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Pesticide Exposure Among Latinx Children: Comparison of Children in Rural, Farmworker and Urban, Non-Farmworker Communities

Thomas A. Arcury[a], **Haiying Chen**[b], **Sara A. Quandt**[c], **Jennifer W. Talton**[b], **Kim A. Anderson**[d], **Richard P. Scott**[d], **Anna Jensen**[e], **Paul J. Laurienti**[f]

[a]Department of Family and Community Medicine, and Center for Worker Health, Wake Forest School of Medicine, Winston-Salem, NC 27157, USA;

[b]Department of Biostatistics and Data Science, Division of Public Health Sciences, Wake Forest School of Medicine, Winston-Salem, NC 27157, USA;

[c]Department of Epidemiology and Prevention, Division of Public Health Sciences, and Center for Worker Health, Wake Forest School of Medicine, Winston-Salem, NC 27157, USA;

[d]Department of Environmental and Molecular Toxicology, Oregon State University, 2750 SW Campus Way, Corvallis, OR 97331, USA;

[e]North Carolina Farmworkers Project, 1238 NC Highway 50 S, Benson, NC 27504, USA;

[f]Department of Radiology, Wake Forest School of Medicine, Winston-Salem, NC 27157, USA;

Abstract

Personal pesticide exposure is not well characterized among children in vulnerable, immigrant communities. We used silicone wristbands in 2018–2019 to assess pesticide exposure in 8 year old Latinx boys and girls in rural, farmworker families (n=73) and urban, non-farmworker families (n=60) living in North Carolina who were enrolled in the PACE5 Study, a community-based participatory research study. We determined the detection and concentrations (ng/g) of 75 pesticides and pesticide degradation products in the silicone wristbands worn for one week using gas chromatography electron capture detection and employed gas chromatography mass spectrometry. Differences by personal and family characteristics were tested using analysis of

Correspondence: Thomas A. Arcury, PhD, Department of Family and Community Medicine, Wake Forest School of Medicine, Medical Center Boulevard, Winston-Salem, NC 27157, Phone: 336-716-9438, Fax: 336-716-3206, tarcury@wakehealth.edu.
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Declaration of interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

variance or Wilcoxon Rank Sum tests when necessary. Pesticide concentrations above the limit of detection were analyzed, and reported as geometric means and 95% confidence intervals (CI). The most frequently detected pesticide classes were organochlorines (85.7%), pyrethroids (65.4%), and organophosphates (59.4%), with the most frequently detected specific pesticides being alpha-chlordane (69.2%), trans-nonachor (67.7%), gamma-chlordane (66.2%), chlorphyrifos (54.9%), cypermethrin (49.6%), and trans-permithrin (39.1%). More of those children in urban, non-farmworker families had detections of organochlorines (93.3% vs. 79.5, p=0.0228) and pyrethroids (75.0% vs. 57.5%, p=0.0351) than did those in rural, farmworker families; more children in rural, farmworker families had detections for organophosphates (71.2% vs. 45.0%, p=0.0022). Children in urban, non-farmworker families had greater concentrations of alpha-chlordane (geometric mean (GM) 18.98, 95% CI 14.14, 25.47 vs. 10.25, 95% CI 7.49, 14.03; p=0.0055) and dieldrin (GM 17.38, 95% CI 12.78 23.62 vs. 8.10, 95% CI 5.47, 12.00; p=0.0034) than did children in rural, farmworker families. These results support the position that pesticides are ubiquitous in the living environment for children in vulnerable, immigrant communities, and argue for greater effort in documenting the widespread nature of pesticide exposure among children, with greater effort to reduce pesticide exposure.

Keywords

Pesticides; Exposure assessment; Personal monitoring; Farmworkers; Health equity; Community-based participatory research

Introduction

Latinx immigrant communities in the United States are vulnerable (Castañeda et al. 2015). These immigrants often have low incomes, live in substandard, crowded housing, have limited access to health care, and suffer from discrimination. Adults in these communities often work in the most hazardous jobs in the most dangerous industries, including agriculture, building maintenance and cleaning, construction, fishing, forestry, landscaping and lawn maintenance, and meat and poultry processing (Moyce & Schenker 2018).

Children in Latinx immigrant communities experience residential and neighborhood environments that expose them to social (Arcury et al. 2015; Hibbert & Tulve 2019; Stone et al. 2019) and physical stressors (Blackowicz et al. 2016; Kataria et al. 2017 Perla et al. 2015). Pesticides are one environmental hazard to which children in Latinx immigrant communities are exposed (Hernandez et al. 2019; Jain 2018; London et al. 2012; Quandt et al. 2020; Tamaro et al. 2018). Pesticide exposure can have immediate and long-term effects on children's health (Roberts & Reighart 2013), with immediate effects, depending on dose, including nausea, rash, burning eyes, coma, and death, and long-term effects including increased risk for cancer, reproductive health problems, and neurocognitive and developmental effects. Developmental effects of prenatal pesticide exposure include neurobehavioral difficulties (Engel et al. 2011; Engel et al. 2015; Eskenazi et al 2007; Rohlman et al. 2005), developmental disorders (Harari et al. 2010; Kofman et al. 2006), and altered brain anatomy (Rauh et al. 2012). Analyses of the developmental effects of postnatal pesticide exposure are not conclusive, but indicate neurobehavioral deficits (Butler-Dawson et al. 2016; Grandjean et al. 2006; Lizardi et al. 2008; Munoz-Quezada et al. 2013; Ruckart et al. 2004).

Latinx child pesticide exposure research in the United States has largely focused on agricultural communities, particularly children in farmworker families (e.g., Arcury et al. 2005, 2006, 2007; Bradman et al. 2011; Butler-Dawson et al. 2016; Eskenazi et al. 2007; Harley et al. 2019; Quandt et al. 2004; Harley et al. 2019; Lu et al. 2000). This is reasonable given the large amounts of pesticides used in agriculture. However, pesticides are used everywhere, and some research indicates that children in non-farmworker communities are also exposed to a large number of pesticides (e.g., Quirós-Alcalá et al. 2011; Rohlman et al. 2005). Comparisons of Latinx adult men and women living in North Carolina rural, farmworker communities and in urban, non-agricultural communities found that pesticide urinary metabolites were detected in high percentages of all groups (men and women, rural and urban) (Arcury et al. 2017, 2018).

Much of the research on Latinx child pesticide exposure in the United States has examined exposures to organochlorine and organophosphate pesticides (which are neurotoxicants) (Arcury et al. 2005, 2006, 2007; Harley et al. 2016; Marks et al. 2010). Most of the organochlorine pesticides are now banned from use in the United States, but, because they are persistent, they still linger in the environment. Many of the organophosphate pesticides also have been withdrawn from use for residential and agricultural purposes. Although the organophosphate pesticides are non-persistent and breakdown when exposed to sunlight (Zhang et al. 2008), they may linger in protected environments (e.g., inside buildings) for years. Less research has documented whether these children are exposed to other insecticides, such as pyrethroids, which are neurotoxicants (Arcury et al. 2007; Quandt et al. 2004; Harley et al. 2019). Nor has research examined child exposure to other pesticides, such as fungicides and herbicides, which include chemicals that are neurotoxicants, endocrine disruptors, and carcinogens.

Understanding the level of pesticide exposure experienced by Latinx children in non-agricultural as well as agricultural communities is important for developing regulations and procedures to reduce this exposure and to monitor potential health effects. The aims of this paper are to document the pesticide exposure of Latinx children, and compare exposure between Latinx children living in rural, farmworker communities and Latinx children living in urban, non-farmworker communities.

Materials and Methods

The data for this analysis are from the baseline visit for Preventing Agricultural Chemical Exposure 5 (PACE5). PACE5 is a community-based participatory research project conducted in partnership between the North Carolina Farmworkers Project (Benson, NC; https://ncfwp.org/) and Wake Forest School of Medicine. It is a large, two-group, prospective, longitudinal study examining the health and cognitive effects of pesticide exposure for Latinx children in farmworker and non-farmworker families. The study's comparative design includes a sample of children in rural, Latinx farmworker families and a sample of children in similar urban, Latinx families that do not include members employed as farmworkers. The Wake Forest School of Medicine Institutional Review Board approved the PACE5 protocol and procedures. The study received a Certificate of Confidentiality from the National Institutes of Health.

Participant Recruitment

Children and their parents or guardians were recruited from March 2018, to December 2019. Seventy-six children were recruited for the rural, farmworker sample and 65 for the urban, non-farmworker sample. The farmworker participants reside in eastern North Carolina, in the counties surrounding the town of Benson. The urban, non-farmworker participants reside in central North Carolina, in the counties surrounding the city of Winston-Salem. The sample for this analysis includes 133 participants (73 children in rural, farmworker families and 60 children in urban, non-farmworker families) who completed the pesticide exposure data collection.

Inclusion criteria for the children were similar in both samples. All children had to be from families that self-identified as Latino or Hispanic, and with household incomes below 200% of the US federal poverty line. Children had to be aged 8 years at baseline, and had to have completed the first grade in the United States. For children in rural, farmworker families, the parent or partner living in the same house must have been employed in farm work on non-organic farms during the past three years. For children in the urban, non-farmworker sample, adults living in the same house could not have been employed in an industry that involves routine exposure to pesticides (e.g., farm work, landscaping, pest control) in the previous three years. Families in the urban, non-farmworker sample could not have lived adjacent to agricultural fields in the previous three years. Children were excluded from the study if they had a life threatening illness, prior history of neurological conditions, physical condition or development disorder that would not allow them to complete or would interfere with the results of neurobehavioral tests or MRIs (used in the larger main study), primary language other than Spanish or English spoken in the home, or refusal of parent/guardian to complete the questionnaires.

For children in rural, farmworker families, North Carolina Farmworkers Project developed a list of families with an 8 year old child, and the locations where they lived. This included families who had participated in a previous study of child growth and nutrition (Arcury et al. 2015). In addition, other community organizations that served farmworker families in the recruitment area were contacted. For the urban, non-farmworker sample, local recruiters in Winston-Salem and community members developed a list of families with an 8 year old child. For both samples, parents were contacted by a bilingual staff member who explained the overall study procedures, answered questions, and, if the parent agreed to participate, obtained signed informed consent from the parent and assent from the child. Because interviewers worked through community partners, the number of potential participants or their parents who refused to participate is not known.

Data Collection

The PACE5 baseline visit included an interviewer-administered questionnaire completed by the child’s parent/guardian and the child wearing a silicone wristband for a week to gather pesticide exposure data. Participants received a $20 incentive for completing the baseline questionnaire and a $10 incentive for wearing the silicone wristband. The season in which the baseline visit was completed differed between the two cohorts (Table 1). More of the rural, farmworker participants completed the baseline data collection in March-May (45.2% versus 23.3%) and September-November (34.2% versus 18.3%); more of the urban, non-farmworker participants completed the baseline data collection in June-August (50.0% versus 5.5%).

The questionnaire included demographic and background data on the family and child. Spanish-language items and scales were adapted from existing questionnaires when available (e.g., Arcury et al. 2014). New items were developed in English, translated into Spanish by a bilingual native Spanish speaker, and back translated into English by a bilingual native English speaker. Community partners reviewed the questionnaire content and items. Seven Spanish-speaking individuals from farmworker and non-farmworker communities completed pre-test interviews. Questionnaire items were revised based on the review and pre-testing.

Interviewers were native Spanish speakers; all spoke English, but with varying degrees of proficiency. They completed training before data collection began which included didactic instruction on the participant inclusion criteria, recruitment procedures, questionnaire content, and collecting silicone wristbands. The interviewers completed audio-recorded practice interviews before the start of data collection. The interviewers entered data in real time during the interviews using Research Electronic Data Capture (REDCap), hosted at Wake Forest School of Medicine through the Clinical and Translational Science Institute. The REDCap system provides secure, web-based applications for a variety of types of research (Harris et al. 2009)

At the end of the interview, interviewers gave the child a silicone wristband for passive pesticide exposure monitoring, and the parent and child were given specific instructions on how it should be worn on seven consecutive days (Anderson et al. 2017). The parent was also given a Teflon bag in which to store the wristband at the end of the seven-day period. The interviewers scheduled a time to retrieve the wristband, and stored it in the Teflon bag until shipment to the laboratory.

Laboratory Procedures

Wristbands were purchased from 24hourwristbands (Houston, TX). Conditioning, post-deployment cleaning, and extraction of the wristbands were performed as described previously (Bergman et al. 2017; Anderson et al. 2017; Donald et al. 2016a). Briefly, wristbands were rinsed in deionized water to remove particulates (Anderson et al. 2017), dried, and conditioned in a Blue-M Model# POM-18VC-2 vacuum-oven (300°C, 0.12 Torr) for three hours with periodic N_2 sweeps. Post-conditioning, individual wristbands were packaged in polytetrafluoroethylene (PTFE) bags prior to deployment.

For post-deployment cleaning, the wristbands were rinsed with 18 MΩ·cm water and isopropanol to remove particulate matter. Extraction surrogates tetrachloro-meta-xylene (TCMX), decachlorobiphenyl, and PCB100 were added and the wristbands extracted with two 50 mL volumes of ethyl acetate, combined and quantitatively reduced to 1 mL. When necessary to remove analytical interferences, a 200 μL aliquot of extract underwent solid-phase extraction (SPE) on a C18 silica column with acetonitrile (Donald et al. 2016a; Kile et al. 2016), followed by a solvent exchange to isooctane for injection. All solvents were Optima-grade or equivalent (Fisher Scientific, Pittsburgh, PA). All analytical grade standards purchased from Accustandard (New Haven, CT) with purities of 95% or higher.

A 22-minute GC-ECD method has been developed and validated for analysis of pesticides in passive sampler wristbands (Donald et al. 2016b; Kile 2016; Harley et al. 2019; Vidi et al. 2017). 4,4′-dibromooctafluorobipheny was added as an internal standard, and extracts analyzed using an Agilent 6890N gas chromatograph (GC) with dual micro-electron detectors (ECD), simultaneous injection was preformed using dual 7683 auto samplers onto DB-17MS and a DB-5MS column. A complete analyte list, detection limits, quantitation limits and chromatographic conditions are given in the electronic supplementary material (Tables S1 and S2). For most analytes, identification and quantitation were made on the DB-17MS column, and the DB-XLB column was used for confirmation.

Quality assurance/quality control: Sample handling, analysis, and quantitation were performed as defined by laboratory data quality objectives and standard operating procedures. Surrogate standard compounds accounted for any loss during extraction and analysis of passive sampling devices. Instrument blanks and continuing calibration checks were analyzed regularly during chromatography. Construction and process blanks were included in the analysis.

Measures

Farmworker family status is the basic child characteristic for the larger study and has the values of rural, farmworker family versus urban, non-farmworker family as defined by the inclusion criteria. Other personal characteristics include the child’s gender, and whether the child was born in the United States or another country (e.g., Mexico, Guatemala).

Household characteristics include whether both parents were present in the household, and number of persons in the household, with the values 3–4, 5–6, 7 or more. Farm work is seasonal; for some months in each year no member of a household may be employed in agriculture, but may still be considered a farmworker family. Three dichotomous measures were constructed: a parent currently employed in farming; a parent currently employed in construction; and a parent currently employed in cleaning and maintenance.

The first measures of pesticide exposure are the wristband detections (presence/absence) of each of 75 specific pesticides and pesticide degradation products. Selection of pesticides and pesticide degradation products was based on toxicology and exposure studies (Anderson et al. 2017) and previous studies (e.g., Harley et al. 2019), coupled with method validation studies for the wristbands and the analytical method. The second measures of pesticide exposure are detections (presence/absence) of at least one specific pesticide from each of 15 pesticide classes; the pesticide classes are organochlorine, pyrethroid, organophosphate, phenylpyrazole, neonicatinoid, chloroneb, dicarboximide, pentachloronitrobenzene, thiadiazole, dinitroaniline, aniline, triazine, benzenedicarboxylic acid, oxadiazole, and thiocarbamate. Total pesticide class detections is the number of different pesticide classes (0 to 15) detected in a wristband. Total specific pesticide detections is the number of different specific pesticides (0 to 75) detected in a wristband. Number of organochlorine detections is the number of different organocholorine pesticides detected in a wristband (0 to 32), and number of pyrethroid detections is the number of different pyrethroid pesticides detected in a wristband (0 to 8). This measure was not calculated for the other pesticide classes because usually only one pesticide from a class was detected in a wristband. Concentrations in ng/g are reported as geometric means and were calculated only for those pesticides with detections and additionally for those with a minimum number of 20 wristbands with detections.

Data analysis

Participant personal and family characteristics were summarized using counts and percentages. Pesticide exposure included detection of specific pesticides and pesticide classess. Presence of pesticide by personal and family characteristics was compared using chi-square tests or Fisher's exact tests when necessary. The number of detections for individual or overall pesticide class was summarized using means and standard deviations (SD), or median and quartiles when the distribution is highly skewed. Differences by personal and family characteristics was tested using analysis of variance or Wilcoxon Rank Sum tests when necessary. Pesticide concentrations above the limit of detection were analyzed on the log scale; including concentrations below the limit of detection would result in lower values. The estimates were then back tranformed and reported as geometric means and 95% confidence intervals (CI). All analyses were performed using SAS 9.4 (Cary, NC).

Results

Personal and Family Chracteristics

Based on the inclusion criteria, all participants were 8 years old, all were Latinx, and all had completed the first grade; all families had incomes below 200% of poverty. This analysis includes 73 children in rural, farmwork families and 60 children in urban, non-farmworker families (Table 2). The children are evenly divided by gender, with 67 girls and 66 boys. Most (92.5%) of the children were born in the United States.

Most (86.3%) participants lived in families in which both of their parents were present. One-third (32.3%) of the children lived in families with 3 or 4 persons, 51.2% lived in families with 5 or 6 persons, and 16.5% lived in families with 7 or more persons. Over one-third (36.1%) of the participants had at least one parent currently employed in farming, 43.6% in construction, and 15.8% in cleaning and maintenance. All 48 (100.0%) of the participants with a parent currently working in agriculture were rural, farmworker children; 23 (39.7%) of the participants with a parent currently working in construction were rural, farmworker children, and 35 (60.3%) were urban, non-farmworker children; and 14 (66.7%) of the participants with a parent currently working in cleaning and maintenance were rural, farmworker children, and 7 (33.3%) were urban, non-farmworker children.

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Pesticide Exposure

Forty-nine of 75 different pesticides and pesticide degradation products included in the laboratory analysis were detected in the wristbands (Table 3). Twenty-three different organochlorine pesticides were detected in the children's wristbands, with many children having detections for alpha-chlordane (69.2%), gamma-chlordane (66.2%), trans-nonachlor (67,7%), and dieldrin (43.6%). Fewer but still a substantial percent of children had detections for 4–4-DDE (15.0%) and heptachlor (13.5%). Eight different pyrethroid pesticides were detected. The most common were cypermethrin (49.6%), cis-permethrin (36.8%), and trans-permetrhin (39.1%). Four different organophosphate pesticdes with detected, with chlorpyrifos (54.9%) being the only commonly detected pesticide in this class.

Several pesticide classes were commonly detected in the wristbands worn by these children (Table 4). High percents of the children had detections for organochlorine (85.7%), pyretrhoid (65.4%), and organophospate (59.4%) pesticides. Far smaller, but still subsantial percents of the children had detections for phenylpyrazole (17.3%) dinitroaniline (12.0%), and aniline (10.5%) pesticides. On average, children had detections for 2.7 different pesticide classess, and 5.7 different pesticides. They had 3.1 average organochlorine detections and a median of 1.0 pyrethorid pesticide detections.

Associations of Personal and Family Characteristics with Pesticide Exposure

More urban, non-farmworker than rural, farmworker children had detections for any organochlorine pesticide (93.3% versus 79.5%) and for any pyrethroid pesticide (75.0% versus 57.5%) (Table 5). More rural, farmworker than urban, non-farmworker children had detections for any organophosphate pesticide (71.2% versus 45.0%). Similarly, more children with a parent not currently employed in farming had detections for any organochlorine pesticide (90.6% versus 77.1%) and for any pyrethroid pesticide (72.9% versus 52.1%), with more of those having a parent currently employed in farming having a detection for a phenylpyrazole pesticides (27.1% versus 11.8%). More children having a parent currently employed in construction had a detection for any organochlorine pesticide (93.1% versus 80.0%).

The total number of specific pesticide detections were greater for urban, non-farmworker children (6.3) versus rural, farmworker children (5.2), as were the total number of organochlorine detections (3.8 versus 2.5), and the total number of pyrethroid detections (1.5 versus 1.0) (Table 6). Similarly, more children with a parent not having a farming occupation had a greater number of organochlorine pesticide detections (3.4 versus 2.5) and pyrethroid pesticide detections (1.0 versus 1.0).

Differences in Detections and Concentrations of Commonly Detected Pesticides

Variation in detections and concentrations were examined for specific pesticides with at least 20 detections (Table 7). For several specific organochlorine pesticides, urban, non-farmworker children had more detections than did rural, farmworker children, including alpha-Chlordane (81.7% versus 58.9%), gamma-Chlordane (88.3% versus 47.9%), Dieldrin (60.0% versus 30.1%), and trans-Nonachlor (90.0% versus 49.3%). Concentrations among those with detections were also greater for urban, non-farmworker children compared to rural, farmworker children for two of these organochlorine pesticides, including alpha-Chlordane (geometric mean of 18.98 versus 10.25), and Dieldrin (geometric mean of 17.38 versus 8.10). Rural, farmworker and urban, non-farmworker children did not differ in detections or concentrations for specific pyrethroid pesticides. More rural, farmworker children than urban, non-farmworker children had detections for the ogranophosphate pesticide chlorpyrifos (67.1% versus 40.0%), but concentrations of chlorpyrifos did not differ between rural, farmworker and urban, non-farmworker children for which chlorpyrifos was detected.

Discussion

Latinx rural, farmworker and urban, non-farmworker children in North Carolina are exposed to a large number of different pesticides. The most common pesticides to which they are exposed are insecticides. They include organochlorines, which have largely been banned for use in the United States; organophosphates, which have largely been banned for residential use in the United States, and have been limited for agricultural use in the United States; and pyrethroids, which are widely used for residential and agricultural insect control, and which are present in an array of consummer products, including home insect sprays, insect repellents, treatments for human head lice, pet sprays and shampoos to control fleas. All three of these pesticides classes are neurotoxicants. These children are also exposed to array of other insecticides, fungicides, and herbicides.

The silicone wristbands used in this research can measure the bioavailable exposure to these pesticides (the bioavailable pesticides in the environment) and not the pesticide dose (the amounts of pesticides absorbed by a person). However, all of these pesticides can be absorbed through the skin, through inhalation, as well as ingested when people (children) put their hands into their mouths. Few studies have compared bioavailable exposure to toxicants using the silicone wristbands with dose, and these studies have been limited polycyclic aromatic hydrocarbons (PAHs) (Dixson et al. 2018), organophosphate flame retardants (Gibson et al. 2019; Hammel et al. 2016, 2018), and nicotine (Quintana et al 2019). Research is needed to document the associations of bioavailable exposure as measured in silicone wristbands with the individual’s actual pesticide dose.

Earlier studies focused on pesticide exposure in North Carolina farmworker houses (Quandt et al. 2004), and pesticide dose measured for children in North Carolina farmworker families (Arcury et al. 2005, 2006, 2007) found residential and agricultural pesticides were present in almost all of these houses, and that most of these children had detections for organophosphate pesticide urinary metabolites, with high concentrations of these pesticide urinary metabolites. The current results are similar to analyses comparing pesticide urinary metabolite detections of adult male and female Latinx rural farmworkers to urban residents not engaged in agriculture or other pesticide intensive industries (Arcury et al. 2016, 2017, 2018). These earlier analyses found that most Latinx male rural farmworkers and urban residents had detections and high concentrations of the six dialkylphosphate urinary metabolites of organophosphate pesticides, of the specific organophosphate metabolites TCPY (3,5,6-trichloropyridinol), MDA (malathion dicarboxylic acid), APE (acephate), and

METH (methamidaphos), and of the pyrethroid metabolites 3PBA (3-phenoxybenzoic acid) and DCCA (cis,trans-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylic acid) (Arcury et al. 2016, 2017). For some of these metabolites, more of the urban, non-farmworker men had detections than did the farmworkers. Detections of the organophosphate and pyrethroid pesticide urinary metabolites were also common among rural, farmworkers and urban, non-farmworker women, with each group having high concentrations of the pesticides metabolites detected (Arcury et al. 2018).

Harley and colleagues (2019) analyzed the same type of silicone wristbands worn by the participants in the current study; these silicone wristbands were analyzed by the same laboratory. Harley et al.'s participants were 14 to 16 year old Latina girls (N=97) living in the agricultural Salinas Valley, California. Samples were collected in June 3 to August 4, 2016. The list of pesticides detected in at least 33% of the wristbands in at least one of the two studies are listed in Table 8. Both Harley et al. and the current study found high prevalence of exposure to a wide variety of pesticides, but children in the two studies were generally exposed to two different sets of pesticides. Only some of the pyrethroid pesticides (cypermethrin, trans-permethrin, cispermethrin) were commonly found in both studies, as well as the organophosphate pesticide chlorpyrifos. Harley et al. report greater detections of the pyrethroids; the current analysis found greater detection of chlorpyrifos. This comparison indicates potential age, gender, regional, and temporal differences in pesticide exposure that need to be addressed in future research and interventions to reduce pesticide exposure.

The current results indicate a consistent pattern of urban, non-farmworker children having more detections than the rural, farmworker children for organochlorine and pyrethroid pesticides, with greater concentrations of several organochlorine pesticides among those with detections. The greater concentration of pyrethroid insecticides among the urban, non-farmworker children should be considered with caution due to seasonal differences in when the data were collected. The rural, farmworker children have more detections for organophosphate and phenylpyrazole pesticides. Further research is needed to determine differences between urban, non-farmworker children and rural, farmworker children leading to greater exposure to organochlorine and pyrethroid insecticides among urban, non-farmworker children, and greater exposure to organophosphate insecticides among rural, farmworker children. Such research could examine residential pesticide application behaviors, adult knowledge of pesticide safety, pesticides endemic in the housing stock, and pesticide drift from commercial applications. Another factor to consider is the need to develop laboratory procedures that can measure additional pesticides. One can only find the pesticides that can be detected with current laboratory procedures, and pesticides commonly used in North Carolina agriculture, for example, acephate, were not addressed with the currently laboratory analysis. Another issue for the PACE5 baseline data is that children in the two cohorts wore the wristbands at different times across the year. This will be addressed when data for quarterly follow-ups are available.

These results indicate that substantial pesticide exposure is not limited to Latinx children in rural North Carolina. All children and all adults (Latinx and non-Latinx; White, Black, Asian and Native American; rural, suburan, and urban) are probably exposed to a variety of pesticides on a daily basis. Several of the pesticides detected in this study, particularly the organochlorines, have been banned for use in the United States and many other nations for decades. Similarly, although organophosphates are still permitted for agricultural application, most, including chlorpyrifos, have been banned for residential use since 2000. The great percentage of children for whom these insecticides were detected indicates that they remain in the residential environments. Our results are similar to those reported in other studies (Harley et al. 2016; Marks et al. 2010). Research is needed to document this exposure in other ethnic, racial, and residential groups. The ubiquitous nature of the pesticide exposure among these children, both rural children living in farmworker families, and urban children living in families not involved in agriculture or other industries in which pesticides are widely used, should raise concerrn for the immediate and long-term health of all children. These pesticides are known to limit neurocognitive development (Bennet et al. 2020), damage reproducive health (Rattan et al. 2017), and increase the risk of cancer (Patel et al. 2020). These children, like all children, are at greater risk than adults for health consequences of pesticide exposure because they are still developing and because they have more years for the these consequences to develop (Chance & Harmsen 1998; Cohen Hubal et al. 2000).

The results of this study should be interpreted in terms of its lmitations. Participants in this study were not randomly selected, and all lived in two circumscribed areas of a single state. The exclusion of potential participants due to neurocognitive conditions that would not allow them to complete components of the larger study is acknowledged; these neurocognitive conditions could result from pesticide exposure. However, these exclusion criteria did not affect this analysis because, first, the neurocognitive conditions would have occurred in advance of the analysis of current pesticide exposure, and, second, no child was actually excluded from the study due to a neurocognitive condition. The seasons in which the wristband data were collected differed between the two cohorts. Measures of pesticide detection and concentration are limited by current laboratory procedures. At the same time, the sample is relatively large with the cohorts living in diverse environments. A large number of pesticides were measured by the laboratory procedures, and these procedures have been used in a variety of studies (e.g., Bergmann et al. 2017; Dixson et al. 2019; Harley et al. 2019). The study's longitudinal design of the study will allow for better control of any seaonal variation in exposure.

These results support the position that pesticides are ubiquitous in the living environment for these children. They argue for greater effort in documenting the widespread nature of pesticide exposure among children, particularly those in vulnerable communities, such as immigrant Latinx communities. Greater effort is needed to reduce pesticide exposure in these communities. These efforts need to go beyond teaching workers and families about pesticide safety, and address approaches to reduce pesticide use. Greater effort is needed to assess and address the potential health effects of pesticide exposure among childrem living in these vulnerable communities.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

Anderson KA, Points GL 3rd, Donald CE, Dixon HM, Scott RP, Wilson G, Tidwell LG, Hoffman PD, Herbstman JB, O'Connell SG. Preparation and performance features of wristband samplers and considerations for chemical exposure assessment. J Expo Sci Environ Epidemiol. 2017 11;27(6):551–559. doi: 10.1038/jes.2017.9. [PubMed: 28745305]

Arcury TA, Quandt SA, Rao P, Doran AM, Snively BM, Barr DB, Hoppin JA, Davis SW. Organophosphate pesticide exposure in farmworker family members in western North Carolina and Virginia: Case comparisons Hum Organ. 2005 Spring;64(1):40–51. [PubMed: 31467451]

Arcury TA, Grzywacz JG, Davis SW, Barr DB, Quandt SA. Organophosphorus pesticide urinary metabolite levels of children in farmworker households in eastern North Carolina. Am J Ind Med. 2006 9;49(9):751–60. doi: 10.1002/ajim.20354. [PubMed: 16804908]

Arcury TA, Grzywacz JG, Barr DB, Tapia J, Chen H, Quandt SA. Pesticide urinary metabolite levels of children in eastern North Carolina farmworker households. Environ Health Perspect. 2007 8;115(8):1254–60. doi: 10.1289/ehp.9975. [PubMed: 17687456]

Arcury TA, Nguyen HT, Summers P, Talton JW, Holbrook LC, Walker FO, Chen H, Howard TD, Galván L, Quandt SA. Lifetime and current pesticide exposure among Latino farmworkers in comparison to other Latino immigrants. Am J Ind Med. 2014 7;57(7):776–87. doi: 10.1002/ajim.22324. [PubMed: 24737498]

Arcury TA, Trejo G, Suerken CK, Grzywacz JG, Ip EH, Quandt SA. Housing and neighborhood characteristics and Latino Farmworker family well-being. J Immigr Minor Health. 2015 17(5):1458–67. doi: 10.1007/s10903-014-0126-4. [PubMed: 25367531]

Arcury TA, Laurienti PJ, Chen H, Howard TD, Barr DB, Mora DC, Summers P, Quandt SA. Organophosphate pesticide urinary metabolites among Latino immigrants: North Carolina farmworkers and non-farmworkers compared. J Occup Environ Med. 2016 11;58(11):1079–1086. doi: 10.1097/JOM.0000000000000875. [PubMed: 27820757]

Arcury TA, Chen H, Laurienti PJ, Howard TD, Barr DB, Mora DC, Quandt SA. Farmworker and nonfarmworker Latino immigrant men in North Carolina have high levels of specific pesticide urinary metabolites. Arch Environ Occup Health. 2017 6 16:1–9. doi: 10.1080/19338244.2017.1342588.

Arcury TA, Laurienti PJ, Talton JW, Chen H, Howard TD, Barr DB, Mora DC, Quandt SA. Pesticide urinary metabolites among Latina farmworkers and nonfarmworkers in North Carolina. J Occup Environ Med. 2018 1;60(1):e63–e71. doi: 10.1097/JOM.0000000000001189. [PubMed: 29023343]

Bennett B, Workman T, Smith MN, Griffith WC, Thompson B, Faustman EM. Characterizing the neurodevelopmental pesticide exposome in a children's agricultural cohort. Int J Environ Res Public Health. 2020 2 25;17(5):1479. doi: 10.3390/ijerph17051479.

Bergmann AJ, North PE, Vasquez L, Bello H, del Carmen Gastanaga Ruiz M, Anderson KA. Multi-class chemical exposure in rural Peru using silicone wristbands. J Expos Sci Environ Epidemiol. 2017. doi: 10.1038/jes.2017.12.

Blackowicz MJ, Hryhorczuk DO, Rankin KM, Lewis DA, Haider D, Lanphear BP, Evens A. The impact of low-level lead toxicity on school performance among Hispanic subgroups in the Chicago Public Schools. Int J Environ Res Public Health. 2016 8 1;13(8):774. doi: 10.3390/ijerph13080774.

Bradman A, Castorina R, Barr DB, Chevrier J, Harnly ME, Eisen EA, McKone TE, Harley K, Holland N, Eskenazi B. Determinants of organophosphorus pesticide urinary metabolite levels in young children living in an agricultural community. Int J Environ Res Public Health. 2011 4;8(4):1061–83. doi: 10.3390/ijerph8041061. [PubMed: 21695029]

Butler-Dawson J, Galvin K, Thorne PS, Rohlman DS. Organophosphorus pesticide exposure and neurobehavioral performance in Latino children living in an orchard community. Neurotoxicology. 2016 3;53:165–172. doi: 10.1016/j.neuro.2016.01.009. [PubMed: 26820522]

Castañeda H, Holmes SM, Madrigal DS, Young ME, Beyeler N, & Quesada J (2015). Immigration as a social determinant of health. Annual Review of Public Health, 36, 375–392. 10.1146/annurev-publhealth-032013-182419

Chance GW, Harmsen E: Children are different: environmental contaminants and children's health. Can J Public Health 1998; 89 (Suppl 1):S9–S13 [PubMed: 9654786]

Cohen Hubal EA, Sheldon LS, Burke JM, McCurdy TR, Berry MR, Rigas ML, Zartarian VG, Freeman NC. Children's exposure assessment: a review of factors influencing Children's exposure, and the data available to characterize and assess that exposure. Environ Health Perspect. 2000 6;108(6):475–86. doi: 10.1289/ehp.108-1638158.

Dixon HM, Scott RP, Holmes D, Calero L, Kincl LD, Waters KM, Camann DE, Calafat AM, Herbstman JB, Anderson KA. Silicone wristbands compared with traditional polycyclic aromatic hydrocarbon exposure assessment methods. Anal Bioanal Chem. 2018 5;410(13):3059–3071. doi: 10.1007/s00216-018-0992-z. [PubMed: 29607448]

Dixon HM, Armstrong G, Barton M, Bergmann AJ, Bondy M, Halbleib ML, Hamilton W, Haynes E, Herbstman J, Hoffman P, Jepson P, Kile ML, Kincl L, Laurienti PJ, North P, Paulik LB, Petrosino J, Points GL 3rd, Poutasse CM, Rohlman D, Scott RP, Smith B, Tidwell LG, Walker C, Waters KM, Anderson KA. Discovery of common chemical exposures across three continents using silicone wristbands. R Soc Open Sci. 2019 2 6;6(2):181836. doi: 10.1098/rsos.181836. [PubMed: 30891293]

Donald CE, Elie MR, Smith BW, Hoffman PD, Anderson KA. Transport stability of pesticides and PAHs sequestered in polyethylene passive sampling devices. Environ Sci Pollut Res Int. 2016a 6;23(12):12392–9. doi: 10.1007/s11356-016-6453-3. [PubMed: 26983811]

Donald CE, Scott RP, Blaustein KL, Halbleib ML, Sarr M, Jepson PC, Anderson KA. Silicone wristbands detect individuals' pesticide exposures in West Africa. R Soc Open Sci. 2016b 8 17;3(8):160433. doi: 10.1098/rsos.160433. [PubMed: 27853621]

Engel SM, Bradman A, Wolff MS, Rauh VA, Harley KG, Yang JH, Hoepner LA, Barr DB, Yolton K, Vedar MG, Xu Y, Hornung RW, Wetmur JG, Chen J, Holland NT, Perera FP, Whyatt RM, Lanphear BP, Eskenazi B. Prenatal organophosphorus pesticide exposure and child neurodevelopment at 24 months: an analysis of four birth cohorts. Environ Health Perspect. 2016 6;124(6):822–30. doi: 10.1289/ehp.1409474. [PubMed: 26418669]

Engel SM, Wetmur J, Chen J, Zhu C, Barr DB, Canfield RL, Wolff MS. Prenatal exposure to organophosphates, paraoxonase 1, and cognitive development in childhood. Environ Health Perspect. 2011 8;119(8):1182–8. doi: 10.1289/ehp.1003183. [PubMed: 21507778]

Eskenazi B, Marks AR, Bradman A, Harley K, Barr DB, Johnson C, Morga N, Jewell NP. Organophosphate pesticide exposure and neurodevelopment in young Mexican-American children. Environ Health Perspect. 2007 5;115(5):792–8. doi: 10.1289/ehp.9828. [PubMed: 17520070]

Gibson EA, Stapleton HM, Calero L, Holmes D, Burke K, Martinez R, Cortes B, Nematollahi A, Evans D, Anderson KA, Herbstman JB. Differential exposure to organophosphate flame retardants in mother-child pairs. Chemosphere. 2019 3;219:567–573. doi: 10.1016/j.chemosphere.2018.12.008. [PubMed: 30553217]

Grandjean P, Harari R, Barr DB, Debes F. Pesticide exposure and stunting as independent predictors of neurobehavioral deficits in Ecuadorian school children. Pediatrics. 2006 3;117(3):e546–56. doi: 10.1542/peds.2005-1781. [PubMed: 16510633]

Hammel SC, Hoffman K, Webster TF, Anderson KA, Stapleton HM. Measuring personal exposure to organophosphate flame retardants using silicone wristbands and hand wipes. Environ Sci Technol. 2016 4 19;50(8):4483–91. doi: 10.1021/acs.est.6b00030. [PubMed: 26975559]

Hammel SC, Phillips AL, Hoffman K, Stapleton HM. Evaluating the use of silicone wristbands to measure personal exposure to brominated flame retardants. Environ Sci Technol. 2018 10 16;52(20):11875–11885. doi: 10.1021/acs.est.8b03755. [PubMed: 30216050]

Harari R, Julvez J, Murata K, Barr D, Bellinger DC, Debes F, Grandjean P. Neurobehavioral deficits and increased blood pressure in school-age children prenatally exposed to pesticides. Environ Health Perspect. 2010 6;118(6):890–6. doi: 10.1289/ehp.0901582. [PubMed: 20185383]

Harley KG, Engel SM, Vedar MG, Eskenazi B, Whyatt RM, Lanphear BP, Bradman A, Rauh VA, Yolton K, Hornung RW, Wetmur JG, Chen J, Holland NT, Barr DB, Perera FP, Wolff MS. Prenatal exposure to organophosphorous pesticides and fetal growth: pooled results from four longitudinal birth cohort studies. Environ Health Perspect. 2016 7;124(7):1084–92. doi: 10.1289/ehp.1409362. [PubMed: 26685281]

Harley KG, Parra KL, Camacho J, Bradman A, Nolan JES, Lessard C, Anderson KA, Poutasse CM, Scott RP, Lazaro G, Cardoso E, Gallardo D, Gunier RB. Determinants of pesticide concentrations in silicone wristbands worn by Latina adolescent girls in a California farmworker community: The COSECHA youth participatory action study. Sci Total Environ. 2019;652:1022–9. doi: 10.1016/j.scitotenv.2018.10.276. [PubMed: 30380470]

Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap) - A metadata-driven methodology and workflow process for providing translational informatics support. J Biomed Inform 2009, 42, 377–381, doi:10.1016/j.jbi.2008.08.010. [PubMed: 18929686]

Hernandez M, Hernández-Valero MA, García-Prieto C, Patterson DG, Hajek RA, Recinos I, Lopez DS, Li Y, Jones LA, Hawk E. A pilot study evaluating organochlorine and organophosphate pesticide exposure in children and adolescents of Mexican descent residing in Hidalgo County, Texas. J Immigr Minor Health. 2019 8;21(4):751–760. doi: 10.1007/s10903-018-0791-9. [PubMed: 30066057]

Hibbert K, Tulve NS. State-of-the-science review of non-chemical stressors found in a child's social environment. Int J Environ Res Public Health. 2019 11 11;16(22):4417. doi: 10.3390/ijerph16224417.

Jain RB. Observed differentials in the levels of selected environmental contaminants among Mexican and other Hispanic American children, adolescents, adults, and senior citizens. Environ Sci Pollut Res Int. 2018 2;25(5):4524–4543. doi: 10.1007/s11356-017-0828-y. [PubMed: 29188596]

Kataria A, Levine D, Wertenteil S, Vento S, Xue J, Rajendiran K, Kannan K, Thurman JM, Morrison D, Brody R, Urbina E, Attina T, Trasande L, Trachtman H. Exposure to bisphenols and phthalates and association with oxidant stress, insulin resistance, and endothelial dysfunction in children. Pediatr Res. 2017 6;81(6):857–864. doi: 10.1038/pr.2017.16. [PubMed: 28099427]

Kile ML, Scott RP, O'Connell SG, Lipscomb S, MacDonald M, McClelland M, Anderson KA. Using silicone wristbands to evaluate preschool children's exposure to flame retardants. Environ Res. 2016;147:365–72. doi: 10.1016/j.envres.2016.02.034. [PubMed: 26945619]

Kofman O, Berger A, Massarwa A, Friedman A, Jaffar AA. Motor inhibition and learning impairments in school-aged children following exposure to organophosphate pesticides in infancy. Pediatr Res. 2006 7;60(1):88–92. doi: 10.1203/01.pdr.0000219467.47013.35. [PubMed: 16788088]

Lizardi PS, O'Rourke MK, Morris RJ. The effects of organophosphate pesticide exposure on Hispanic children's cognitive and behavioral functioning. J Pediatr Psychol. 2008 Jan-Feb;33(1):91–101. doi: 10.1093/jpepsy/jsm047. [PubMed: 17569709]

London L, Beseler C, Bouchard MF, Bellinger DC, Colosio C, Grandjean P, Harari R, Kootbodien T, Kromhout H, Little F, Meijster T, Moretto A, Rohlman DS, Stallones L. Neurobehavioral and neurodevelopmental effects of pesticide exposures. Neurotoxicology. 2012 8;33(4):887–96. doi: 10.1016/j.neuro.2012.01.004. [PubMed: 22269431]

Lu C, Fenske RA, Simcox NJ, Kalman D. Pesticide exposure of children in an agricultural community: evidence of household proximity to farmland and take home exposure pathways. Environ Res. 2000 11;84(3):290–302. doi: 10.1006/enrs.2000.4076. [PubMed: 11097803]

Marks AR, Harley K, Bradman A, Kogut K, Barr DB, Johnson C, Calderon N, Eskenazi B. Organophosphate pesticide exposure and attention in young Mexican-American children: the CHAMACOS study. Environ Health Perspect. 2010 12;118(12):1768–74. doi: 10.1289/ehp.1002056. [PubMed: 21126939]

Moyce SC, Schenker M. Migrant workers and their occupational health and safety. Annu Rev Public Health. 2018 4 1;39:351–365. doi: 10.1146/annurev-publhealth-040617-013714. [PubMed: 29400993]

Muñoz-Quezada MT, Lucero BA, Barr DB, Steenland K, Levy K, Ryan PB, Iglesias V, Alvarado S, Concha C, Rojas E, Vega C. Neurodevelopmental effects in children associated with exposure to organophosphate pesticides: a systematic review. Neurotoxicology. 2013 12;39:158–68. doi: 10.1016/j.neuro.2013.09.003. [PubMed: 24121005]

Patel DM, Jones RR, Booth BJ, Olsson AC, Kromhout H, Straif K, Vermeulen R, Tikellis G, Paltiel O, Golding J, Northstone K, Stoltenberg C, Håberg SE, Schüz J, Friesen MC, Ponsonby AL, Lemeshow S, Linet MS, Magnus P, Olsen J, Olsen SF, Dwyer T, Stayner LT, Ward MH; International Childhood Cancer Cohort Consortium. Parental occupational exposure to pesticides, animals and organic dust and risk of childhood leukemia and central nervous system tumors: Findings from the International Childhood Cancer Cohort Consortium (I4C). Int J Cancer. 2020 2 15;146(4):943–952. doi: 10.1002/ijc.32388. [PubMed: 31054169]

Perla ME, Rue T, Cheadle A, Krieger J, Karr CJ. Population-based comparison of biomarker concentrations for chemicals of concern among Latino-American and non-Hispanic white children. J Immigr Minor Health. 2015 6;17(3):802–19. doi: 10.1007/s10903-014-0002-2. [PubMed: 24668388]

Quandt SA, Arcury TA, Rao P, Snively BM, Camann DE, Doran AM, Yau AY, Hoppin JA, Jackson DS. Agricultural and residential pesticides in wipe samples from farmworker family residences in North Carolina and Virginia. Environ Health Perspect. 2004 3;112(3):382–7. doi: 10.1289/ehp.6554.. [PubMed: 14998757]

Quandt SA, Mora DC, Seering TL, Chen H, Arcury TA, Laurienti PJ. Using life history calendars to estimate in utero and early life pesticide exposure of Latinx children in farmworker families. Int J Environ Res Public Health. 2020 5 16;17(10):E3478. doi: 10.3390/ijerph17103478. [PubMed: 32429422]

Quintana PJE, Hoh E, Dodder NG, Matt GE, Zakarian JM, Anderson KA, Akins B, Chu L, Hovell MF. Nicotine levels in silicone wristband samplers worn by children exposed to secondhand smoke and electronic cigarette vapor are highly correlated with child's urinary cotinine. J Expo Sci Environ Epidemiol. 2019 10;29(6):733–741. doi: 10.1038/s41370-019-0116-7. [PubMed: 30728487]

Quirós-Alcalá L, Bradman A, Nishioka M, Harnly ME, Hubbard A, McKone TE, Ferber J, Eskenazi B. Pesticides in house dust from urban and farmworker households in California: an observational measurement study. Environ Health. 2011 3 16;10:19. doi: 10.1186/1476-069X-10-19. [PubMed: 21410986]

Rattan S, Zhou C, Chiang C, Mahalingam S, Brehm E, Flaws JA. Exposure to endocrine disruptors during adulthood: consequences for female fertility. J Endocrinol. 2017 6;233(3):R109–R129. doi:10.1530/JOE-17-0023 [PubMed: 28356401]

Rauh VA, Perera FP, Horton MK, Whyatt RM, Bansal R, Hao X, Liu J, Barr DB, Slotkin TA, Peterson BS. Brain anomalies in children exposed prenatally to a common organophosphate pesticide. Proc Natl Acad Sci U S A. 2012 5 15;109(20):7871–6. doi: 10.1073/pnas.1203396109. [PubMed: 22547821]

Roberts JD, Reighart JR. Recognition and Management of Pesticide Poisonings. 6th ed. Washington, DC: Office of Pesticide Programs, US Environmental Protection Agency; 2013.

Rohlman DS, Arcury TA, Quandt SA, Lasarev M, Rothlein J, Travers R, Tamulinas A, Scherer J, Early J, Marín A, Phillips J, McCauley L. Neurobehavioral performance in preschool children from agricultural and non-agricultural communities in Oregon and North Carolina. Neurotoxicology. 2005 8;26(4):589–98. doi: 10.1016/j.neuro.2004.12.002. [PubMed: 16112324]

Ruckart PZ, Kakolewski K, Bove FJ, Kaye WE. Long-term neurobehavioral health effects of methyl parathion exposure in children in Mississippi and Ohio. Environ Health Perspect. 2004 1;112(1):46–51. doi: 10.1289/ehp.6430. [PubMed: 14698930]

Stone GA, Fernandez M, DeSantiago A. Rural Latino health and the built environment: a systematic review. Ethn Health. 2019 4 19:1–26. doi: 10.1080/13557858.2019.1606899.

Tamaro CM, Smith MN, Workman T, Griffith WC, Thompson B, Faustman EM. Characterization of organophosphate pesticides in urine and home environment dust in an agricultural community. Biomarkers. 2018 3;23(2):174–187. doi: 10.1080/1354750X.2017.1395080. [PubMed: 29047308]

Vidi P-A, Anderson KA, Chen H, Anderson R, Salvador-Moreno N, Mora DC, Poutasse C, Laurienti PJ, Daniel SS, Arcury TA. Personal samplers of bioavailable pesticides integrated with a hair follicle assay of DNA damage to assess environmental exposures and their associated risks in children. Mutation Research/Genetic Toxicology and Environmental Mutagenesis. 2017;822:27–33. doi: 10.1016/j.mrgentox.2017.07.003

Zhang X, Driver JH, Li Y, Ross JH, Krieger RI. Dialkylphosphates (DAPs) in fruits and vegetables may confound biomonitoring in organophosphorus insecticide exposure and risk assessment. J Agric Food Chem. 2008 11 26;56(22):10638–45. doi: 10.1021/jf8018084. [PubMed: 18947233]

HIGHLIGHTS

- Latinx rural, farmworker and urban, non-farmworker children are exposed to a large number of different pesticides.
- The most common pesticide classes to which they are exposed include organochlorines, organophosphates, and pyrethroids.
- Urban, non-farmworker children more than rural, farmworker children experienced more organocholorine and pyrethroid class detections, more specific organocholorine and pyrethroid pesticide detections, and greater concentrations of the specific organocholorine pesticides alpha-chlordane and diedrin.
- Rural, farmwoker children more than urban, non-farmworker children experienced more detections of the organophosphate pesticide chlorpyriphos.

Table 1.

Completion of Baseline Data Collection by Season for Rural, Farmworker and Urban, Non-farmworker Participants (n=133)

Season Baseline Data Collection Completed	Rural, Farmworker (n=73)	Urban, Non-Farmworker (n=60)
	n (%)	n (%)
December – February	11 (15.1)	5 (8.3)
March – May	33 (45.2)	14 (23.3)
June – August	4 (5.5)	30 (50.0)
September – November	25 (34.2)	11 (18.3)

Table 2:

Participant Personal and Family Characteristics, PACE5 Study, 2018–2019 (n=133)

Participant Personal and Family Characteristics	n (%)
Farmworker Status	
Rural, farmworker	73 (54.9)
Urban, non-farmworker	60 (45.1)
Gender of child	
Female	67 (50.4)
Male	66 (49.6)
Child US Born	
Yes	123 (92.5)
No	10 (7.5)
Both parents present[a]	113 (86.3)
Number of persons in family[b]	
3–4	41 (32.2)
5–6	65 (51.2)
7 or more	21 (16.5)
Parent currently employed in farming	48 (36.1)
Parent currently employed in construction	58 (43.6)
Parent currently employed in cleaning and maintenance	21 (15.8)

[a] 2 missing

[b] 6 missing

Table 3:

Specific Pesticides Included in Each Class and Their Frequency of Detection, PACE5 Study, 2018–2019 (n=133).

Specific Pesticides and Pesticide Degradation Products	n (%)
Insecticides	
Organochlorine (23 detected)[a]	
1,2-Dibromo-3-chloropropane	1 (0.8)
4_4_DDD	2 (1.5)
4_4_DDE	20 (15.0)
4_4_DDT	4 (3.0)
Aldrin	4 (3.0)
alpha_Chlordane	92 (69.2)
beta-BHC	2 (1.5)
Chlorothalonil	2 (1.5)
Dieldrin	58 (43.6)
EndosulfanI	7 (5.3)
Endosulfan_sulfate	1 (0.8)
Endrin - banned	1 (0.8)
gamma_Chlordane	88 (66.2)
HCCPD	1 (0.8)
Heptachlor	18 (13.5)
Heptachlor_epoxide	5 (3.8)
Isodrin	1 (0.8)
Lindane	3 (2.3)
Methoxychlor	2 (1.5)
Mirex	2 (1.5)
o,p'-Dicofol	1 (0.8)
Perthane	1 (0.8)
trans_Nonachlor	90 (67.7)
Pyrethroid (8 detected)	
Bifenthrin	3 (2.3)
Cyfluthrin	1 (0.8)
Cypermethrin	66 (49.6)
cis_Permethrin	49 (36.8)
trans Permethrin	52 (39.1)
deltamethrin and tralomethrin	3 (2.3)
Esfenvalerate	10 (7.5)
L-Cyhalothrin	3 (2.3)
Organophosphate (4 detected)[b]	
Chlorpyrifos	73 (54.9)
Dimethoate	1 (0.8)
Ethoprophos	7 (5.3)

Specific Pesticides and Pesticide Degradation Products	n (%)
Parathion-ethyl	5 (3.8)
Phenylpyrazole (3 detected)	
Fipronil	2 (1.5)
Fipronil-sulfide	17 (12.8)
Fipronil-sulfone	6 (4.5)
Neonicatinoid – acetamiprid	0
Fungicides	
Aromatic Fungicide - Chloroneb	10 (7.5)
Dicarboximide - Captan[c]	5 (3.8)
Pentachloronitrobenzene	
Thiadiazole - Etridiazole	0
Herbicides	
Dinitroaniline (2 detected)	
Pendimethalin	1 (0.8)
Trifuralin	15 (11.3)
Aniline / Chloroacetanilide (2 detected)[d]	
Metolachlor	3 (2.3)
Propachlor	11 (8.3)
Triazine (2 detected)	
Atrazine	1 (0.8)
Simazine	3 (2.3)
Benzenedicarboxylic acid – Dacthal	1 (0.8)
Oxadiazole - Oxadiazon	1 (0.8)
Thiocarbamate - Diallate I	1 (0.8)

[a]Organochlorine pesticides not detected: alpha-bhc; chlorobenzilate; chloropropylate; delta-bhc; endosulfan ii; endrin aldehyde; endrin ketone; hexachlorobenzene; p,p’-dicofol

[b]Organophosphate pesticides not detected: chlorpyrifos_methyl; diazinon; ethion; fenitrothion; fonofos; imidan; malathion; parathion-methyl; phorate

[c]Dicarboximide pesticides not detected: captafol; iprodione; vincolzolin

[d]Aniline / Chloroacetanilide pesticides not detected: propanil; alachlor

Table 4:

Number of Participants with Detections for Each Pesticide Class, PACE5 Study, 2018–2019 (n=133).

Number of Pesticide Class Detections	n (%)
Insecticides	
Organochlorine	114 (85.7)
Pyrethroid	87 (65.4)
Organophosphate	79 (59.4)
Phenylpyrazole	23 (17.3)
Neonicatinoid	0
Fungicides	
Chloroneb (aromic fungicide)	10 (7.5)
Dicarboximide	5 (3.8)
Pentachloronitrobenzene	0
Thiadiazole	0
Herbicides	
Dinitroaniline	16 (12.0)
Aniline / Chloroacetanilide	14 (10.5)
Triazine	4 (3.0)
Benzenedicarboxylic acid	1 (0.8)
Oxadiazole	1 (0.8)
Thiocarbamate	1 (0.8)
	Mean (SD[a])
Total Pesticide Class Detections	2.7 (1.2)
Total Specific Pesticide Detections	5.7 (2.8)
Number of Organochlorine Detections	3.1 (1.8)
	Median (Q1,Q3[b])
Number of Pyrethroid Detections	1.0 (0.0–3.0)

[a]SD: standard deviation

[b]Q1, Q3: first quartile, third quartile

Table 5:

Detection of any Organochlorine, Pyrethroid, Organophosphate, or Phenylpyrazole Pesticide by Child and Family Characteristics, PACE5 Study, 2018–2019 (n=133).

Child and Family Characteristics	Pesticide Classes							
	Any Organochlorine Detection		Any Pyrethroids Detection		Any Organophosphate Detection		Any Phenylpyrazole Detection	
	n (%)	p value	n (%)	p value	n (%)	p value	n (%)	p value
Farmworker								
Rural, farmworker	58 (79.5)	0.0228	42 (57.5)	0.0351	52 (71.2)	0.0022	16 (21.9)	0.1198
Urban, non-farmworker	56 (93.3)		45 (75.0)		27 (45.0)		7 (11.7)	
Child Gender								
Female	58 (86.6)	0.7770	46 (68.7)	0.4282	37 (55.2)	0.3233	11 (16.4)	0.7880
Male	56 (84.8)		41 (62.1)		42 (63.6)		12 (18.2)	
Number of Persons in Family								
3–4	35 (85.4)	0.8426	29 (70.7)	0.4212	24 (58.5)	0.9671	8 (19.5)	0.2087
5–6	56 (86.2)		38 (58.5)		39 (60.0)		8 (12.3)	
7 +	17 (81.0)		14 (66.7)		13 (61.9)		6 (28.6)	
Farming Occupation								
Yes	37 (77.1)	0.0326	25 (52.1)	0.0152	32 (66.7)	0.1996	13 (27.1)	0.0249
No	77 (90.6)		62 (72.9)		47 (55.3)		10 (11.8)	
Construction Occupation								
Yes	54 (93.1)	0.0322	41 (70.7)	0.2606	33 (56.9)	0.6054	8 (13.8)	0.3479
No	60 (80.0)		46 (61.3)		46 (61.3)		15 (20.0)	
Cleaning and Maintenance Occupation								
Yes	19 (90.5)	0.4968	11 (52.4)	0.1712	12 (57.1)	0.8186	4 (19.0)	0.8168
No	95 (84.8)		76 (67.9)		67 (59.8)		19 (17.0)	

Table 6:

Total Detections Across Pesticide Classes, Specific Pesticides, Organochlorine Pesticides, and Pyrethroid Pesticides by Child and Family Characteristics, PACE5 Study, 2018–2019 (n=133).

Child and Family Characteristics	Total Pesticide Class Detections		Total Specific Pesticide Detections		Total Organochlorine Pesticide Detections		Total Pyrethroid Pesticide Detections	
	Number of Detections Mean (SD[a])	p value	Number of Detections Mean (SD[a])	p value	Number of Detections Mean (SD[a])	p value	Number of Detections Median (Q1,Q3[b])	p value
Farmworker								
Rural, farmworker	2.8 (1.3)	0.3150	5.2 (3.0)	0.0182	2.5 (1.9)	<.0001	1.0 (0.0–3.0)	0.0321
Urban, non-farmworker	2.6 (1.1)		6.3 (2.4)		3.8 (1.5)		1.5 (0.5–3.0)	
Child Gender								
Female	2.6 (1.3)	0.5923	5.6 (2.8)	0.7202	3.1 (1.8)	0.5362	1.0 (0.0–3.0)	0.8677
Male	2.7 (1.2)		5.8 (2.8)		3.0 (1.8)		1.0 (0.0–3.0)	
Number of Persons in Family								
3–4	2.7 (1.1)	0.9768	6.0 (2.8)	0.4423	3.3 (1.9)	0.2645	1.0 (0.0–3.0)	0.3492
5–6	2.6 (1.3)		5.4 (2.7)		3.0 (1.8)		1.0 (0.0–3.0)	
7 +	2.7 (1.2)		5.1 (2.8)		2.5 (1.7)		1.0 (0.0–3.0)	
Farming Occupation								
Yes	2.7 (1.3)	0.8983	5.2 (3.3)	0.1112	2.5 (2.0)	0.0075	1.0 (0.0–2.5)	0.0279
No	2.7 (1.2)		6.0 (2.5)		3.4 (1.6)		1.0 (0.0–3.0)	
Construction Occupation								
Yes	2.8 (1.2)	0.4648	6.1 (2.5)	0.1863	3.3 (1.6)	0.1486	1.0 (0.0–3.0)	0.2483
No	2.6 (1.3)		5.4 (3.0)		2.9 (2.0)		1.0 (0.0–3.0)	
Cleaning-Maintenance Occupation								
Yes	2.7 (1.4)	0.9920	5.5 (2.8)	0.7771	2.9 (1.8)	0.6843	1.0 (0.0–3.0)	0.4477
No	2.7 (1.2)		5.7 (2.8)		3.1 (1.8)		1.0 (0.0–3.0)	

[a]SD: standard deviation

[b]Q1, Q3: first quartile, third quartile

Table 7:

Detection and Concentration[a] (ng/g) Differences between Rural, Farmworker (n=73) and Urban, Non-farmworker (n=60) Children for Commonly Detected Pesticides and Pesticide Degradation Products (at least 20 detections), PACE5 Study, 2018–2019

Specific Pesticides and Pesticide Degradation Products	Detection		Concentration			
	n (%)	p-value	Log Mean (SE[b])	Range	geometric mean (CI[c])	p-value
Organochlorines						
4_4_DDE		0.8080				0.8258
Rural, farmworker	12 (16.4)		2.3 (0.2)	0.9 – 4.2	10.06 (6.04, 16.76)	
Urban, non-farmworker	8 (13.3)		2.2 (0.3)	1.0 – 3.1	9.23 (4.94, 17.26)	
alpha_Chlordane		0.0047				0.0055
Rural, farmworker	43 (58.9)		2.3 (0.2)	0.7 – 5.0	10.25 (7.49, 14.03)	
Urban, non-farmworker	49 (81.7)		2.9 (0.1)	0.9 – 5.4	18.98 (14.14, 25.47)	
Dieldrin		0.0005				0.0034
Rural, farmworker	22 (30.1)		2.1 (0.2)	1.2 – 3.4	8.10 (5.47, 12.00)	
Urban, non-farmworker	36 (60.0)		2.9 (0.2)	1.1 – 5.0	17.38 (12.78, 23.62)	
gamma_Chlordane		<.0001				0.2522
Rural, farmworker	35 (47.9)		2.3 (0.2)	0.5 – 4.4	10.27 (6.99, 15.08)	
Urban, non-farmworker	53 (88.3)		2.3 (0.2)	0.5 – 4.4	13.68 (10.02, 18.70)	
trans_Nonachlor		<.0001				0.1188
Rural, farmworker	36 (49.3)		1.5 (0.2)	−0.5 – 3.5	4.70 (3.20, 6.89)	
Urban, non-farmworker	54 (90.0)		1.9 (0.2)	−0.6 – 4.9	6.95 (5.09, 9.51)	
Pyrethroids						
Cypermethrin		0.4380				0.2226
Rural, farmworker	34 (46.6)		5.9 (0.2)	4.1 – 8.6	380.56 (232.66, 622.46)	
Urban, non-farmworker	32 (53.3)		5.5 (0.3)	2.5 – 8.9	246.16 (148.24, 408.78)	
cis_Permethrin		0.0770				0.5463
Rural, farmworker	22 (30.1)		5.4 (0.2)	3.0 – 8.3	230.86 (139.71, 381.49)	
Urban, non-farmworker	27 (45.0)		5.2 (0.2)	3.3 – 7.5	188.19 (119.59, 296.14)	
trans_Permethrin		0.1049				0.2665
Rural, farmworker	24 (32.9)		6.0 (0.3)	3.5 – 9.1	395.85 (238.97, 655.75)	
Urban, non-farmworker	28 (46.7)		6.4 (0.2)	4.6 – 8.5	581.65 (364.52, 928.12)	
Organophosphates						
Chlorpyrifos		0.0018				0.9567
Rural, farmworker	49 (67.1)		2.8 (0.2)	1.0 – 6.9	16.41 (12.14, 22.18)	
Urban, non-farmworker	24 (40.0)		2.8 (0.2)	1.6 – 4.3	16.18 (10.52, 24.87)	

[a]Values above the limit of detection

[b]SE = Standard error

[c]CI = Confidence interval

Table 8.

Percent detections for frequency detected pesticides (≥33% in at least one study) comparing results from Harley et al. 2019 with those of the current study.

Pesticide	Harley et al. 2019 Percent Detections for 2016	Current Study Percent Detections for 2018–19
Fipronil sulfidea	86.6	12.8
DDE	55.7	15.0
Cypermethrin	55.7	49.6
ΣPermethrin	54.6	36.8
trans-permethrin	51.5	39.1
cis-permethrin	48.5	36.8
Propachlor	53.6	8.3
Dacthal	52.6	0.8
Fipronil sulfonea	45.4	4.5
Esfenvalerate	41.2	7.5
Ethion	39.2	Not detected
Chlorpyrifos	36.1	54.9
Chloroneb	34.0	7.5
Ethoprop	34.0	5.3
Dicofol	33.0	Not detected
Dieldrin	22.7	43.6
trans_Nonachlor	14.4	67.7
alpha_Chlordane	12.3	69.2
gamma_Chlordane	9.4	66.2