Agricultural Task and Exposure to Organophosphate Pesticides Among Farmworkers

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Little is known about pesticide exposure among farmworkers, and even less is known about the exposure associated with performing specific farm tasks. Using a random sample of 213 farmworkers in 24 communities and labor camps in eastern Washington State, we examined the association between occupational task and organophosphate (OP) pesticide residues in dust and OP metabolite concentrations in urine samples of adult farmworkers and their children. The data are from a larger study that sought to test a culturally appropriate intervention to break the take-home pathway of pesticide exposure. Commonly reported farm tasks were harvesting or picking (79.2%), thinning (64.2%), loading plants or produce (42.2%), planting or transplanting (37.6%), and pruning (37.2%). Mixing, loading, or applying pesticide formulations was reported by 20% of our sample. Workers who thinned were more likely than those who did not to have detectable levels of azinphos-methyl in their house dust (92.1% vs. 72.7%; $p = 0.001$) and vehicle dust (92.6% vs. 76.5%; $p = 0.002$). Thinning was associated with higher urinary pesticide metabolite concentrations in children (91.9% detectable vs. 81.3%; $p = 0.02$) but not in adults. Contrary to expectation, workers who reported mixing, loading, or applying pesticide formulations had lower detectable levels of pesticide residues in their house or vehicle dust, compared with those who did not perform these job tasks, though the differences were not significant. Future research should evaluate workplace protective practices of fieldworkers and the adequacy of reentry intervals for pesticides used during thinning. *Key words:* applicators, farmworker, field worker, job task, occupational exposure, pesticide. *Environ Health Perspect* 112:142–147 (2004). doi:10.1289/ehp.6412 available via *http://dx.doi.org/* [Online 22 October 2003]

Farmworkers in various aspects of U.S. agriculture are routinely exposed to pesticides as part of their occupation. Many of these workers perform job tasks that have high risk for direct exposure to pesticides, such as mixing, loading, or applying pesticide formulations. The U.S. Environmental Protection Agency's Worker Protection Standards (U.S. EPA 1992) mandates that personal protective equipment and training be provided to these workers. Workers with direct pesticide contact are required to carry a pesticide handlers' permit or a pesticide license and, therefore, are required to receive training in the proper use and storage of pesticides and in protective measures to minimize exposure. The patterns of pesticide exposure and the effectiveness of protective measures among this group have been the topics of previous research (Alavanja et al. 1999a, 1999b; Arbuckle et al. 2002; Dosemeci et al. 2002; Garry et al. 2002a, 2002b; Gladen et al. 1998; Hoppin et al. 2002; Karr et al. 1992; Loewenherz et al. 1997; O'Fallon and Dearry 2001) and policy recommendations (cholinesterase monitoring) in recent years (Wilson et al. 1997).

The pattern of exposure is less understood among workers who perform tasks that do not require the use of personal protective equipment or safety training, such as harvesting crops, pruning vines and trees, loading or packing plants fruits and vegetables, or thinning orchards. Some of these workers may have substantial physical contact with fruits, leaves, twigs, and branches that may contain pesticide residues. Because many fieldworkers work on several crops, they may be exposed to several different types of pesticides throughout a given growing season. A limited number of previous investigations have examined workplace protective practices of this group (such as the frequency of use of gloves, long-sleeve shirts, and long pants) (Jackson 2002; Vela-Acosta et al. 2002); only a limited number have assessed pesticide exposure among this group (Fenske et al. 1999; McCurdy et al. 1994; Simcox et al. 1999).

Even less is known about the patterns of exposure of children living in households with farmworkers. A limited number of previous investigations have suggested that the children of farmworkers may experience adverse effects of pesticide exposure. Two studies that examined cancer end points among children of farmworkers reported elevated incidence of leukemia (Daniels et al. 1997) and cancers of the brain (Daniels et al. 1997) and kidney (Fear et al. 1998). A related study found miscarriage and fetal loss to be more common among spouses of pesticide applicators than among spouses of nonagricultural workers. Moreover, miscarriage and fetal loss were more commonly experienced during the spray season (Garry et al. 2002a, 2002b).

It is widely believed that pesticide residues in the home environment are exposed to little sunlight or water and thus break down at a slower pace than pesticides in fields and orchards. Children may be uniquely susceptible to this exposure because they spend greater amounts of time on carpets and floors (where pesticides accumulate), they often wear minimal clothing during the summer spray season (increasing their likelihood of dermal exposure), and they engage in hand-to-mouth behavior (increasing their likelihood of ingesting pesticides) (Mills and Zahm 2001). With less developed immune systems than adults, children may be less able to clear pesticides from their bodies, thus prolonging the effects of exposure (Mills and Zahm 2001).

Using a quasi-population-based sampling technique and a large sample of farmworkers from several agricultural communities in eastern Washington State, we sought to examine the association between specific agricultural tasks and levels of pesticide exposure among adult workers and children living in the same household. We used adult and child urinary pesticide metabolite concentrations and dust residues from vehicles and cars of the same set of households as markers of exposure. In this report, we use the term farmworker generally to mean any agricultural worker, including seasonal workers and growers.

Methods

Setting. This study is part of a larger study that sought to develop and test a culturally appropriate intervention to break the take-home pathway of pesticide exposure. The setting, study design, study participants, and survey procedures have been described previously

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(Thompson et al. 2003). Briefly, the study took place in the Yakima Valley of Washington State, a region that includes many small agricultural communities. An estimated 50,000 people in the region work in agriculture; the primary crops are apples, pears, peaches, cherries, grapes, and hops. Approximately 50% of the area's population is Hispanic.

Agriculture in the valley. The agricultural products grown in this area require that farmworkers perform a variety of farm tasks. Workers in apple and pear orchards remove small buds from the limbs of trees (known as thinning) so that the remaining buds provide larger fruit. Pruning is commonly performed on grape vines and orchard trees.

For most crops cultivated in the Yakima Valley, such as apples, pears, and cherries, harvesting is done by hand. Pesticide application is generally carried out by air blast sprayers, which are attached to tractors. In recent years, some growers in the valley have begun to use alternative methods of pest control, such as pheromone disruption systems, although the use of such methods remains limited. The main agricultural pest in the Yakima Valley is the coddling moth. The amount of pesticides used in a given year depends on the infiltration of the coddling moth, which itself is determined by soil and air temperatures, wind, and humidity.

Organophosphate pesticide use in Washington State. One of the most commonly used pesticides in the Yakima Valley is azinphos-methyl, a broad spectrum insecticide registered for use in the control of many insect pests on a wide variety of fruit, vegetable, nut, and field crops as well as on ornamentals, tobacco, and forest and shade trees. In the Yakima Valley, it is generally used to control the coddling moth. Azinphos-methyl works as both a contact insecticide and a stomach poison; it is one of the most toxic organophosphate insecticides and is classified at level I toxicity (Extension Toxicology Network 1996). It is reported to be highly toxic through inhalation, dermal absorption, ingestion, and eye contact (Extension Toxicology Network 2001). The current reentry interval for azinphos-methyl applied to apple crops is 14 days (although thinning may be performed 7 days after application if < 1.0 lb/acre has been applied in a calendar year) (Bayer Corporation Crop Protection 2003). Data from the Washington Agricultural Statistics survey show that, in the year 2001, > 241,000 lb of azinphos-methyl were applied to Washington State apple orchards and > 22,000 lb were applied to pear orchards [U.S. Department of Agriculture (USDA) 2002]. Other organophosphate (OP) pesticides such as malathion, methyl-parathion, phosmet, and parathion are also used on crops grown in the Yakima Valley.

A previous study conducted in the Yakima Valley emphasized the populations' concern with pesticide exposure, especially among children. Funding for the Child Environmental Health Center at the University of Washington (Faustman et al. 2000) made it possible to address the pesticide concerns. An advisory board, which included community, health department, and agricultural department representatives, farmworkers, and grower advocates, was formed before baseline data collection (Thompson et al. 2001). The board met monthly, hired a local project coordinator, and guided the entire project. The community advisory board and staff from the Fred Hutchinson Cancer Research Center (subcontractor for the Community Intervention Project) formed a strong partnership, where the board had input on all aspects of the project. All study procedures were reviewed and approved by the Fred Hutchinson Cancer Research Center (Institutional Review Board #5105).

Study procedures. An initial cross-sectional sample of farmworkers was identified as part of a larger community study in the same valley (Thompson et al. 2002). Additional households were included from local labor camps and from areas of previously identified communities that were known to have a high concentration of farmworkers. A total of 571 households were surveyed as part of the project. Of these households, 218 had age-eligible children (2–6 years of age); this group is the sample used for this study.

Questionnaire. An in-person interview was conducted with the farmworkers using a 73-item questionnaire that included nine sections. Before implementation, the questionnaire was translated into Spanish, piloted among farmworkers, and reviewed by members of the community advisory board.

Questions about job tasks asked workers if they had performed the following tasks in the last 3 months: harvesting or picking, pruning, and loading plants, fruits, or vegetables; packing plants, fruits, or vegetables; sorting or grading plants, fruits, or vegetables; planting or transplanting; weeding; thinning; irrigating; mixing or loading farm chemicals; and spraying or applying farm chemicals. An additional question asked workers whether they had performed any other job task. Questions about workplace spraying of pesticides asked if pesticides had been sprayed at the respondent's work in the past 3 months. Those who responded affirmatively were asked when the most recent spraying occurred: today, yesterday, 2–3 days ago, 4 days–1 week ago, 1–2 weeks ago, 2–4 weeks ago, or > 4 weeks ago.

Survey procedures. Among eligible households (those with a farmworker and an age-eligible child), an adult respondent was identified. Where more than one adult farmworker or age-eligible child lived in the household, we used birth date to select a single adult respondent and a study child. The selected farmworker was interviewed by a study staff member. All interviewers were bilingual (Spanish–English), bicultural, and from the local area, and they had been trained and certified in data collection (Thompson et al. 2003).

In farmworker households with children between the ages of 2 and 6 years, families were invited to participate in the specimen collection aspect of the study. For these families, we collected urine samples from the adult farmworker and study child, as well as dust samples from selected areas of the home (where the child was thought to play) and from the vehicle used to commute to and from work. Our analysis is limited to families that participated in the specimen collection aspect of the study.

Specimen collection. The urine and dust collection procedures have been described previously (Curl et al. 2002). Briefly, for each household, two or three urine samples were collected from an adult farmworker and from the age-eligible child. Each collection was separated by a minimum of 3 days, and most samples were collected within a 2-week period. All samples from each individual were combined, and the composite samples were separated into three equal volumes and stored at −10°C.

Dust samples were collected from homes and commuter vehicles using the Nilfisk vacuum cleaner (Nilfisk -Advance Inc., Plymouth, MN). The selection of area to be vacuumed was determined by asking the parent or adult participant where the child played most frequently. The size of the area vacuumed depended on the floor type, and ranged from a 1 m^2 area for plush carpets to a 4 m^2 area for hard or smooth floors. Foot wells from both the front and back of cars (and only the front of trucks) were vacuumed. Mats were not removed before vacuuming. All dust samples were stored at −10°C in the field office laboratory.

Specimen analysis. Urine samples were analyzed for the presence of five dialkylphosphate (DAP) compounds produced by the metabolism of most OP pesticides: dimethylphosphate (DMP), dimethylthiophosphate (DMTP), dimethyldithiophosphate (DMDTP), diethylphosphate (DEP), and diethylthiophosphate (DETP). Dust samples were analyzed for the presence of four dimethyl OP pesticides (azinphos-methyl, malathion, methyl parathion, and phosmet), and two diethyl OP pesticides (chlorpyrifos and diazinon) (Curl et al. 2002).

Statistical analysis. We calculated the frequency of demographic characteristics among our subsample of farmworkers with age-eligible children. We also calculated the frequency that these farmworkers performed specific job tasks.

For each individual, the values for the urinary metabolites were combined to generate values for two broad categories: dimethyl (i.e., DMP, DMTP, DMDTP) and diethyl (i.e., DEP and DETP). For the purposes of this analysis we limited our investigation to dimethyl compounds because they are more commonly used in the Yakima Valley. For each job task, we chose to report workers' values for the individual metabolites, because metabolic pathways for a given pesticide may be different from that of another. Where the value of a given individual metabolite was below the limit of quantitation, we treated it as nondetectable. We limited our analysis of house and vehicle dust samples to azinphos-methyl because it is most commonly used in the valley and it was found in the greatest number of households and vehicles.

We used chi-square tests to compare the observed and expected percentage of detectable samples among workers who did and did not perform a given job task. A difference in proportions was determined to be significant if the associated p values were < 0.05. Although our analysis compares percentages of detectable urinary metabolite or pesticide concentrations for workers who may have performed several job tasks, we consider our analysis exploratory; thus, we chose not to report Bonferroni-adjusted p-values.

Because timing of spray activity may be associated with both job tasks and exposure levels, we used chi-square tests to examine the association between recent pesticide spraying (within 3 days) and selected job tasks. Associated p-values are reported as measures of significance.

Results

Initially, a total of 218 households had an age-eligible child and agreed to enroll in the specimen collection aspect of the study. Seven children declined to provide urine samples at the time of collection; thus, we collected urine samples from one adult and one child in 211 households. Dust samples were collected in 210 homes and 205 commuter vehicles. For 54 homes and 15 vehicles, insufficient masses of dust were collected for analysis. Thus, we conducted residue analysis on 156 house-dust samples and 190 vehicle-dust samples. Samples were collected June–October 1999.

Nearly two-thirds of our study respondents were younger than 35 years of age (Table 1). The majority had completed ≤ 8 years of schooling; only 5% had graduated from high school or earned an advanced degree. Annual household income was generally low, with nearly 90% of families earning < $25,000. In general, the farmworkers in this study were married (88.2%) and were born in Mexico (92.4%). Nearly half had worked in agriculture for < 10 years. Slightly less than two-thirds were male, and the vast majority (92.9%) completed the interview in Spanish.

Approximately three-fourths of our sample had harvested or picked agricultural products in the 3 months prior to being interviewed; a substantially lower proportion had pruned trees or vines; loaded, packed, or sorted plants, fruits or vegetables; or planted or transplanted seeds, plants, or trees (Table 2). Half of our sample reported having weeded fields or orchards, and about two-thirds had thinned plants or trees. Approximately one-fourth of

Table 1. Demographic characteristics of selected adult farmworkers having a child between 2 and 6 years of age in the household (n = 211).

Characteristic	No. (%)
Age (years)	
18–24	24 (13.3)
25–34	90 (49.7)
35–49	57 (31.5)
≥ 50	10 (5.5)
Education	
< 4th grade	63 (29.9)
5th–8th grade	85 (40.3)
8th–12th grade	52 (24.6)
High school graduate or higher	11 (5.2)
Annual household income	
< 10,000	44 (21.2)
10,000 to < 15,000	58 (27.9)
15,000 to < 25,000	85 (40.9)
≥ 25,000	21 (10.1)
Marital status	
Married or living as married	186 (88.2)
Separated or divorced	5 (2.4)
Never married	19 (9.0)
Other	1 (0.5)
Birthplace	
United States	13 (6.2)
Mexico	195 (92.4)
Other	3 (1.4)
No. of years working in agriculture	
< 10	102 (48.3)
10 to < 20	63 (29.9)
≥ 20	46 (21.8)
Sex	
Male	136 (64.5)
Language for interview	
Spanish	196 (92.9)

Table 2. Percentage of farmworkers who performed selected job tasks (n = 211).[a]

Job task	No (%)
Harvesting or picking	
Pruning	
Loading plants, fruits, or vegetables	
Packing plants, fruits, or vegetables	
Sorting plants, fruits, or vegetables	
Planting or transplanting	
Weeding	
Thinning	
Irrigating	
Mixing or loading pesticides	
Spraying pesticides	

[a]Each respondent was asked about each task.

Table 3. Percent detectable dimethyl urinary metabolites among adult farmworkers, by job task (n = 211).

Job task	DMP		DMTP		DMDTP	
	Percent	p-Value	Percent	p-Value	Percent	p-Value
Harvesting or picking						
Yes	23.5		93.3		56.4	
No	12.3	0.07	91.2	0.61	49.1	0.35
Pruning						
Yes	23.4		94.8		58.4	
No	18.6	0.41	91.5	0.37	51.9	0.37
Loading plants, fruits, or vegetables						
Yes	25.8		92.1		57.3	
No	16.2	0.09	93.2	0.78	52.1	0.46
Packing plants, fruits, or vegetables						
Yes	31.8		90.9		54.6	
No	17.3	0.03	93.2	0.60	54.3	0.98
Sorting plants, fruits, or vegetables						
Yes	23.7		89.8		54.2	
No	19.1	0.45	93.9	0.31	54.4	0.98
Planting or transplanting						
Yes	27.3		94.8		49.4	
No	16.3	0.06	91.5	0.37	57.4	0.26
Weeding						
Yes	24.0		94.2		55.8	
No	16.7	0.19	91.2	0.40	52.9	0.68
Thinning						
Yes	23.3		94.0		56.4	
No	15.1	0.16	90.4	0.35	50.7	0.43
Irrigating						
Yes	23.6		89.1		63.6	
No	19.2	0.49	94.0	0.23	51.0	0.11
Mixing or loading pesticides						
Yes	18.2		90.9		54.6	
No	21.0	0.68	93.2	0.60	54.3	0.98
Spraying pesticides						
Yes	15.6		95.6		46.7	
No	21.7	0.36	91.9	0.41	56.5	0.24

our sample had irrigated fields or orchards. Slightly more than 20% of workers had mixed, loaded, or applied pesticide formulations.

When we examined individual metabolites, we observed differences in the proportion of workers who had and had not performed a given job task (Table 3). The proportion of detectable levels of DMP showed a slight trend for greater proportions among workers who performed fieldwork (harvesting or picking, pruning, loading, packing, or sorting plants, fruits, or vegetables; weeding, thinning, or irrigating) compared to workers who mixed, loaded, or applied pesticides; the differences were significant for workers who packed plants, fruits, or vegetables and close to significant (p = 0.06) for workers who planted or transplanted. Notably, workers who mixed, loaded, or applied pesticides had slightly lower (18.2%), although nonsignificant, proportions of detectable DMP compared to those who did not perform these tasks (21.0%).

Children living in the same household as adult farmworkers who had performed thinning in the previous 3 months had higher percentages of detectable levels of composite dimethyl metabolite concentration in their urine than those not living with such adult farmworkers (Table 4). This observation appears to be attributable to the higher percentages of DMTP found in these children. By contrast, we found that children of workers who mixed, loaded, or applied pesticide formulations had a slightly lower, although nonsignificant, percentage of detectable levels of dimethyl metabolites. When we examined differences in the proportion of detectable levels of DMP and DMDTP in samples from children, we found no significant differences on the basis of whether or not the childrens' parents performed any of the job tasks.

Our analysis of vehicle and house dust showed varying percentages of detectable samples by job task (Table 5). A similar share of workers who did and did not harvest or pick fruits or vegetables had detectable levels of azinphos-methyl in their house and vehicle dust. This pattern was observed for workers who reported loading, packing, or sorting plants, fruits, or vegetables; planting or transplanting; and irrigating. Workers who thinned orchards were found to have a greater likelihood of having detectable levels of azinphos-methyl in their homes and vehicles used for commuting than those who did not. Workers who pruned vines or branches or weeded were found to have a significantly greater proportion of detectable azinphos-methyl residues in their vehicle dust, but not in their house dust, than those who did not. We found that a similar share of workers who mixed, loaded, or applied pesticide formulations had detectable levels of azinphos-methyl in their homes and vehicles compared to workers who had not performed these tasks.

When we examined the association between recent pesticide spraying and selected job tasks, we found that workers who mixed, loaded, and applied pesticides were more likely than other workers to report recent spray activity (Table 6). No other job task was found to be significantly associated with recent spray activity.

Table 4. Percent detectable dimethyl urinary metabolites among children 2–6 years of age by farmworker's job task (n = 211).

Job task	DMP Percent	DMP p-Value	DMTP Percent	DMTP p-Value	DMDTP Percent	DMDTP p-Value
Harvesting or picking						
Yes	21.7		88.8		44.7	
No	13.6	0.18	86.4	0.63	44.1	0.93
Pruning						
Yes	18.2		89.6		46.8	
No	20.2	0.73	87.3	0.62	43.3	0.63
Loading plants, fruits, or vegetables						
Yes	16.7		87.8		41.1	
No	21.5	0.38	88.4	0.89	47.1	0.39
Packing plants, fruits, or vegetables						
Yes	24.4		84.4		55.6	
No	18.1	0.34	89.2	0.39	41.6	0.09
Sorting plants, fruits, or vegetables						
Yes	17.0		89.9		44.3	
No	20.4	0.57	88.2	0.99	41.5	0.15
Planting or transplanting						
Yes	15.2		89.9		44.3	
No	22.0	0.23	87.1	0.55	44.7	0.96
Weeding						
Yes	17.9		87.7		50.0	
No	21.0	0.58	88.6	0.85	39.1	0.11
Thinning						
Yes	22.8		91.9		44.1	
No	13.3	0.10	81.3	0.02	45.3	0.87
Irrigating						
Yes	16.1		87.5		42.9	
No	20.7	0.46	88.4	0.86	45.2	0.77
Mixing or loading pesticides						
Yes	17.8		86.7		35.6	
No	19.9	0.75	88.6	0.73	47.0	0.17
Spraying pesticides						
Yes	13.0		84.8		39.1	
No	21.2	0.22	89.1	0.42	46.1	0.40

Discussion

In this study, we found that workers who thinned crops appeared to have greater levels of azinphos-methyl residues in their homes and vehicles than workers who did not thin crops; this probably contributed to the levels of pesticides to which children in the households were exposed. The results of this study appear to support our hypothesis that pesticides brought home on workers' bodies, clothing, and shoes accumulate in the home environment, thus potentially exposing children and other family members. Curl et al. (2002) suggested that this leads to children's exposure; using the same data, these authors demonstrated a strong correlation between urinary dimethyl concentrations of adult farmworkers and children living in the same household.The urinary dimethyl concentration is the sum of DMP, DMTP, and DMDTP metabolite concentrations expressed as micromoles per liter of urine. The take-home pathway was further demonstrated by analysis showing a significant correlation between pesticide concentrations in house dust and respective vehicle dust (Curl et al. 2002). Because there is considerable scientific interest in the manner in which workers are exposed to pesticides, these findings are potentially important in informing policy and programs that aim to train farmworkers in pesticide safety.

The presence of a take-home pathway of pesticide exposure has also been demonstrated in Oregon by McCauley et al. (2001), who showed a direct correlation between the number of agricultural workers living in a household and the concentration of azinphos-methyl found in dust collection from the home. This finding is consistent with a limited number of studies that show elevated risk of illness among children of farmworkers. In a review of 31 studies, Daniels et al. (1997) showed greater risk for developing leukemia and brain cancer among children of farmworkers who experienced frequent occupational exposure to pesticides, compared with children of exterminators. Daniels et al. also reported kidney cancer, Ewing's (bone) sarcoma, and germ cell tumors to be associated with occupational pesticide exposure. That parents' occupational exposure is linked to the subsequent development of cancer in offspring is also supported by Fear et al. (1998), who used 167,703 childhood death records in England and Wales to show elevated incidence of kidney cancer among children of men with potential occupational exposure to pesticides.

Our data show that a significantly greater proportion of children in households in which the adult farmworker had performed thinning had detectable concentrations of dimethyl metabolites compared with those in which the adult farmworker had not thinned crops. However, we found no significant differences in urinary metabolite concentrations of adult thinners compared with those who had not thinned. This finding may be explained by the longer half-life of pesticides in the home environment, the greater opportunity for children to be exposed in this environment, or the lessened ability of children's bodies to metabolize pesticides.

In the Yakima Valley, thinners may be at high risk for exposure to pesticides because they are the first to enter recently sprayed fields. The region receives scant precipitation, and orchards are generally irrigated using sprinklers that direct water upward. Thus, pesticide residues can remain on the foliage for long periods, thereby enhancing opportunities for exposure among workers who thin crops or otherwise have direct contact with the foliage.

Table 5. Percent detectable azinphos-methyl residues in vehicle and house dust.

Job task	Vehicle (n = 190) Percent	Vehicle (n = 190) p-Value	House (n = 150) Percent	House (n = 150) p-Value
Harvesting or picking				
Yes	88.2		87.3	
No	84.0	0.44	85.0	0.72
Pruning				
Yes	95.5		89.8	
No	82.4	0.01	85.2	0.43
Loading plants, fruits, or vegetables				
Yes	81.5		87.5	
No	91.4	0.05	86.1	0.80
Packing plants, fruits, or vegetables				
Yes	84.6		87.5	
No	87.8	0.60	86.4	0.88
Sorting plants, fruits, or vegetables				
Yes	87.0		93.0	
No	87.1	0.99	84.1	0.15
Planting or transplanting				
Yes	84.5		86.0	
No	88.7	0.41	87.1	0.84
Weeding				
Yes	81.9		85.7	
No	92.4	0.03	87.7	0.73
Thinning				
Yes	93.3		92.8	
No	76.1	0.001	75.5	0.003
Irrigating				
Yes	87.2		86.5	
No	87.1	0.97	86.7	0.97
Mixing or loading pesticides				
Yes	87.2		84.9	
No	87.1	0.99	87.2	0.73
Spraying pesticides				
Yes	87.5		83.9	
No	87.0	0.93	87.4	0.61

Masses of dust from 15 vehicles and 54 homes were insufficient for analysis.

Table 6. Association between job task and recent pesticide spray activity (within the past 3 days).

Job task	No. performing task	Pesticides were sprayed ≤ 3 days No. (%)	Pesticides were sprayed ≤ 3 days p-Value
Harvesting or picking	113	19 (16.8)	0.16
Pruning	59	11 (18.6)	0.81
Loading plants, fruits, or vegetables	75	13 (17.3)	0.49
Packing plants, fruits, or vegetables	32	5 (15.6)	0.52
Sorting plants, fruits, or vegetables	42	6 (14.3)	0.31
Planting or transplanting	65	16 (24.6)	0.19
Weeding	87	16 (18.4)	0.67
Thinning	106	19 (17.9)	0.44
Irrigating	48	14 (29.2)	0.05
Mixing or loading pesticides	44	17 (38.6)	< 0.001
Spraying pesticides	43	17 (39.5)	< 0.001

p-Values are based on chi-square tests comparing job task (yes, no) and recent pesticide exposure (≤ 3 days or ≥ 4 days).

Because the half-life of some pesticides is ≥ 2 weeks, it is likely that some farmworkers enter pesticide-treated fields within the time that pesticides are present in substantial amounts (Stewart et al. 2001). De Cock et al. (1998a, 1998b) reported that exposure intensity for orchard thinning is about twice that of orchard harvesting or pruning. This may be due to the workers' substantial physical contact with tree foliage or to the high dermal absorption of pesticides such as azinphos-methyl (Simcox et al. 1999). Moreover, the duration of exposure may be greater for field workers than for pesticide handlers (Fenske and Birnbaum 1997); although our analyses demonstrate that the recency of spray activity did not account for the relatively high pesticide levels among thinners. In contrast, compared to pesticide handlers, field workers may be disproportionately affected by a lack of available work-site laundering facilities, showers, and handwashing facilities, thus prolonging their exposures to pesticides and other farm chemicals (Ward et al. 2001).

Contrary to our expectation, we found that workers who reported having mixed, loaded, or applied pesticide formulations had slightly lower proportions of detectable residues in their house dust and vehicle dust than nonhandlers, although these differences were not significant. This finding is particularly notable in light of our analyses showing pesticide handlers to be more likely than nonhandlers to report recent workplace spraying of pesticides. Pesticide handlers have the greatest risk for direct exposure to pesticides at times when the pesticides are most highly toxic. Provisions of the Worker Protection Standards (U.S. EPA 1992) aim to limit this exposure by requiring the use of personal protective equipment and pesticide safety training; however, personal protective equipment is not required for workers who do not handle pesticides. Thus, our findings suggest that personal protective equipment confers a relative benefit to those who work directly with pesticides.

For pesticide mixers, loaders, and applicators, training in pesticide safety may reinforce the importance of protective practices, and this attitude may carry over to the home environment, motivating safe practices. Analysis conducted by Thompson et al. (2003) on these data showed that, compared with nonhandlers, workers who mixed, loaded, or applied pesticides were significantly more likely to wash their hands after work, wash their clothing after wearing one time, and remove their work clothes before hugging their children. Moreover, training may foster a greater sense of control over one's environment, a factor that several researchers have found to be directly associated with the likelihood of engaging in home protective practices (Arcury et al. 2001; Austin et al. 2001; Quandt et al. 2001).

Also, reentry intervals, which is the major form of protection for fieldworkers, may inadequately protect workers from pesticide exposure. For azinphos-methyl, workers are allowed to return to the fields 14 days after the pesticide has been sprayed. The reentry intervals and provisions for personal protective equipment use of fieldworkers are established for the workers themselves. Consideration for potential exposure to children is not a basis for the standard, although this exposure appears to affect them.

Farmworkers as a group are difficult populations to assess, both in term of identifying them and adequately assessing their exposure levels (Kamel et al. 2001; Zahm and Blair 2001). The previous studies we cited (Fenske et al. 1999; Karr et al. 1992; Loewenherz et al. 1997; McCurdy et al. 1994; Simcox et al. 1999) have generally been convenience samples or samples obtained from a small selection of farms (where workplace norms may confer greater protection), or the samples may have been limited to certain farm tasks (such as mixing, loading, or applying pesticides) and it is not possible to determine whether the samples represent the larger population of workers within the same region. The strength of this study is the large study sample and the recruitment of both fieldworkers and pesticide mixers, loaders, and applicators.

One potential disadvantage of our study is that our samples were collected relatively late in the season. Nevertheless, we found differential patterns of exposure in the home environment, which lends support to the theory that pesticide levels persist in this setting. We also found that all pesticide mixers, loaders, and applicators in our study had detectable levels of dimethyl compounds in their urine, which suggests recent exposure.

Our findings suggest that farmworkers who thin crops are more likely than those who do not perform this task to have detectable concentrations of azinphos-methyl in their homes, where the children appear to be affected. Future investigations should examine the association between fieldworkers' use of protective clothing, such as gloves, hats, and other equipment, and levels of personal exposure to pesticides and concentrations of pesticides in the home environment.

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