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Organophosphorus pesticide exposure from house dust and parent-reported child behavior in Latino children from an orchard community

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Abstract

Background: Organophosphorus pesticide (OP) exposure is known to have adverse effects on the nervous system. Children from agricultural communities are at risk of exposure to these chemicals from their indoor environments that can lead to neurological and developmental problems, including changes in behavior.

Objective: The aim of this study is to evaluate whether the take-home pathway exposure is associated with behavioral deficits in Latino Orchid Community children.

Method: The study was implemented over a period of two years (2008-2010) in an orchard farming community with a total of 324 parents who had children between the ages of 5-12 years old. Mothers of the children were asked to complete a Child Behavior Checklist (CBCL) and dust from their carpets was collected. Emotional and behavioral deficits were assessed based on the CBCL and house dust was assessed for OP concentrations. In this study, correlations between OPs in house dust and CBCL subscales were estimated using linear regression models with total OP concentrations classified by tertiles. This study also facilitated the comparison

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between the agricultural and non-agricultural families in terms of behavioral deficits and house dust concentrations of pesticides.

Results: The data from the study shows that there was a positive association between the concentration of OP residues in house dust and internalizing behavior (β=2.06, p=0.05) whereas the association with externalizing behavior was not significant after accounting for sociocultural covariates. Significant positive associations of OP residues with somatic problems (p=0.02) and thought problems (p=0.05) were also found.

Conclusion: The data support a potential role of OP exposure in childhood development, with a specific focus on internalizing behavior. Future work focused on longitudinal studies may uncover the long-term consequences of OP exposure and behavior.

Keywords

Organophosphorus pesticides; children; behavioral deficits; agricultural communities; take-home exposure pathways

Introduction

Occupational exposure to organophosphorus pesticides (OPs) is an important public health concern for people living in agricultural communities. This is because of the numerous health consequences caused by acute and chronic OP exposure. One such consequence is disruption of the nervous system of agricultural workers due to OP exposures, leading to a cluster of neurological and cognitive deficits. Neurobehavioral deficits in measures of motor speed and coordination, attention, and working memory in agricultural workers have been already reported (Farahat et al., 2003; Fiedler et al., 1997; Kamel et al., 2003; Rohlman et al., 2007). Our own study in Egypt on younger agricultural workers (i.e., adolescents and young adults) also reported association between neurotoxic chlorpyrifos exposure and neurological symptoms (Khan et al., 2014).

Importantly, children living in agricultural communities are also exposed to OPs at low levels in indoor environments. Animal studies have revealed that through prenatal exposure, chlorpyrifos and other OPs can interrupt the maturation of neural cells and activity of synapses, leading to abnormal behavior in exposed young animals with developing brains. (Qiao et al., 2003; Slotkin and Seidler, 2005; Venerosi et al., 2010). In addition, repeated exposure to chlorpyrifos during the postnatal period is associated with emotional behaviors related to the serotonergic nervous system in adolescent rats (Chen et al., 2011; Li et al., 2012). However, fewer studies have been conducted on children and adolescents to examine neurobehavioral effects associated with OP exposure.

A study among pre-school children in North Carolina reported higher median concentration of OPs in house dust samples compared to soil, outdoor, and indoor air samples (Morgan et al., 2014). Another recent study found that OP levels in dust from agricultural homes in California were influenced by household cooling strategies, secondary occupational exposure to pesticides, and geographical location (Kuiper et al., 2022). Take-home exposure factors responsible for the deposition of OP residues inside the house include proximity to the agricultural field (Curl et al., 2003; Gunier et al., 2011; Lu et al., 2000), lack of safety behavior, (Curwin et al., 2007; Fenske et al., 2002; Fenske et al., 2000) and insufficient house hygiene practices including removing work shoes, changing clothes and washing carpets (Quandt et al., 2004). Possible routes of exposure in indoor environments include inhalation of suspended and re-suspended particles, non-dietary ingestion of dust from the floor, and absorption through the skin (Butte and Heinzow, 2002). Child-like behaviors such as crawling on the floor and hand-to-mouth-activities make children more vulnerable to exposure of house dust OP residues. Overall, a clear association between the number of adults working in agriculture and OP concentration in dust samples were reported in multiple studies (Bradman et al., 1997; McCauley et al., 2003). However, fewer studies have characterized the negative health consequences in children associated with take-home exposure.

The increased risk of OP exposure in children, often at low levels, may produce subtle health effects that could neither be detected by clinical examinations nor easily recognized by parents. In a study of 518 mother-child dyads, a 10-fold increase of maternal urinary 3 dimethyl (DM) and 3 diethyl (DE) alkyl phosphate metabolites during pregnancy were found to be associated with alteration of normal white matter of children leading to possible negative neurobehavioral consequences (van den Dries et al., 2020). Apart from this imaging study, other epidemiological studies have mainly used cognitive assessment batteries to measure subtle effects of OPs. Studies have demonstrated associations of prenatal OP exposure (measured by urinary dialkyl phosphate metabolites (DAPs)) with loss of IQ points (Bouchard et al., 2011) and with mental and pervasive developmental deficits (Eskenazi et al., 2007). Similarly, another study found an association between prenatal OP metabolites and executive function in preschool children (Thistle et al., 2022). Studies have also observed motor deficits in agricultural communities. One study on children from agricultural communities found significantly poorer performance on measures of response speed (Finger Tapping) and latency (Match-to-Sample) when compared to those from non-agricultural families (Rohlman et al., 2007). Deficits in learning were also observed in agricultural children compared to non-agricultural children (Butler-Dawson et al., 2018). Several studies have observed associations between early childhood exposure and neurodevelopmental outcomes (Bouchard, M. et al. 2011, Engel, S. et al. 2011, Xu et al., 2023, Wang et al., 2022). However, fewer studies have examined behavioral deficits, internalizing behavior, attention, and conduct problems (Fiedler et al., 2015, Manley et al., 2022)

The present study examined if the take-home exposure pathway is associated with behavioral deficits in Latino children. OP concentrations were measured in house dust samples and assessed the presence of behavioral symptoms using the Child Behavior Checklist (CBCL) (Achenbach and Rescorla, 2001) in 5-12 year old Latino children living in an orchard community in Oregon. The hypothesis was that increased OP exposure in the house would be associated with increased levels of behavioral deficits in the children.

2. Methods

2.1 Study area

This study was conducted from 2008 to 2010 in an agricultural area of tree fruit orchards located in the Pacific Northwest. The orchard community consists of approximately 30%

Latino families according to the 2010 Census (United States Census Bureau, 2010). Most pesticides have a re-entry interval where workers are prohibited from entering an orchard, except under specific conditions including wearing PPE. Pesticide applications take place during flower and fruit development including dormant, late dormant, pink, bloom stages. OPs were applied between approximately March and August. Farmworkers, other than pesticide handlers, did not work in the orchards during applications, but did activities such as pruning and cultivation after the re-entry period. Four commonly used OPs for orchard pests in this area at the time of this study were azinphos-methyl, chlorpyrifos, phosmet, and malathion.

2.2 Study Population

Parent-child dyads were recruited as previously described (Butler-Dawson et al., 2016). Field staff made initial contact with adult members from families involved in orchard related agricultural activities (agricultural families) or from families without any involvement in agriculture (non-agricultural families) and identified individuals who had children between 5 to 12 years of age. Initial communication methods included both in person conversations at schools, community events and phone calls. These parents, along with one of their children, were invited to participate in a longitudinal study examining pesticide exposure among children living in an agricultural community. A total of 324 parents including 215 individuals of Latino ethnicity agreed to participate in the study and finalized schedules for home visits by the field staff. Activities during home visits, conducted between May 2008 through July 2010, included a questionnaire survey for demographic information, CBCL form completed by the mothers of the children, and collection of dust samples if carpet was present at the house. Although CBCL data were collected from 215 mothers, 43 were excluded from the final analysis as there were no corresponding dust samples from their houses. Therefore, this study is reporting the data for 172 Latino children whose mothers completed CBCL forms and provided dust samples from house carpet. Children and parents were presented with test materials in either Spanish or English, depending on their preference. Written informed consent was obtained from parents as well as child assent. The recruitment and study procedure were approved by the Institutional Review Board at Oregon Health and Science University.

2.3 Sample collection and analysis

House dust samples were collected using a high-volume surface sampler (HVS4, CS3, Inc.) from the main entrance or living area of the house or from the area where children played most frequently as previously described (Butler-Dawson et al., 2016, 2018). For sampling, a 122 square cm area was divided longitudinally into three strips with masking tape. The HVS4 was placed at the beginning of the first strip and pushed to the end. The strips were sampled four times back and forth (Fenske et al., 2002). These samplers collect dust from deep in the carpet reflecting accumulation of OPs over time.

The bulk material of each sample was sieved with a 150 μm sieve (No. 100 USA Standard Testing Sieve, ASTME-11 specification; VWR, West Chester, PA) and shaken for 10 mins with a sieve shaker (Model RX −24; WS Tyler, Inc., Mentor, OH) to obtain dust fines. Around 1 gram of dust fines were extracted using 4.0 mL of acetonitrile containing internal standards, followed by 40 minutes of sonication at 60 °C and 10 minutes of centrifugation at 2,500 rpm. By using liquid chromatography-mass spectrometry, samples were analyzed for the four targeted pesticides azinphos-methyl, chlorpyrifos, phosmet and malathion (Fenske et al., 2002; Fenske et al., 2013; Lu et al., 2000). The limit of detection varied between 2-4 ng/sample over the period of laboratory analysis. After the analysis at the University of Washington laboratory, pesticide concentrations were calculated, and data were entered in a database using Microsoft Excel. To calculate the total OP value, concentrations (ng/μl) were added together. Time of dust sample collection was recorded and subsequently entered in the house dust result dataset.

2.4 Outcome assessment

The 113-item CBCL for children aged 6-18 years old (Achenbach and Rescorla, 2001) was administered to Latina mothers who observed the emotional and behavioral symptoms of their children and subsequently reported them. The field research assistants of this study, who had prior experience training community groups in this community, visited the households and subsequently read over and discussed the CBCL items with the mothers and encouraged them to ask questions to clarify any item they found questionable. The trainer provided instructions to the mothers of the study participants about how to fill in the CBCL form. Mothers scored the items on a 3-point system (0 = not true, 1 = somewhat or sometimes true, 2 = very true or often true). Each item was placed under one of the eight behavioral subscales; anxious/depressed, withdrawn/depressed, somatic problems, rule breaking behavior, aggressive behavior, social problems, thought problems, or attention problems. Item scores were summed to generate subscale scores and summed subscale scores to generate internalizing and externalizing behavior scores. Additionally, a summary internalizing score was calculated by combining anxious/depressed, withdrawn/depressed, and somatic problems; and a summary externalizing score was calculated combining rule-breaking and aggressive behavior.

2.5 Statistical Analysis

SAS version 9.3 was used to conduct the statistical analysis. Cronbach's alpha for each subscale was calculated to assess the internal consistency. Bivariate associations between the CBCL subscales were evaluated using Spearman's correlations. A Chi-square test for categorical variables and a t-test for continuous variables were used to detect group differences between agricultural and non-agricultural children.

There were numerous concentrations below the limit of detection (LOD) and the data were highly skewed. The value LOD/2 for all the non-detects was imputed before calculating the summary measure; an approach used previously elsewhere (Rothlein et al., 2006). The differences between OP concentrations in house dust samples collected from agricultural and non-agricultural houses were evaluated by the t-test.

The association between OPs in house dust and CBCL subscales were estimated using linear regression models in which total OP concentrations were categorized by tertiles. Tertiles were determined by using the summary measure (Total OP concentration) to create three equal groups of samples (low, medium, and high OP concentrations) by using the standard tertile calculation procedure. Models were estimated both with and without adjustment for potential covariates. A two-step process was used to select these variables. First, sociodemographic variables were identified in the literature that could be associated with behavioral deficits in children. Second, the estimated regression coefficient relating exposure to outcome was examined for change by more than 0.5 standard error after exclusion of potential confounders from the model. The final model included a group of covariates including sex, age, proximity of house near agricultural field, number of family members in agriculture, housing characteristics, maternal education, number of people per bedroom, and acculturation score. Finally, the estimated association between OP concentration and internalizing behavior was compared to the association between OP concentration and externalizing behavior using the Wald statistic.

3. Results

3.1 Sample characteristics

Two groups of 172 Latino children were compared: 122 children from agricultural families and 50 from non-agricultural families. No significant differences were found for child's age, education, parental educational status, or number of family members. A significantly greater proportion of non-agricultural children had computers at home (77% vs 55%) and a better type of housing (apartment/duplex vs. a cabin or trailer). As anticipated, more than half of the children from agricultural families lived within 25 m of the agricultural land whereas a little more than one-fourth of the children from non-agricultural families lived within that distance. Children from agricultural families had a lower acculturation score measured by the Short Acculturation Scale for Hispanic Youth (SASH-Y) than those from non-agricultural families. Sample characteristics including the means, standard deviations, and ranges for the sociodemographic variables are presented in Table 1.

3.2 Determining OP concentrations in the house of the participants.

The aim of the first analysis was to determine the amount of OPs unintentionally brought into the house on the clothes, shoes, skin and hair of the resident agricultural workers. To do this, OP concentrations in house dust were measured from the homes of 172 children (Table 2). Except for phosmet, significantly higher concentrations of the OPs were found in agricultural homes compared to non-agricultural homes ($p<0.05$). Compared to agricultural houses, non-agricultural houses had a higher proportion of dust samples that remained non-detected for OPs.

Similar take-home exposure factors were identified as the predictors of dust OP residues. For instance, the houses of pesticide handlers (n=12) had almost two times higher geometric mean OP residues concentrations than the houses with other types of agricultural workers (n=160) (139.6 vs 68.2 ng/g). Other significant predictors of higher OP residues included poor housing conditions such as living in a cabin or trailer as opposed to living in a duplex or apartment (geometric means: 91.5 vs 65.8 ng/g; n=45 vs 127), more than one individual working in agriculture in the family (geometric means: 88.7 vs 66.6 ng/g; n=44 vs 128), and living within 25 meters of the agricultural fields (geometric means: 102.6 vs 53.3 ng/g; n=78 vs 94).

3.3 Reliability of the outcome measures

The aim of the second analysis was to determine the level of behavioral deficits reported by the mothers in the study using the CBCL. Descriptive characteristics of CBCL subscales with number of items (behavioral deficits) are presented in Table 3. All the eight CBCL subscales showed very high Cronbach's alpha values (between 0.85 and 0.88) indicating high reliability of the instrument across all the subscales. The CBCL internalizing behavior (anxious/depressed, withdrawn/depressed, and somatic problems) score was positively and significantly correlated with CBCL externalizing behavior (rule-breaking behavior and aggressive behavior) score ($r = 0.48$; $p < 0.001$). Social problems, thought problems, and attention problems, which are not included in either the internalizing or externalizing scores, were also significantly correlated with each of the internalizing or externalizing scores (Spearman correlation coefficients ranged from 0.23 to 0.60 and $p<0.001$ for all correlation coefficients).

3.4 Behavior deficits among agricultural and non-agricultural children

When the CBCL raw scores between agricultural and non-agricultural were examined, no significant differences were observed between these two groups for any of the eight subscales. Mean CBCL scores in Table 4 indicate that agricultural children had slightly higher mean scores for internalizing and externalizing behavioral problems than non-agricultural children. However, for attention and thought problems, the mean scores were higher in non-agricultural children.

3.5 Associations between OP in house dust and child behavior

Table 5 presents the relationships between tertiles of total OP (low, medium, and high concentrations) in house dust in ng/g and child behavior as rated by their mother. After adjustment for sociodemographic covariates including sex, age, maternal education, proximity of house to agricultural field, housing characteristics, number of family members working in agriculture, and an acculturation score, internalizing behavioral deficits were positively associated with the highest tertile of house dust OP (estimated β=2.06, p=0.05). Although externalizing behavior showed an association in the same direction, it was non-significant in both unadjusted and adjusted models. When the associations of the tertiles of OPs with the subscales of child behavior were examined, positive and significant associations of the highest tertile of OP with somatic problems and thought problems were found (estimated βs = 1.07 and 0.55 with p-values of 0.02 and 0.05, respectively). Also, the highest tertile of OP was positively associated with anxious/depressed, withdrawn/depressed, attention problems, and aggressive behavior although these associations were non-significant.

The means of CBCL raw internalizing, somatic, and thought problem scores resemble a dose-response relationship even after accounting for the potential covariates when the lowest and highest tertile were compared (Figure 1).

4. Discussion

Findings from this study focused on children of Latino farmworkers, because the majority of parents from these families in several areas of the United States have been associated with pesticide application in agriculture thus creating occurrences of take-home OP exposure for their children (Arcury et al., 2021; Farquhar et al., 2009; Tamaro et al., 2018). Results of this study indicated that Latino children with the highest concentration of OP residues in the house were at a risk of developing several types of behavioral deficits. A significant association was observed between the exposure variable (tertiles of OP residues in house dust) and internalizing behavior. Among various subscales, somatic and thought problems were found to be positively and significantly associated with the highest tertile of OP residues. The same type of relationship for aggressive behavior was also close to statistical significance (p=0.07). OP residues were also associated with internalizing behavior and two subscales in a dose-response manner even after accounting for potential covariates (Figure 1). These findings expand on earlier studies of OP exposure in Latino children and neurodevelopmental problems (Butler-Dawson et al., 2018). These studies used biological surrogates of exposure and demonstrated positive associations between prenatal urinary DAP metabolites, intellectual function, and neurodevelopment (Bouchard et al., 2011; Wang et al., 2017), pre and postnatal DAPs and attention problems (Marks et al., 2010), and being children of agricultural workers and acquisition of neurobehavioral computer-based test performance (Rohlman et al., 2005). Another study on Latino inner city children observed associations of prenatal DAPs with children's cognitive development (Rauh et al., 2006). These studies provided information about neurodevelopmental problems in children at an early age (a maximum age of six years in one study). Using functional indicators of behavior, this study provides additional evidence that older children at their pre-adolescent stage with relatively higher OP exposure opportunities through the house OP residues could manifest visible behavioral deficits.

Findings of the study reinforce the importance of take-home exposure as a key exposure pathway for children living in agricultural communities. A study conducted in an eastern Washington State orchard community demonstrated that characteristics of occupational behavior are major predictors of the take-home exposure pathway as reflected by the accumulation of higher concentrations of OPs in house dust of workers involved in pesticide handling (Fenske et al., 2013). In this study similar take-home exposure factors were also identified as predictors of dust OP residues including houses of pesticide handlers, living in a cabin or trailer, more than one individual working in agriculture in the family, and living within 25 meters of the agricultural fields. These findings are consistent with previous studies that demonstrated agricultural task and pesticide drift related factors as important determinants of pesticide accumulations in the house (Fenske et al., 2013; Hofmann et al., 2010). In Latino agricultural communities all these factors are highly abundant leading to higher accumulation of OPs and more exposure opportunities for the children (Harnly et al., 2009). Similarly, a 2014 study showed that farmworkers had higher levels of OP residues in their houses and farmworkers and their children showed higher levels of OP metabolites in their urine than non-farmworkers and their children during the seasons where OPs were in use (Thompson et al., 2014).

The cross-sectional nature of this study hinders cause–effect inferences. However, the direction of the relation is exposure to outcome because it is unlikely that different types of behavioral deficits can influence the take-home OP exposure pathway demonstrated in this study. Additionally, a narrow age range was examined and it is unknown whether the behavior-related problems intensified at older ages in this cohort (e.g. adolescent or post-adolescent stages). Future studies are necessary to follow Latino children and reassess neurodevelopment longitudinally. This would provide evidence of long-term consequences from early-life OP exposure and correlate with studies showing a link between psychiatric symptoms such as depression, anxiety and suicide in adults exposed to OPs (Beard et al., 2014; Beseler et al., 2006; Beseler et al., 2008; Freire and Koifman, 2013; Harrison and Mackenzie Ross, 2016; London et al., 2005).

This study had some limitations. This study was conducted in an orchard community in the Pacific Northwest where the majority of the families were Latino. These findings, then, may not be generalizable to Latino agricultural communities where other types of agricultural activities take place. The present study relied exclusively on OP residues in environmental samples limiting us to take only one exposure pathway into account. Other pathways of exposure such as consumption of OP contaminated agricultural products and outdoor OP exposure during the spray events, through contaminated soil, outdoor play equipment near homes, in parks and at schools were not measured. This might have resulted in underestimation of exposure. However, the associations of OP residues in house dust with several subscales of behavioral deficits still emphasizes the public health significance of the take-home exposure pathway. Using a summed total OP concentration does not consider the molar equivalents of each compound. However, the highest molecular weight (chlorpyrifos, 350.6 g/mol) is only 10% greater than the lowest molecular weight (azinphos-methyl, 317.32 g/mol) and, therefore, this would not impact the overall results. Several confounders and/or effect modifiers could impact the magnitudes of the relationships between OP exposure and behavioral deficits. For instance, a higher rate of depression and stress among Latino adults has been reported compared to the general U.S. population (Mossakowski, 2008; Wassertheil-Smoller et al., 2014). Among Latino farmworkers, depression and stress have been found to be direct consequences of migration, acculturation and poor housing quality (Ramos et al., 2015; Siantz et al., 2010). Previous studies have already indicated associations between these factors and behavioral changes in children (Connell and Goodman, 2002; Kane and Garber, 2004; McCarty and McMahon, 2003). Poor quality of parenting and poverty may also be associated with child behavior (Evans 2004). Although information is not available for some of these factors, two important variables such as acculturation and housing condition were included in these models to address this challenge.

This study is unique in several ways. First, it has reported findings using a well-standardized measure of child behavioral symptoms that assessed a range of syndromes including those under externalizing and internalizing behavior categories. This allowed the specific investigation of the exposure/parent-reported behavior associations using the hypothesis that take-home pesticide exposure pathway is a major risk factor for child neurodevelopment. Also, these subscales demonstrated good to excellent reliability and validity in this Latino agricultural population. Furthermore, a diverse set of sociodemographic and occupational variables were taken into account while examining the relationship between exposure and childhood behavioral deficits.

This study shows the importance of the take-home exposure pathway in the development of behavioral outcomes in Latino children from an orchard agricultural community in the Pacific Northwest. Higher OP concentration was observed in agricultural versus non-agricultural homes. The highest tertile of OP exposure was correlated with higher internalizing behavior scores in children, suggesting that take-home exposure plays a role in the development of this behavior. Future longitudinal studies should include examining the take-home exposure pathway while considering the changes in EPA regulations for Chlorpyrifos and Azinophos-methyl in other Latino farming communities, as well as investigating other exposure pathways. From an agricultural health point of view, these findings serve as an indication of concern for Latino communities where higher degrees of mitigation will be necessary to minimize transportation of agricultural OPs from the workplace to the house.

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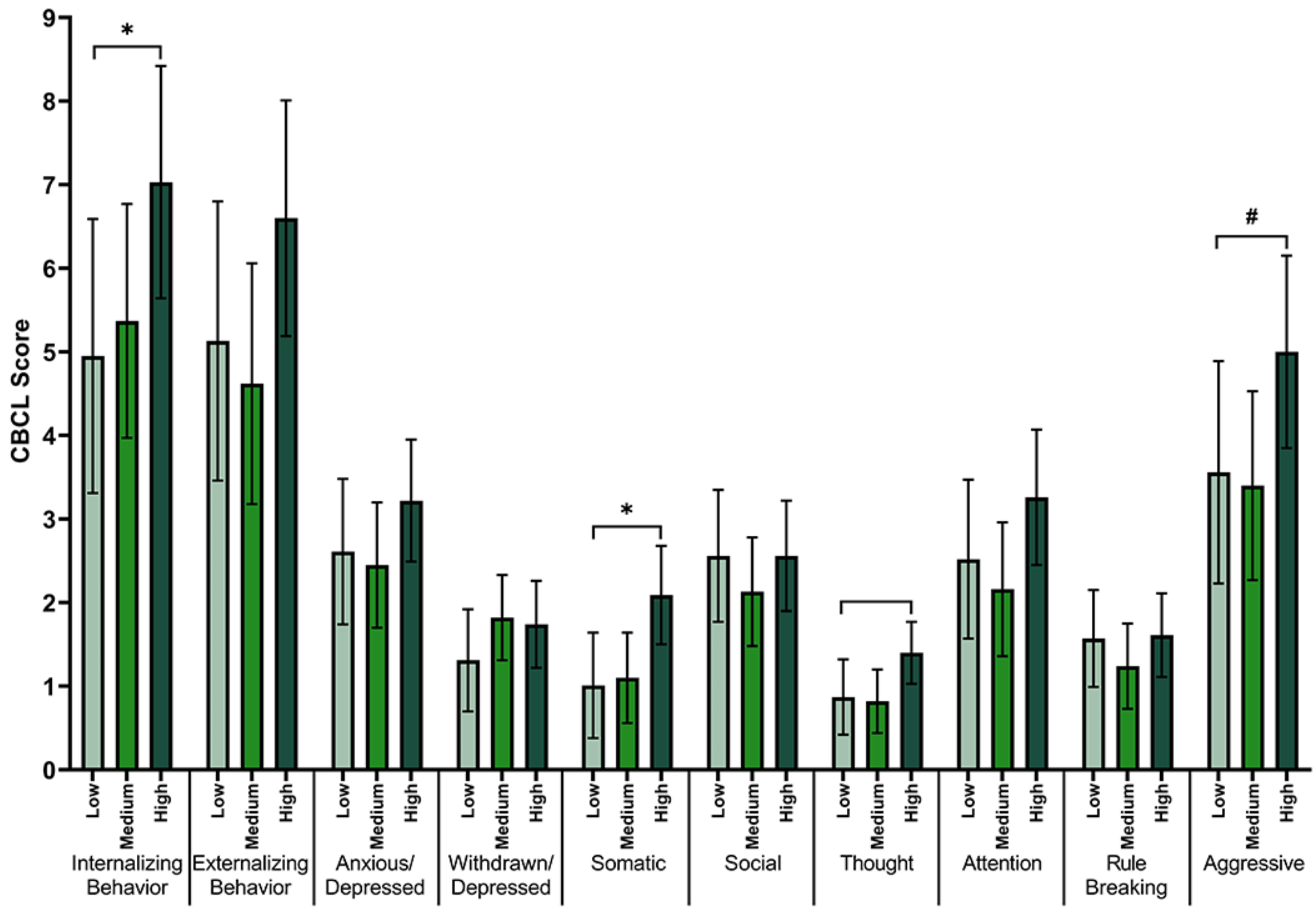

Figure 1:
CBCL subscales means adjusted for potential covariates by dust OP categories.
*p-value ≤ 0.05 for the differences in means of the highest and lowest tertiles of OP concentration in house dust (ng); #p-value = 0.07

Table 1.

Sociodemographic characteristics of the participants

	Latino Agricultural Children (n=122)		Latino Non-Agricultural Children (n=50)		p-value[a] t-test
	Mean (SD)	**Range**	**Mean (SD)**	**Range**	
Age (years)	8.5 (2.2)	5.0-12.0	8.2 (2.1)	5.0-12.0	0.40
Education (years)	2.8 (2.2)	0.0-7.0	2.8 (2.0)	0.0-7.0	0.86
Mother Education (years)	8.1 (3.4)	0.0-15.0	8.6 (4.4)	0.0-14.0	0.42
Father Education (years)	6.6 (3.2)	0.0-17.0	7.6 (4.6)	0.0-14.0	0.18
Number of people in House	4.6 (1.4)	1.0-11.0	4.9 (1.4)	3.0-9.0	0.23
Bedroom/Person	0.7 (0.2)	0.2-1.5	0.7 (0.3)	0.3-1.3	0.77
Acculturation Score (SASH-Y)	28.6 (6.1)	11.0-38.0	33.3 (7.8)	15.0-55.0	<0.001
	% (n)		**% (n)**		**Chi-sq test[b]**
Sex (Male)	54.1 (66)		54.0 (27)		0.99
Close to Agriculture field (~25 meters)	51.6 (63)		30.0 (15)		0.01
Computer at Home	56.6 (69)		78.0 (39)		0.02
Housing					0.002
Apartment/Duplex	67.2 (82)		90.0 (45)		
Cabin/Trailer	32.8 (40)		10.0 (5)		

[a] using t-test.

[b] using Chi-square test.

AL denotes agricultural land.

Table 2.

OP concentrations (ng/g) in house dust samples from the homes of Latino children

	Agricultural homes (n=122)				Non-Agricultural homes (n=50)			
OP in House Dust Samples (ng/g)	**Mean (SD)**	**Geometric Mean (GSD)**	**Median**	**Non-Detect (%)**	**Mean (SD)**	**Geometric Mean (GSD)**	**Median**	**Non-Detect (%)**
Azinophos-methyl *	51.5 (176.9)	9.2 (5.3)	4.0	34.4 (42)	15.2 (78.5)	2.9 (3.2)	2.5	60.0 (30)
Phosmet	26.5 (55.3)	9.7 (4.3)	7.5	21.3 (26)	27.8 (104.9)	5.5 (4.9)	3.0	40.0 (20)
Malathion *	96.3 (267.4)	16.3 (5.9)	11.0	9.8 (12)	24.7 (73.0)	8.4 (3.4)	7.0	14.0 (7)
Chlorpyrifos *	26.8 (32.8)	13.2 (3.7)	12.0	10.7 (13)	14.5 (39.6)	6.0 (3.2)	7.0	18.0 (9)
Total OP *	201.1 (336.6)	92.6 (3.2)	59.5		82.3 (159.4)	38.4 (2.8)	38.0	

* $p<0.05$ for group difference

Table 3.

CBCL subscale characteristics

CBCL Subscales	Number of items	Mean (SD)	Median	Range
Anxious/Depressed	13	2.5 (2.3)	2.0	0.0-11.0
Withdrawn/Depressed	8	1.4 (1.6)	1.0	0.0-8.0
Somatic problems	11	1.3 (1.7)	1.0	0.0-9.0
Social problems	11	1.9 (2.1)	1.0	0.0-9.0
Thought problems	15	1.3 (1.5)	1.0	0.0-9.0
Attention problems	10	3.0 (2.8)	2.0	0.0-14.0
Rule-breaking behavior	17	1.3 (1.8)	1.0	0.0-11.0
Aggressive behavior	18	4.2 (4.1)	3.0	0.0-24.0

Raw scores; n=172

Table 4.

Summary statistics of subscales of child behavior in both agricultural and non-agricultural Latino children.

	Latino Agricultural Children (n=122)		Latino Non-Agricultural Children (n=50)		p-value[a]
CBCL Subscales	**Mean (SD)**	**Range**	**Mean (SD)**	**Range**	
Internalizing Behavior	5.9 (4.8)	0.0-19.0	5.3 (4.4)	0.0-19.0	0.36
Externalizing Behavior	5.5 (5.1)	0.0-22.0	5.0 (4.5)	0.0-20.0	0.50
Anxious/Depressed	2.8 (2.4)	0.0-11.0	2.4 (2.3)	0.0-10.0	0.40
Withdrawn	1.7 (1.7)	0.0-8.0	1.5 (1.8)	0.0-7.0	0.43
Somatic Problems	1.4 (1.9)	0.0-9.0	1.3 (1.5)	0.0-6.0	0.69
Social Problems	2.2 (2.3)	0.0-9.0	1.9 (2.0)	0.0-7.0	0.26
Thought Problems	1.1 (1.3)	0.0-7.0	1.2 (1.3)	0.0-6.0	0.57
Attention Problems	2.9 (2.8)	0.0-12.0	3.2 (2.7)	0.0-12.0	0.37
Rule-Breaking Behavior	1.3 (1.7)	0.0-11.0	1.3 (1.4)	0.0-6.0	0.90
Aggressive Behavior	4.1 (4.1)	0.0-18.0	3.8 (3.6)	0.0-15.0	0.40

[a] T-test

Table 5:

Association between categories of total OP (ng/g) in House Dust and Child Behavior (n=172)

	Unadjusted Models		Adjusted* Models	
CBCL Subscales	**Estimated β (SE)**	**p-value**	**Estimated β (SE)**	**p-value**
Internalizing Behavior				
Low vs Medium	0.70 (0.90)	0.44	0.41 (1.02)	0.50
Low vs High	2.00 (0.88)	0.02	2.06 (1.03)	0.05
Externalizing Behavior				
Low vs Medium	−0.75 (0.92)	0.45	−0.49 (1.07)	0.61
Low vs High	0.88 (0.89)	0.29	1.20 (1.07)	0.14
Anxious/Depressed[a]				
Low vs Medium	−0.03 (0.47)	0.96	−0.19 (0.54)	0.72
Low vs High	0.70 (0.45)	0.11	0.84 (0.51)	0.09
Withdrawn/Depressed[a]				
Low vs Medium	0.48 (0.33)	0.12	0.51 (0.38)	0.17
Low vs High	0.46 (0.32)	0.13	0.42 (0.37)	0.25
Somatic Problems[a]				
Low vs Medium	0.22 (0.35)	0.53	0.06 (0.40)	0.87
Low vs High	0.82 (0.34)	0.01	1.07 (0.40)	0.02
Social Problems				
Low vs Medium	−0.30 (0.43)	0.49	−0.41 (0.49)	0.40
Low vs High	0.02 (0.42)	0.96	−0.01 (0.49)	0.98
Thought Problems				
Low vs Medium	−0.07 (0.26)	0.80	−0.04 (0.27)	0.87
Low vs High	0.40 (0.25)	0.08	0.55 (0.28)	0.05
Attention Problems				
Low vs Medium	−0.51 (0.54)	0.34	−0.36(0.59)	0.55
Low vs High[#]	0.50(0.42)	0.30	0.72 (0.60)	0.21
Rule-Breaking Behavior[b]				
Low vs Medium	−0.35 (0.32)	0.27	−0.34 (0.36)	0.33
Low vs High	−0.05 (0.31)	0.89	−0.06 (0.37)	0.87
Aggressive Behavior[b]				
Low vs Medium	−0.39 (0.72)	0.58	0.31 (0.60)	0.60
Low vs High	0.92 (0.69)	0.10	1.44 (0.83)	0.07

*Models adjusted for sex, age, agricultural field near home, number of family members in agriculture, housing condition, mothers' education, number of people per bedroom, and acculturation score.

[a]Included in internalizing behavior;

[b]Included in externalizing behavior