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The role of diet in children's exposure to organophosphate pesticides ☆

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ABSTRACT

Background: Studies suggest that some of the greatest exposure to OPs in children occurs in agricultural communities and various pathways of exposure including the take-home pathway, proximity to orchards, and diet have been explored. However, the importance of the dietary pathway of exposure for children in agricultural communities is not well understood.
Objectives: Our goal was to ascertain whether there were associations between measures of OP exposure and apple juice, fruit, and vegetable consumption across growing seasons by children of farmworkers and non-farmworkers in a rural agricultural setting.
Methods: Study participants were children of farmworker (N=100) or non-farmworker (N=100) households from a longitudinal cohort study. Dietary intake of fruits and vegetables was assessed using a "5-A–Day" abbreviated food frequency questionnaire, and exposure to OPs was characterized using three urinary di-methyl and three di-ethyl metabolite measurements per child for each of three growing seasons. We used generalized estimating equations to examine data.
Results: Consumption frequency of fruits and vegetables was similar between children of farmworkers and non-farmworkers and across seasons. There were a few significant trends between dimethyl metabolites (DMAP) and fruit, vegetable or apple juice consumption; however, no clear pattern held across seasons or occupation. One difference was found in vegetable consumption during the harvest season, where the farmworker families showed a significant relationship between vegetable consumption and dimethyl metabolite levels ($p=0.002$). We also found a significant difference in this relationship between farmworkers and non-farmworkers ($p=0.001$). No significant trends between fruit and vegetable consumption and diethyl (DEAP) metabolites were found.
Conclusions: Our study shows the importance of considering season and parents' occupation in understanding OP exposure routes among children in an agricultural community. The impact of these factors on dietary OP exposure requires a more thorough analysis of the availability and consumption of produce from different sources including farms using pesticides where parents worked.

1. Introduction

Organophosphate pesticides (OPs) are the most heavily used insecticides in United States (US) farming (Rosas and Eskenazi, 2008), posing a widespread risk of occupational and environmental exposure. Children are particularly sensitive to environmental toxicants such as pesticides due to a variety of factors, including more sensitive organ systems (particularly the brain and nervous system) and lower capacity to absorb and eliminate chemicals compared to adults (Makri et al., 2004; National Research Council, 1993; Perera et al., 2006). Characterizing various environmental contributors to children's exposure is an important step toward understanding health effects among children and ultimately protecting this vulnerable population from harm.

A possible source of OP exposure among children is diet. A 2004 study of National Health and Nutrition Examination Survey (NHANES) data by Barr et al. found that up to 70% of children aged 6–11 in the general population had detectable levels of at least one

Abbreviations: OP, Organophosphate pesticide; DMAP, A combined concentration measure consisting of the three dimethyl urinary metabolites of organophosphate pesticides (DMP, DMTP, and DMDTP); DMP, Dimethylphosphate; DMTP, Dimethylthiophosphate; DMDTP, Dimethyldithiophosphate; DEAP, A combined concentration measure consisting of the three dimethyl urinary metabolites of organophosphate pesticides (DEP, DETP, and DEDTP); DEP, Diethylphosphate; DEPT, Diethylthiophosphate; DEDTP, Diethyldithiophosphate

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urinary metabolite of OPs (Barr et al., 2004), suggesting widespread exposure of the kind one might expect from dietary sources. A 2008 study by Boon et al. showed that 15% of produce consumed by Dutch children ages 1–6 contained residues of at least one OP pesticide (Boon et al., 2008). It has also been hypothesized that fruit and vegetable consumption is a particularly important source of OP exposure in children because OP residues are typically detected in greater amounts on fruits and vegetables compared to other foods (Mills and Zahm, 2001; US Food and Drug Administration, 2008), and children tend to eat more of these products than adults per unit of body weight. For example, the National Research Council reported that children between 1 and 6 years of age eat 2.8–4.8 times more food per pound of apples, apple juice, orange juice, and bananas than the average American adult (National Research Council, 1993).

Dietary consumption of fruits and vegetables has been further studied as a source of pesticide exposure among children in urban and suburban communities. A 2003 study of urban preschool age children by Curl et al., for example, found that the 18 children in the study who consumed nearly all organic fruits, vegetables, and juices had lower concentrations of urinary metabolites of OPs (diethylthiophosphate (DETP) and dimethylthiophosphate (DMTP)) compared to the 21 children who consumed nearly all conventionally grown produce. These findings held even after excluding families that reported some use of OPs in the household or garden (Curl et al., 2003). A longitudinal study by Lu et al. (2008) of 19 suburban children aged 3–11 measured urinary metabolites of OPs for 12 to 15 d sampling periods at each of the four seasons of the year. The children primarily ate conventionally-grown fruits and vegetables, and were given all organic substitutes to eat during two five-day intervals: one during the spring sampling period and one in the fall. Metabolites of two OPs, malathion and chlorpyrifos, dropped during the periods in which the children ate organic produce. None of the families reported household use of OPs. Lu et al. concluded that diet was the primary contributor to OP exposure in these children. A 2005 analysis of data from five previous studies further demonstrated that among the 110 children analyzed who lived in metropolitan areas, median DMTP and DMAP levels were respectively indistinguishable from and greater than levels in 211 children of farmworkers during the winter months when pesticides were not applied to crops (Fenske et al., 2005). The researchers speculate that the higher metabolite levels in urban children may be due to greater intake of juices, fresh fruits, and vegetables (Fenske et al., 2005).

The dietary pathway of exposure has only recently been explored in agricultural communities. In their 2011 study, Bradman et al. found significant associations between fruit and vegetable intake and levels of urinary metabolites of dimethyl OPs among children living in the Salinas Valley in California, at 6 months and 24 months of age (Bradman et al., 2011).

In this study, we examined the relationship between dietary consumption of fruits, vegetables, and juices and OP exposure among children living in an agricultural community in eastern Washington State. Because we wished to understand the role of diet on pesticide exposure among children in the agricultural community whose parents worked or did not work in agricultural fields, we identified children in each category. We then analyzed data on dietary habits and urinary metabolites of OPs collected during a research project examining multiple exposure pathways among farmworker and non-farmworker adults and children as part of the Centers for Child Environmental Health Risks Research at the University of Washington and the Fred Hutchinson Cancer Research Center. Given the associations observed in other studies between dietary consumption of fruits and vegetables and urinary metabolites of OPs, we hypothesized that consumption of fruits, fruit juices, and vegetables contributes substantially to OP exposure in children of farmworkers compared to children of non-farmworkers in the Lower Yakima Valley.

2. Materials and methods

2.1. Setting

The setting is a rich agricultural region in Washington State that is known for its fruit and vegetable production. Orchard crops, such as apples, pears, cherries, and peaches are predominant, as are hops and grapes (Greater Yakima Chamber of Commerce, 2012). The Hispanic population in the Valley has burgeoned in recent years; the U.S. census bureau estimates that people of Hispanic or Latino origin made up 47% of the population in Yakima county in 2007, compared to 23.9% in 1990 (US Census, 2000). In the setting where this study took place, the population is 67% Hispanic, making it a majority minority area in the state.

2.2. Study design

Data were collected during a longitudinal cohort study that took place in the region between June 2005 and February 2006. Two cohorts were recruited: A cohort of 100 farmworkers along with a referent child between 1 and 7 years of age in the household; and a cohort of 100 non-farmworkers, also with a referent child between 1 and 7 years of age. All farmworkers worked in pome fruit crops (apples and pears). The non-farmworkers did not work in agriculture or in produce-packing plants; occupations included positions in dairies, factories, schools, and daycares. Both cohorts lived in the agricultural communities and an analysis of residence showed no differences between farmworker and non-farmworker families in proximity to orchards (data not shown). The cohorts were contacted three times: during the thinning season for apples and pears, when OPs are in heavy use and farmworkers remove small buds, shoots, and fruit from the limbs of trees; during the harvest season for pome fruits, when OPs are used less frequently on orchard crops; and in the non-spray season, when crops are dormant and pesticides are not in use.

Cohort members were recruited through flyers distributed through multiple means throughout the region; project staff distributed them at grocery stores, community organizations, churches, worksites, health fairs, and other activities and events. The flyers specified the eligibility criteria and provided information on samples that would be taken. All families who became members of the cohort were given a household total of $160 for participation in all the phases of data collection in the study. Informed consent was obtained for all participants. The inclusion criteria required that the participant be 18 or older, have a child between 1 and 7 years of age who could participate in the study, and plan to be in the region for an entire year. All study materials and sample collection protocols were approved by the Institutional Review Board at the FHCRC (File #5946).

Six bilingual (Spanish and English) project staff members were trained in survey interviewing. At the end of the training, staff were tested and certified in interview and consent procedures. Staff interviewed each participating adult twice each season, five days apart. Topics included socio-demographic characteristics, self-reported level of general pesticide exposure, family pesticide use, proximity to fields, child behavioral practices, and child eating behaviors.

The questionnaire included dietary items from the “5-A–Day” abbreviated food frequency questionnaire, which is widely used to assess fruit and vegetable consumption in many diverse communities (Field et al., 1998; Kristal et al., 2000; Serdula et al., 1993). Our questionnaire items were adapted slightly to reflect dietary