28%). A total of 166 (23%) parents reported their child had a history of asthma at enrollment. There were 130 children (18%) with wheezing in the 12 months prior to the survey.

Pesticide applications

Within 400 m of child residences, there were 150 different pesticides applied over a 12-month period. This amounted to a total of 56,824 kg of pesticides applied to agricultural fields in our Imperial Valley study area. Applications of sulfur only were the main contributor with a total of 28,060 kg, followed by all pesticides except sulfur (28,763 kg), glyphosate (3319 kg), and chlorpyrifos (523 kg) (Table 2).

Wheezing

Of the 708 participants, 658 had complete information on sex, the language of survey, asthma status, and a complete geocoded address for inclusion in minimally adjusted models. In minimally adjusted models, children in the "high" total pesticide exposure group had a prevalence of 12-month prior wheeze that was 10 percentage points (95% confidence interval [CI]: 2%, 17%) higher than that of children not exposed to any pesticides (Table 4). Similarly, the difference in the prevalence of 12-month prior wheeze in the "high" exposure group to sulfur compared to the "no" exposure group was 12 percentage points higher (95% CI: 5%, 20%). Estimates were similar for the "high" exposure group to all other pesticides excluding sulfur to the unexposed group, with a difference of 9.0 percentage points (95% CI: 1%, 16%). For chlorpyrifos, children in the "high" exposure group had a 15.0 percentage point (95% CI: 5%, 26%) higher prevalence than the unexposed group. Finally, those in the "high" exposure group for glyphosate had a prevalence difference of 9.0 percentage points (95% CI: 1%, 16%) higher than the unexposed group. There was limited evidence of an association in the prevalence of 12-month prior wheeze in the "low" exposure groups to the unexposed groups for any of the pesticide groups, although estimates were suggestive of a positive trend in wheezing prevalence with any pesticide exposure. In fully adjusted models, a total of 614 had full information for health insurance, parent or guardian education, and exposure to secondhand smoking; adjustment for these additional covariates did not materially change estimates (Table 4).

Table 4.

Adjusted association for pesticide exposures (kg) within a 400-m radius of a child's residence and wheezing symptoms at baseline in the AIRE cohort

Exposure	n	Wheezing prevalence (95% CI) Crude	n	Wheezing prevalence (95% CI) Min adjusted[a]	n	Wheezing prevalence (95% CI) Fully adjusted[b]
All						
None	194	Ref	194	Ref.	179	Ref.
Low (<67 kg)	235	0.07(–0.01, 0.14)	235	0.07 (–0.007, 0.14)	222	0.07 (–0.008, 0.15)
High (≥67 kg)	229	0.09 (0.02, 0.17)	229	0.10 (0.02, 0.17)	213	0.10 (0.03, 0.18)
Sulfur						
None	397	Ref	397	Ref.	371	Ref.
Low (<80 kg)	133	0.04 (–0.04, 0.12)	133	0.03 (–0.05, 0.11)	123	0.04 (–0.04, 0.12)
High (≥80 kg)	128	0.12 (0.04, 0.20)	128	0.12 (0.05, 0.20)	120	0.13 (0.05, 0.21)
All minus Sulfur						
None	197	Ref	197	Ref.	182	Ref.
Low(<34 kg)	232	0.07(–0.005, 0.15)	232	0.07 (–0.004, 0.15)	221	0.07 (–0.006, 0.15)
High (≥34 kg)	229	0.08 (0.007, 0.16)	229	0.09 (0.01, 0.16)	211	0.09 (0.02, 0.17)
Chlorpyrifos						
None	530	Ref	530	Ref.	492	Ref.
Low (<2 kg)	62	0.07(–0.03, 0.17)	62	0.06 (–0.04, 0.16)	59	0.07 (–0.04, 0.17)
High (≥2 kg)	66	0.15 (0.04, 0.25)	66	0.15 (0.05, 0.26)	63	0.16 (0.06, 0.27)
Glyphosate						
None	360	Ref	360	Ref.	332	Ref.
Low (<7 kg)	148	0.02 (–0.05, 0.10)	148	0.02 (–0.05, 0.10)	138	0.04 (–0.04, 0.12)
High (≥7 kg)	150	0.09 (0.01, 0.17)	150	0.09 (0.01, 0.16)	144	0.10 (0.02, 0.18)

Low and high categories split at the median (kg) for those with pesticide exposures greater than 0 within a 400-m radius of the residence. None indicates no pesticide applications were applied within a 400-m radius of the child's residence.

[a]Minimally adjusted for sex and language of survey.

[b]Fully adjusted for sex, language of survey, health insurance, parent/guardian education, and exposure to environmental smoking.

Ref indicates reference group.

Associations between exposure to pesticides and respiratory symptoms appear to be higher in children with asthma (Table 3). Among children with a history of asthma, those in the "high" exposure group had a prevalence of wheezing that was 17% (95% CI: –4%, 39%), 14% (95% CI: –6%, 35%), 19% (95% CI: –4%, 42%), 24% (95% CI: –2%, 51%), and 19% (95% CI: –0.8%, 38%) percentage points higher than that among children not exposed to all pesticides, sulfur only, all pesticides except sulfur, chlorpyrifos, or glyphosate, respectively (Table 3). While a stronger effect is observed among asthmatics there are significant positive associations for nonasthmatics in the high category of chlorpyrifos and all minus sulfur. Among nonasthmatic children, those in the "high" exposure group had a prevalence of wheeze that was 6 (95% CI: 0.2%, 12%) and 10 (95% CI: 0.8%, 18%) percentage points higher than that among unexposed children to all pesticides except sulfur and chlorpyrifos, respectively (Table 3).

In sensitivity analyses that excluded children exposed to environmental secondhand smoking, estimates of association were similar (Table S1; http://links.lww.com/EE/A296). Excluding participants whose biological mom smoked during pregnancy did not materially change the estimates (Tables S2 and S3; http://links.lww.com/EE/A296). We also investigated adjustment and stratifying by time of residence in the home since birth (lifetime never moved vs. moved), with estimates attenuating for all participants (Tables S4–S6; http://links.lww.com/EE/A296).

Discussion

We observed consistent cross-sectional associations between exposure to pesticides applied within 400 m of children's residences within the past 12 months and reported wheeze during this time. Those in the highest exposure group experienced a higher prevalence of wheeze compared to unexposed children for all pesticides groups we examined: all pesticides, sulfur only, all pesticides except sulfur, chlorpyrifos, and glyphosate, respectively. There was limited evidence of an association in the prevalence of 12-month prior wheeze between the "Low" exposure group and the unexposed group for any of the pesticide groups; however, we saw a suggestive positive trend across categories. Associations between exposure to pesticides and respiratory symptoms appear to be higher in children with asthma, but positive, albeit weaker trends, also were observed among nonasthmatic children.

Our findings are consistent with previous studies reporting an association between general exposure to pesticides and increased wheezing in children.[58–61] While our sample size is small, we did find a consistent association between recent exposures (12 months) to chlorpyrifos or glyphosate and wheezing in children. Previous studies in urban environments have not reported an association between prenatal exposure to OPs and wheezing in children at ages 5[34] or 8.[35] Exposure to glyphosate and wheezing among children has not been previously reported, however, exposure to glyphosate has been linked to wheezing among farmers.[62,63] Furthermore, a previous cohort study in rural Salinas Valley, CA, USA, the CHAMACOS (the Center for the Health Assessment of Mothers and Children of Salinas) study, utilized the CDPR PUR database to assess pesticide exposures and respiratory health.[17,64] Similar to our findings, a 10-fold increase in exposure to sulfur within 1000 m of a child's residence was associated with a decrease in lung function.[17] However, in the same CHAMACOS cohort, no associations were found between exposure to chloropicrin, metam sodium, 1,3-dichloropropene, or methyl bromide within 8000 m and lung function.[64] In contrast, a different study in Central and Southern California found that ambient concentrations of methyl bromide and 1,3-dichloropropene were each associated with asthma emergency department visits.[65,66] In our present AIRE cohort, we were limited in finding associations with the same pesticides (i.e., 1,3-dichloropropene, pendimethalin, bensulide, or trifluralin [data not shown]) as their use in Imperial Valley was less widespread.

Mechanism of action and class of pesticide (e.g., herbicide, fumigant, and OPs) are important factors to consider in relation to public health concerns. While the mechanisms of action may differ, the fumigant sulfur, the OP chlorpyrifos, and the herbicide glyphosate are all considered respiratory irritants.[67–70] Experimental models also suggest that low-level organophosphorus pesticides (OP's) exposure can activate many of the inflammatory mediators involved in asthma hyperactivity.[71] The mechanism of action will vary by class and type of pesticide, for example, OPs (e.g., chlorpyrifos) contribute to airway hyperreactivity via neurogenic inflammation[72–75] and oxidate stress.[76] Lung inflammation, characterized by type 2 (TH2) immune responses, is associated with allergy and plays a key role in asthma development.[77] However, unlike OPs, sulfur has not been found to induce an inflammatory response in the lungs.[78]

For children residing in rural communities, such as the Imperial Valley, it is important to not only consider mechanisms of action but also cumulative exposures. In 2018, California started limiting the application of pesticides within 402 m (1/4 mile) of schools.[12] However, in the AIRE study, we find that within 400 m of child residences, there were 150 different pesticides applied over a 12-month period. Our findings suggest that reducing pesticide applications near residential homes could protect children's respiratory health. While both the CHAMACOS and AIRE cohorts enrolled primarily children from under-resourced Latino families, the majority of the children in the AIRE cohort are not from a household where a parent or caretaker is a farmworker. This suggests that pesticide drift and inhalation may be of greater concern than the take-home exposure pathway of the CHAMACOS cohort.[1,13,14,79] Interventions aimed at reducing exposure through the take-home pathway include having the parents/caregivers change into different clothes, recommending wet cloth mopping, and extra mats outside the home; however, these recommendations are unlikely to reduce pesticide exposure through drift.[1,13,14]

Pesticide exposures have long been identified by researchers and community voices as an important environmental justice issue impacting not only agricultural workers but also nearby residents.[2,80–82] In the United States alone, the agricultural sector accounts for nearly 90% of the total pesticide usage, making agricultural farmworkers, their families, and nearby residents particularly vulnerable to the effects of pesticides.[44] While efforts have been made to advance labor and occupational safety laws, these have continuously excluded agricultural workers, who have fewer protections than most other occupations in the United States.[83] Over the years, significant gains in monitoring, reporting, and policy changes such as limiting agricultural pesticide use within 0.4 km of schools have been achieved.[84] However, disparities persist, pesticide use is disproportionately located in communities experiencing the highest levels of poverty, and communities of color.[8,9] Rural communities such as Imperial Valley continue to rank among the top communities most burdened by toxic pollution, including pesticides according to CalEnviroScreen 4.0 (Table S7; http://links.lww.com/EE/A296).[85]

Our study has several strengths and limitations. We leveraged data from a relatively large, ongoing cohort study of children's respiratory health, with detailed health and covariate information, and available agricultural pesticide application data to address a key gap in the literature. We utilized the validated ISAAC questionnaire to assess respiratory symptoms and had a geographical location of the child's residence, which allowed us to individually link each child to administrative records of nearby pesticide applications through the CDPR. Because we did not use direct biological or environmental monitoring, we were unable to estimate body burden, which may have resulted in some exposure misclassification during the 12-month period exposure period. Additionally, while a previous study has estimated that a large amount of the variability in outdoor air for the fumigant methyl bromide can be explained by the use of proximity to agricultural applications using the PUR data, the fumigant sulfur assessed in this study has not been evaluated in a similar manner.[86] Furthermore, the sample size for the children in "high" exposure group for chlorpyrifos and glyphosate is small (n = 63 and n = 144, respectively). We also cannot rule out unmeasured confounding by other sources of pesticide exposure, such as pesticide use in the home, as we do not have reliable data on pesticide use at home for these participants.

Conclusion

We found that children highly exposed to pesticide applications (including sulfur, chlorpyrifos, and glyphosate) within 400 m of their homes had an increased prevalence of 12-month prior wheeze compared to unexposed children in a rural, predominantly Latino community in southeast California. Children living in agricultural communities are often exposed to multiple pesticides[16] and Imperial Valley remains one of the highest pesticide use areas in CA.[40–44] In this intensively farmed community, fields are planted and harvested several times a year. There are over 100 different types of crops cultivated and over 50 pesticides (differentiated by active ingredient) used in Imperial Valley amounting to over five million pounds of pesticides applied annually. As schools and homes are located in close proximity to agricultural fields, exposure to pesticides is of great concern. The pesticide drift exposure pathway is of particular concern for rural children, as these often come on top of social and economic challenges faced in rural communities. In addition to future studies evaluating the relationships between other classes of pesticides and objective measures of respiratory health, policies aimed at reducing pesticide applications near residential zones should be prioritized.

Conflicts of interest statement

The authors declare that they have no conflicts of interest with regard to the content of this report.

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