Environmental Research 156 (2017) 559–570

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Review of take-home pesticide exposure pathway in children living in agricultural areas☆

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A R T I C L E I N F O

Keywords:
Pesticides
Organophosphates
Take-home exposure
Children
Farmworker
Agricultural

A B S T R A C T

Background: Children of farmworkers may be chronically exposed to pesticides via the take-home exposure pathway.
Objective: The goal of this review was to analyze scientific literature evaluating the role of the take-home pesticide exposure pathway in children of agricultural workers.
Methods: A systematic review was undertaken and inclusion criteria were applied to identify original articles of interest. Of the 30 articles included in this review, some belonged to the same studies, resulting in a total of 23 studies. Eight studies assessed environmental samples, nine collected biological samples, and the remaining six analyzed both. Eleven studies compared pesticide levels between farm and non-farm families.
Results: There is convincing evidence that children of farmworkers are exposed to pesticides at higher levels than "non-agricultural" children, even when residing in the same agricultural communities. These levels were shown to depend on the season, occupation, number of farmworkers per home, and type of crops. Other factors such as age, gender and, sex seem to also influence this pathway. Some studies have shown that pesticides used solely in agriculture are found only in households of farmworkers spraying these pesticides. Moreover, intervention studies have shown that behaviors among farmworkers can significantly lower exposure of people living in the same households as farmworkers.
Discussion and conclusion: The evidence presented here raises concerns regarding health effects associated with exposure to pesticides in children living in agricultural communities, and indicates that strategies should be developed to reduce exposures in these populations.

1. Introduction

Pesticide exposures are particularly toxic in children and have been related to a wide range of adverse health outcomes including delayed neurodevelopment and neurobehavioral deficits, higher risk of reported attention problems, lower intelligence, altered growth, decreased lung function, certain rare cancers, and other serious conditions (Eskenazi et al., 1999; Guillette et al., 1998; Raanan et al., 2016). Detailing the effects of chronic pesticide exposures has become more critical with the increasing evidence of a "take-home" exposure pathway, in which agricultural workers track pesticide residues from their clothes, shoes and skin into their homes and vehicles, indirectly exposing their families to these pesticides (Butler-Dawson et al., 2016; Thompson et al., 2003).

Understanding the health impacts of pesticide exposure is particularly critical in children, as they may be exposed to higher doses and are more vulnerable than adults. Factors influencing children's increased pesticide exposure include engaging in higher frequency of hand-to-mouth activity, spending more time on the floor where dust-borne pesticide residues settle, and having less varied diets that include foods with higher levels of pesticide residues, such as fruits, fruit juices, and milk (Cohen Hubal et al., 2000; Freeman et al., 2005, 2001; Lu et al., 2006). Children also eat, breathe, and drink more on a per kilogram basis than adults; estimates have shown that caloric consumption is about two and a half times greater for infants than adults, when normalized for body weight (NRC, 1993). In addition to higher exposure levels and higher absorption rates, children also have less ability to metabolize and eliminate chemicals (Roberts and Karr, 2012). For example, extensive research has shown that children below the age of seven have significantly lower levels of paraoxonase 1 (PON1), an

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http://dx.doi.org/10.1016/j.envres.2017.04.017
Received 11 January 2017; Received in revised form 22 March 2017; Accepted 15 April 2017

enzyme that detoxifies organophosphate (OP) pesticides in humans. This raises the possibility that OP exposure may have a disproportionate effect on children (Eskenazi et al., 2010). Children may also be uniquely vulnerable to pesticides' toxicological effects due to greater physiological susceptibility during development (Marks et al., 2010).

Multiple studies have indicated that children living in agricultural communities may be disproportionately exposed to pesticides when compared to children in the general population (Butler-Dawson et al., 2016; Fenske et al., 2002). Furthermore, a 2015 review of the impacts of non-occupational pesticide exposure pathways in women living in agricultural areas found that various pathways, including the take-home exposure pathway, may contribute to disproportionate pesticide exposures compared to women living in non-agricultural areas (Deziel et al., 2015). Although the take-home exposure pathway has not yet been included in risk assessments, there is growing awareness by regulatory agencies such as the US Environmental Protection Agency (US EPA), the US General Accounting Office (GAO) and the California Department of Pesticide Regulation (CDPR) that this may be a significant pathway (CDPR, 2011; GAO, 2000; US EPA, 2010). An increased understanding of how farmworkers' families are exposed to pesticides via the take-home pathway may facilitate the introduction of improved workplace standards to reduce and prevent such exposure.

The objective of this literature review was to systematically examine available publications assessing how children of agricultural workers and those residing in agricultural communities may be exposed to pesticides via the take-home pathway and to gauge the significance of this pathway relative to others.

2. Methods

To ensure a systematic approach to our review, we applied PRISMA guidance protocol (http://www.prisma-statement.org/). We used PubMed (http://www.ncbi.nlm.nih.gov/pubmed/) and Web of Science (http://www.isiknowledge.com) to identify relevant pesticide exposure studies in the scientific literature. We focused our search on peer reviewed journal articles already published and available in English from January 1, 1989 to August 23, 2016. Applying PICO principle, we selected the studies using the following terms: ("agricultural"[All Fields] OR "agriculture"[All Fields] OR "rural"[All Fields] OR "farm"[All Fields] OR "farmworker"[All Fields]) AND (pesticide*[All Fields]) AND ("take-home"[All Fields] OR "take home"[All Fields] OR "house"[All Fields] OR "home"[All Fields] OR "indoor"[All Fields]) AND (dust*[All Fields] OR "blood"[All Fields] OR "urine"[All Fields] OR "urinary"[All Fields]) AND ("exposure"[All Fields] OR "exposed"[All Fields]). The search resulted in 141 articles from PubMed and 212 from Web of Sciences for a total of 261 articles (92 duplicates). Review articles, meta-analysis, methodology articles and articles highlighting study design without results were all excluded this analysis (N = 54). The search was also expanded using same author names, cited or similar articles. Articles were critically compared using exclusion/inclusion criteria related to the study design, study conduct and reporting, and study relevance age group (newborns, infants and children), exposure pathway (take-home), activity (no time spent in the field, working or playing), parental occupation (farmworker, pesticide applicator), samples collected (blood, urine or dust), and study location (homes in an agricultural area). All studies that were available online in English that met the inclusion criteria were included. No limitations on geographic location were applied. A significant number of studies were excluded because they did not meet all the exclusion/inclusion criteria and therefore did not specifically evaluate the take-home exposure pathway in a population of farmworker children (Fig. 1). Ninety articles were excluded based on their title, 82 based on their abstract and 5 after full article review. Ultimately, thirty articles were identified as relevant to our review because they all met our inclusion criteria. As seen in Tables 1–3, some of these publications belonged to the same study and were grouped together, resulting in the inclusion of 23 studies in this review.

The studies reviewed were grouped by the type of samples collected to assess the take-home exposure pathway in children: biological and environmental samples, only biological samples, and only environmental samples. All of the publications collected biological samples from children or analyzed environmental samples from homes in which children were residing. Children in the studies ranged from less than 1 year to 16 years. Characteristics such as age, gender, residential proximity to pesticide-treated farmland, and specific parental occupation were examined in order to assess the various factors influencing the impact of the take-home pesticide exposure pathway in children.

3. Results

The studies included in this review are summarized in Tables 1–3 based on whether biological, environmental, or both biological and environmental monitoring methods were used to analyze the take-home exposure pathway. Table 1 presents a summary of the studies (n = 8) that analyzed environmental samples collected from homes of study participants, Table 2 summarizes the studies (n = 9) that analyzed biological samples collected from study participants, and Table 3 summarizes the studies (n = 6) that analyzed both environmental and biological samples.

A large variety of pesticides, study designs, and methodologies used for assessing exposure were observed across the different studies. Overall, the majority of the studies were conducted in California or Washington and the remainder assessed populations in various locations such as Iowa, Oregon, Texas, Florida, North Carolina/Virginia, and Ecuador. OPs and their metabolites were the primary pesticides analyzed in the studies (n = 15), with the majority of OP parent compounds including azinphos methyl, chlorpyrifos, malathion, phosmet, diazinon, and methyl-parathion. OP metabolites largely included non-specific dialkyl phosphates (DAPs). In addition, eight studies analyzed a combination of various pesticide metabolites. Six studies analyzed OP and/or pyrethroid pesticides in combination with other herbicides and fungicides. One study assessed pyrethroids only and one study assessed the activity cholinesterase in the blood as a non-specific biomarker of exposure to OPs and carbamates. Because some studies collected more than one biological and/or environmental samples and some samples contained pesticide levels below the Limit of Detection (LOD) and because the way spot urine samples were treated (grouped, averaged, etc) was not always specified, the number of samples listed in Tables 1–3 is not always directly proportional to the number of participants in the study.

Table 1 presents a summary of the eight studies that assessed the take-home pesticide exposure pathway by analyzing environmental samples collected from homes and/or commuter vehicles of study participants. Samples collected included dust from homes and commuter vehicles, air samples, and floor, toy, and hand wipes. Three of these studies compared farmworker and non-farmworker homes and found significantly higher pesticide levels in the samples collected from the homes/vehicles of farmworkers for at least one pesticide (Butler-Dawson et al., 2016; Quiros-Alcala et al., 2011; Simcox et al., 1995). Furthermore, McCauely et al. (2001) compared pesticide levels in housedust among farmworker and grower homes in two counties in Oregon and found slightly higher median pesticide levels in grower homes (McCauley et al., 2001). The remaining three studies looked at the presence of pesticides in the dust of farmworker households and vehicles and did not include a non-farmworker control group (Coronado et al., 2010; McCauley et al., 2001; Quandt et al., 2004; Trunnelle et al., 2013).

Table 2 presents a summary of the nine studies that assessed the take-home pesticide exposure pathway by analyzing biological samples. Eight of the studies collected urine samples and one collected finger-stick blood. Three studies used a reference group within their population (Fenske et al., 2000; Loewenherz et al., 1997; Suarez-Lopez et al.,