Gender Differences in Acute Pesticide-Related Illnesses and Injuries Among Farmworkers in the United States, 1998–2007

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Background *Farmworkers have a high risk for acute pesticide-related illness and injury, and the rate among female farmworkers is approximately twice as high as that among males. Surveillance data were used to identify reasons for this gender difference.*

Methods *We identified acute pesticide-related illness and injury cases among farmworkers from the Sentinel Event Notification System for Occupational Risks (SENSOR)-Pesticides Program and the California Department of Pesticide Regulation. Gender-specific associations with acute pesticide-related illness and injury were assessed using chi-square tests. National Agricultural Workers Survey data were also examined.*

Results *The over-representation of females among farmworker illness and injury cases was confined to females who did not handle pesticides (non-handlers). Female non-handler farmworkers who were affected were more likely to be working on fruit and nut crops, to be exposed to off-target pesticide drift, and to be exposed to fungicides and fumigants compared to males.*

Conclusions *Although there is an increased risk for acute pesticide-related illness and injury among female farmworkers, the absolute number of farmworkers with acute pesticide-related illness and injury is far higher among males than females.*

Abbreviations: CPS, Current Population Survey; FTE, full-time equivalent; IR, incidence rate; IRR, incidence rate ratio; NIOSH, National Institute for Occupational Safety and Health; SENSOR, Sentinel Event Notification System for Occupational Safety and Health; US, United States; DOL, US Department of Labor; EPA, US Environmental Protection Agency.

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Furthermore, farmworkers have little or no control over many of the identified contributing factors that led to illness and injury. Stringent enforcement of existing regulations and enhanced regulatory efforts to protect against off-target drift exposures may have the highest impact in reducing acute pesticide-related illness and injury among farmworkers. Am. J. Ind. Med. Published 2012. This article is a U.S. Government work and is in the public domain in the USA. Am. J. Ind. Med. 55:571–583, 2012.

KEY WORDS: pesticides; agriculture; farmworker; gender differences; poisoning

INTRODUCTION

Pesticides are more commonly used in the agricultural industry compared to any other industry. In the US, approximately 80% of pesticides are used in agriculture [US Environmental Protection Agency (EPA) 2011]. Farmworkers account for a large proportion of workers employed in US agriculture [US Bureau of Labor Statistics, 2010]. Farmworkers are a particularly vulnerable group in the agricultural industry and in the working population in general. Farmworkers can be exposed to pesticides by mixing, loading, and applying them, by performing duties that bring them in contact with pesticide-treated materials (e.g., weeding, harvesting, thinning), or by drift of pesticides applied to nearby areas [Calvert et al., 2008]. They also receive low wages and have reduced access to health care and other resources, due to lack of health insurance, limited access to workers' compensation, poverty, and undocumented immigrant status [Mehta et al., 2000].

A recent analysis of data collected by the California Department of Pesticide Regulation (CDPR) and the Sentinel Event Notification System for Occupational Risks (SENSOR)-Pesticides program from 1998 to 2005 revealed that the incidence rates of acute pesticide-related illness were consistently higher for agricultural workers than for non-agricultural workers [Calvert et al., 2008]. One noteworthy finding was that the incidence rates of acute pesticide-related illness among all females in the agricultural industry, as well as females employed specifically as farmworkers, were approximately twice as high as those of their male counterparts. However, the reasons for this gender difference have not been explored.

The purpose of this data analysis is to explore factors that may explain the discrepancy in incidence rates between male and female farmworkers. Data collected by CDPR and the SENSOR-Pesticides program from 1998 to 2007 were analyzed to compare factors involved in pesticide exposure, to explore possible differences in illness characteristics, and differences in work tasks between male and female farmworkers. Data from the National Agricultural Workers Survey (NAWS), a national survey designed to obtain national estimates on the crop farmworker population, were also examined to identify demographic differences between female and male farmworkers.

MATERIALS AND METHODS

Data Collection

Data for this analysis were obtained from CDPR, the SENSOR-Pesticides program, and NAWS. The SENSOR-Pesticides program was created by the National Institute for Occupational Safety and Health (NIOSH) to monitor risks for acute pesticide exposure. The number of states that collect pesticide-related illness and injury surveillance data varies by year and has been as high as 12 states. These data are organized into an aggregated database. State health departments in eleven states contributed data for this analysis. These state health departments include: Arizona Department of Health (1998–1999), California Department of Public Health (CDPH; 1998–2007), Florida Department of Health (1998–2007), Iowa Department of Public Health (2006–2007), Louisiana Department of Health and Hospitals (2001–2007), Michigan Department of Community Health (2001–2007), New Mexico Department of Health (through an agreement with the University of New Mexico; 2005–2007), New York State Department of Health (1998–2007), Oregon Health Authority (1998–2007), Texas Department of State Health Services (1998–2007), and the Washington State Department of Health (2001–2007). Because CDPH and CDPR are independent agencies and their access to data sources differs, CDPH cross-referenced its cases with those from CDPR based on social security number (SSN), first and last name, date of illness or injury, and date of birth. A total of 838 agricultural workers from California were identified as cases by both programs and were counted only once. This ability to compare cases from the two programs using SSN and name only became available in 2011. In previous articles describing findings from CDPH and CDPR (e.g., Calvert et al., 2008), NIOSH cross-referenced cases without the of use personal identifiers since these identifiers are not available to NIOSH. As such, the earlier identification of duplicates was less successful causing some cases to be counted twice. Because each state removes any personal identifiers from the data prior to submission to NIOSH, this study was exempt from consideration by the federal Human Subjects Review Board.

Data on the national demographic characteristics of crop farmworkers were obtained from NAWS (farmworkers working with livestock or on ranches are excluded from participation in NAWS). The primary objective of NAWS is to obtain national estimates of crop farmworker characteristics [CDC, 2009]. NAWS is a nationally representative annual survey of US crop farmworkers conducted by the US Department of Labor (DOL) [US DOL, 2011]. Participating farmworkers are selected through a multi-stage stratified process. The farmworkers are recruited at their worksite but are interviewed face-to-face outside of working hours at home or at another non-workplace location. The interview lasts about 1 hr. Data collected in 1999 and between 2002 and 2007 were analyzed.

Study Population and Case Definition

Farmworkers, defined as individuals who work on, but do not own, a farm, were identified by the 1990 or 2002 Census Industry Codes (CIC) and Census Occupation Codes (COC) [US Bureau of the Census, 1992; US Census Bureau, 2005]. First, all agricultural worker cases were identified by the following industry codes: agricultural production, excluding livestock (1990 CIC = 010; 2002 CIC = 0170); agricultural production, including livestock (1990 CIC = 011; 2002 CIC = 0180); and agricultural services (1990 CIC = 030; 2002 CIC = 0290). Among these agricultural workers, farmworker cases were identified by occupation codes: 1990 COC = 477, 479, 484; 2002 COC = 6050, 6120, 8710, 8960. Additionally, other agricultural workers were also identified to compare incidence rates by gender and occupation: farmers, defined as individuals who own and/or operate a farm (1990 COC = 473–476; 2002 COC = 0200, 0210), processing/packing plant workers (1990 COC = 488, 699; 2002 COC = 6040, 7830, 7850, 8640, 8720, 8800, 8860, 9640), and other miscellaneous agricultural workers (workers employed in agriculture but whose 1990 COC and 2002 COC did not match any of those specified for the other three agricultural occupations). A pesticide handler was defined as a farmworker who mixed, loaded, transferred, disposed of and/or applied pesticides, or who repaired or maintained pesticide application equipment at the time of pesticide exposure. All other farmworkers were considered non-handlers. Data were obtained for individuals aged 15 through 64 who developed an acute pesticide-related illness or injury after experiencing an occupational pesticide exposure.

All participating SENSOR-Pesticides states use a standardized case definition. Cases of acute pesticide illness and injury classified as definite, probable, possible or suspicious were included. The case definition is based on three factors: (i) the strength of evidence that a pesticide exposure occurred; (ii) whether adverse health effects were observed by a healthcare professional versus being self-reported; and (iii) the presence of sufficient evidence that the known toxicology of the agent was consistent with the observed health effects. Cases exposed to pesticides for which there is limited toxicological data were classified as suspicious [CDC, 2001a]. CDPR uses a similar case definition [CDPR, 2006]. In this article, ‘‘affected’’ and ‘‘acute pesticide-related illness and injury’’ are used interchangeably.

Illness severity was assigned to all cases based on signs and symptoms, medical care received, and lost time from work [CDC, 2001b]. Low severity illnesses or injuries generally resolve without treatment, with <3 days lost from work. Illnesses or injuries of moderate severity manifest as non-life-threatening health effects that are generally systemic and require medical treatment. No residual disability is detected, and time lost from work is 5 days or less. High severity illness or injury consists of life-threatening health effects that usually require hospitalization (>3 days), often involve substantial time lost from work (>5 days), and may result in permanent impairment or disability. Fatal illnesses refer to deaths resulting from exposure to one or more pesticides.

Factors contributing to pesticide illness and injury were obtained from several sources. In the SENSOR-Pesticides program, some factors are captured systematically during follow-up (e.g., drift, use in conflict with label, early re-entry, notification, transport for care not provided). In the assessment of PPE factors, NIOSH compared pesticide label requirements with information provided by the state on a case’s PPE use. All cases captured by CDPR are investigated by the relevant county agriculture commissioner. The commissioner’s investigation reports were reviewed by CDPR staff to identify some contributing factors (i.e., drift, early re-entry, failure to use required PPE, equipment failure). Other contributing factors were identified by NIOSH investigators reviewing the narratives submitted by state partners.

NAWS data were analyzed for crop farmworkers employed in field work or nurseries. Farmworkers employed in packing houses or other settings were excluded from analysis. Handlers were defined as those who answered ‘‘yes’’ to the question ‘‘In the last 12 months, have you loaded, mixed or applied pesticides?’’ The farmworkers were also asked to identify the crop on which they were working at the time of the interview, and the response categories were: field crops, fruits and nuts, horticulture, vegetables, and miscellaneous/multiple. In addition, the farmworkers were asked if they received training in the safe use of pesticides in the last 12 months.

In 1999 only, NAWS included questions to determine if crop workers were affected by pesticides. This information was collected in two parts. First NAWS asked the crop worker if they were exposed to pesticides in the previous 12 months by "having them sprayed or blown on you," "spilled on you," or "when cleaning or repairing containers or equipment used for applying or storing pesticides." NAWS then asked if the crop worker became "sick or [had] any reaction because of this incident."

Statistical Analysis

SAS v. 9.2 software was used for data management and analysis [SAS Institute Inc., 2008]. Incidence rates (IR) for acute occupational pesticide illness and injury were calculated for all agricultural workers combined, and for each agricultural occupation. Among US farmworkers, rates were calculated for each year, age group, and US geographic region. The numerator represents the number of relevant cases captured by CDPR and SENSOR-Pesticides from 1998 through 2007. Denominator data (i.e., estimates of employment counts and hours worked) were obtained from the Current Population Survey (CPS) [US Bureau of Labor Statistics, 2010]. The hours worked data were used to derive full-time equivalent (FTE) estimates, with one FTE equal to 2,000 hr worked. Denominator data correspond to the states and time periods of numerator availability. Because the rates calculated with the two denominator estimates (employment counts and FTE estimates) produced similar results, only rates calculated with FTEs as the denominator are provided, as they have been demonstrated to be conceptually preferable to the use of raw employment counts [Ruser, 1998].

Incidence rate ratios (IRR) were calculated to determine the risk of acute pesticide illness and injury for female workers compared to male workers. This ratio was calculated by dividing the IR among female workers by that of male workers. A ratio greater than one suggests an increased risk among females. Significance testing for the IRRs was performed using the z-test statistic, which assumed normal distribution of the logarithm of the rate ratio. Two-sided 95% confidence intervals (95% CI) were also calculated for each IRR as described by Rothman [1986].

Female and male case data were described by pesticide product toxicity category (these are assigned by EPA to indicate the toxicity of the pesticide and range from I to IV, with toxicity category I products being most toxic), pesticide handler status, pesticide functional class, pesticide chemical class, illness severity, symptoms, the source of the pesticide illness report (e.g., poison control center, workers' compensation, or other government agency), event size (i.e., how many affected individuals in a given event), type of exposure (e.g., off-target drift, contact with pesticide residue, etc.), the crop with which farmworkers were working when exposed, and factors that contributed to pesticide exposure. Chi square statistical analyses using two-tailed tests at the $\alpha = 0.05$ significance level were performed to compare female and male case characteristics on select variables.

NAWS data were analyzed to estimate the gender distribution of the national farmworker population. In addition, the proportions of farmworkers who were handlers and non-handlers and who were working on various crops, stratified by gender, were determined. All proportions were calculated using sampling weights provided by DOL.

RESULTS

From 1998 to 2007, 3,646 cases of acute pesticide illness and injury were identified among agricultural workers. Among these, 2,534 cases were farmworkers, consisting of 1,777 male and 757 female cases (11 farmworker cases did not have information on gender and were thus excluded from analysis). Table I displays incidence rates for males and females in each agricultural occupation. Over two-thirds of the agricultural cases were farmworkers (70.0%, N = 2,534). Farmworkers had a higher incidence rate of acute pesticide illness and injury than farmers and other agricultural occupations, although processing/packing plant workers had a much higher incidence rate than any other agricultural occupation. The incidence rate among female agricultural workers was nearly twice that of male agricultural workers. However, when broken down by occupation, this discrepancy is seen only among farmworkers. Female farmworkers had an incidence rate that was 2.2 times higher than that of male farmworkers. Males had significantly higher incidence rates than females in all other agricultural occupations (i.e., farmers, processing/packing plant workers, and all other agricultural occupations).

Region, Year of Exposure, and Age Group

Table II shows incidence rates for male and female farmworkers and IRRs by region, year of exposure, and age group. Female farmworkers had a higher IR than males in the southern and western states, but a lower IR in eastern/central states. They also had a higher rate for all years. Additionally, females experienced significantly higher rates for all age groups, except for the youngest (15–17 years) and oldest (55–64 years) groups.

Comparison With Farmworker Demographic Data From NAWS

NAWS and CPS provide very similar estimates of farmworker gender distribution: 21% and 16% female,

TABLE I. Incidence Rates for Acute Pesticide-Related Illness and Injury Cases by Gender and Occupation in the Agricultural Industry, 1998–2007

	All			Females			Males				
	Count	FTE estimate[a]	IR[b]	Count	FTE estimate	IR[b]	Count	FTE estimate	IR[b]	IRR[c]	95% CI[d]
All Agricultural Workers	3,646	7,616,752	47.9	1,163	1,570,239	74.1	2,483	6,046,513	41.1	1.8*	1.7, 1.9
Farmworkers	2,534	3,769,409	67.2	757	600,643	126.0	1,777	3,168,766	56.1	2.2*	2.1, 2.4
Farmers	116	2,383,745	4.9	12	432,353	2.8	104	1,951,392	5.3	0.5**	0.3, 0.9
Processing/Packing Plant Workers	432	149,425	289.1	309	113,046	273.3	123	36,379	338.1	0.8**	0.7, 1.0
Other Agricultural Occupations	564	1,314,173	42.9	85	424,197	20.0	479	889,976	53.8	0.4*	0.3, 0.5

[a]FTE = full-time equivalent. These were calculated from the Current Population Survey using employment counts and hours worked. One FTE = 2,000 hr worked.
[b]IR = incidence rate per 100,000 FTEs.
[c]IRR = incidence rate ratio = IR Females/IR Males. Compares the rate of acute pesticide illness and injury among female agricultural workers with male agricultural workers. A rate ratio greater than one suggests an increased risk in female farmworkers.
[d]95% confidence intervals were calculated for each rate ratio as described by Rothman [1986].
*$P < 0.0001$.
**$P < 0.05$.

respectively. These figures fall well below the percentage we found among farmworkers apparently affected by pesticide exposure, of whom 30% were female. Figure 1 compares NAWS demographic findings to the distribution of illness data. Except among handlers, women constitute a larger fraction of illness cases than of the workforce. The disparity is greatest among workers tending fruit and nut crops, a category that NAWS found to employ a third of all farmworkers, both male and female. Illness data further differentiate between small fruits (such as grapes or strawberries), where most female cases occurred, and tree fruits, where more males were affected (Table III). NAWS crop data do not distinguish small fruits from tree fruits. Comparisons between California NAWS data and California illness data produced findings very similar to the national comparisons. Finally, NAWS found that among non-handler farmworkers, 77% of both males and females reported receiving pesticide training in the previous 12 months.

According to 1999 NAWS data, a lower proportion of female crop workers acknowledged pesticide exposure during the previous 12 months (1.0% of females vs. 3.8% of males), but among those exposed, females were more likely to report getting sick or having a reaction (76.6% of females vs. 41.0% of males). When these proportions were multiplied, a lower proportion of female farmworkers were affected in 1999 (0.77% of female farmworkers vs. 1.6% of males). Among crop workers interviewed in 1999 who handled pesticides at any time in the last 5 years, 9% were female, but 12% of female handlers and 6% of male handlers reported getting ill from this work, and 17% of the ill handlers were female.

Circumstances and Factors of Exposure

Circumstances and factors surrounding the exposure events are provided in Table III. Females with acute pesticide-related illness or injury were significantly more often involved in multi-person exposure events than males (71.6% vs. 40.5%, $P < 0.0001$). Even when the handlers were removed from the analysis, affected non-handler females were significantly more often involved in multi-person exposure events (74.1% vs. 62.0%, $P < 0.0001$). The two most common types of exposure reported by both affected males and females were from drift of pesticides away from the application site or contact with pesticide residues on treated surfaces.

Information on factors that contributed to pesticide exposure was available for 1,774 (70.0%) of the acute pesticide-related illness or injury cases. The most commonly identified contributing factor was exposure to off-target drift. A higher proportion of affected females reported exposure due to off-target drift compared to affected males (80.2% of non-handler females vs. 64.7% of non-handler males, $P < 0.0001$; Table III). Males, on the other hand, were more frequently affected when the use of the pesticide was in conflict with the label (4.7% of non-handler females vs. 14.9% of non-handler males, $P < 0.0001$). No contributing factors were identified in 134 (5.3%) cases—i.e., no restriction entry interval was apparently violated, the required PPE was apparently worn, and label instructions appeared to have been followed.

Pesticide Characteristics

Characteristics of the pesticides involved in the acute illnesses and injuries of farmworkers, stratified by gender, are provided in Table IV. A higher proportion of affected female farmworkers were exposed to fungicides (38.7% vs. 30.4%, $P < 0.0001$) and fumigants (14.3% vs. 8.7%, $P < 0.0001$) compared to affected males. As for chemical class, a larger proportion of affected females had exposure to inorganic compounds (29.7% vs. 19.5%, $P < 0.0001$), as well as dithiocarbamates [the majority of

TABLE II. Acute Pesticide-Related Illness and Injury Incidence Rates among Farmworkers by Gender, Region, and Year of Exposure, 1998–2007

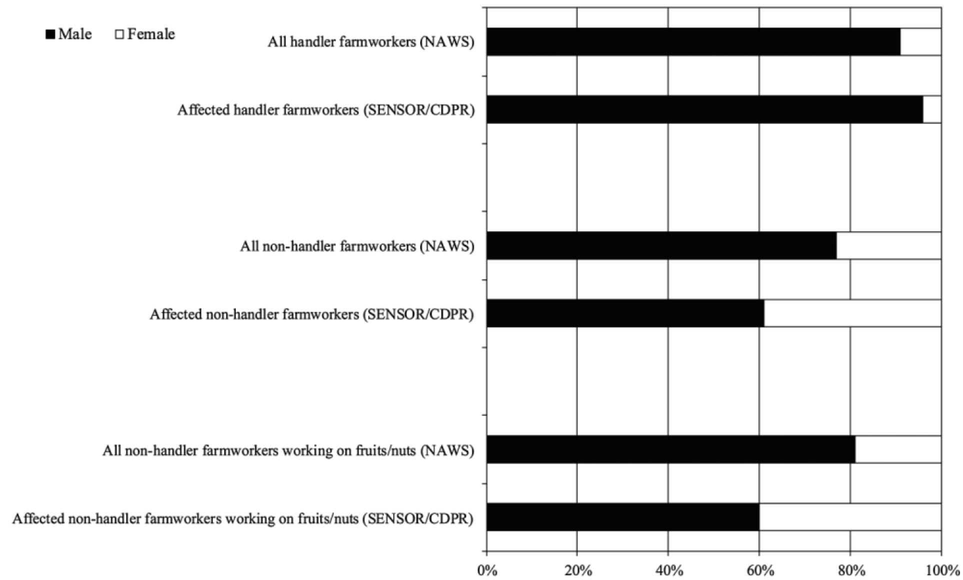
	Females			Males				
	Count	FTE estimate[a]	IR[b]	Count	FTE estimate[a]	IR[b]	IRR[c]	95% CI[d]
Total	757	600,643	126.0	1,777	3,168,766	56.1	2.2*	2.1, 2.4
Region								
East/Central[e]	13	57,110	22.8	82	236,721	34.6	0.7	0.4, 1.2
South[f]	42	138,277	30.4	166	927,542	17.9	1.7**	1.2, 2.4
West[g]	702	405,256	173.2	1,529	2,004,503	76.3	2.3*	2.1, 2.5
Age group								
15–17	6	22,591	26.6	39	89,082	43.8	0.6	0.3, 1.4
18–24	133	87,775	151.5	370	642,063	57.6	2.6*	2.2, 3.2
25–34	200	183,311	109.1	490	909,265	53.9	2.0*	1.7, 2.4
35–44	190	163,240	116.4	367	800,267	45.9	2.5*	2.1, 3.0
45–54	101	105,116	96.1	220	449,356	49.0	2.0*	1.6, 2.5
55–64	22	38,610	57.0	112	278,733	40.2	1.4	0.9, 2.2
Unknown	105	—		179	—			
Year of exposure								
1998	47	64,594	72.8	203	391,242	51.9	1.4**	1.0, 1.9
1999	65	64,363	101.0	163	380,093	42.9	2.4*	1.8, 3.1
2000	89	64,878	137.2	130	377,392	34.4	4.0*	3.0, 5.2
2001	30	62,243	48.2	145	324,512	44.7	1.1	0.7, 1.6
2002	152	67,290	225.9	223	302,514	73.7	3.1*	2.5, 3.8
2003	57	65,462	87.1	161	302,537	53.2	1.6**	1.2, 2.2
2004	66	50,902	129.7	268	256,777	104.4	1.2	0.9, 1.6
2005	124	54,524	227.4	155	290,072	53.4	4.3*	3.4, 5.4
2006	52	52,792	98.5	146	275,015	53.1	1.9**	1.4, 2.5
2007	75	53,595	139.9	183	268,612	68.1	2.1*	1.6, 2.7

[a]FTE = full-time equivalent. These were calculated from the Current Population Survey using employment counts and hours worked. One FTE = 2,000 hr worked.
[b]IR = incidence rate per 100,000 FTEs. Includes agricultural workers in Arizona, California, Florida, Iowa, Louisiana, Michigan, New Mexico, New York, Oregon, Texas, and Washington.
[c]IRR = incidence rate ratio (IR Females/IR Males). Compares the rate of acute pesticide illness and injury among female agricultural workers with male agricultural workers. A rate ratio greater than one suggests an increased risk in female farmworkers.
[d]95% confidence intervals were calculated for each rate ratio as described by Rothman [1986].
[e]Iowa, Michigan, New York.
[f]Florida, Louisiana, Texas.
[g]Arizona, California, New Mexico, Oregon, Washington.
*$P < 0.0001$.
**$P < 0.05$.

dithiocarbamates were metam sodium (66.1%)] (17.7% vs. 9.6%, $P < 0.0001$), whereas a larger proportion of affected males reported exposures to cholinesterase inhibitors (e.g., organophosphates) (30.0% vs. 36.2%, $P < 0.05$). Affected males and females did not differ with respect to the toxicity category of the pesticide exposure. Non-handler female farmworkers working with fruits and nuts accounted for the largest proportions of affected female farmworkers exposed to various pesticide functional and chemical classes, including fumigants (84.3%), fungicides (68.9%), inorganic compounds (81.3%), and dithiocarbamates (70.1%).

Illness Characteristics and Sources of Illness Reports

Table V compares the characteristics of pesticide-related illness reported between male and female cases. The distribution of moderate-severity, high-severity, and fatal illnesses were similar between the two genders (11.2% of females vs. 13.3% of males, $P = 0.2$). Affected females had respiratory (41.5% vs. 29.6%, $P < 0.0001$), gastrointestinal (50.3% vs. 35.4%, $P < 0.0001$), and neurological (63.3% vs. 50.4%, $P < 0.0001$) signs and symptoms more often than affected males, though there were no major



a. NAWS = National Agricultural Workers Survey, 2002-2007
b. "Affected" is defined as having an acute pesticide-related illness or injury
c. SENSOR/CDPR = Sentinel Event Notification System for Occupational Risks (SENSOR)-Pesticides / California Department of Pesticide Regulation (Pesticide Illness Surveillance System), 1998-2007

FIGURE 1. Gender distribution of farmworkers by pesticide handler status among all farmworkers using NAWS[a] data, and among farmworkers affected[b] with acute pesticide-related illness or injury using SENSOR/CDPR[c] data, United States.

differences by gender in other signs/symptoms. Among reporting sources, affected male farmworkers were more often captured through poison control centers (7.7% of females vs. 15.9% of males, $P < 0.0001$), physician or other health care provider reports (including hospital and emergency room reports; 3.2% of females vs. 4.8% of males, $P = 0.06$), and workers' compensation documents (23.7% of females vs. 34.7% of males, $P < 0.0001$).

DISCUSSION

Pesticide illness and injury data collected by CDPR and the SENSOR-Pesticides program from 1998 to 2007 show that the incidence rate of acute pesticide-related illness is twice as high among female farmworkers as among their male counterparts. However, because approximately 84% of farmworkers are male, the absolute number of farmworkers with acute pesticide-related illness and injury is far higher among males than females.

Based on the national farmworker demographic estimates from NAWS, it appears that the over-representation of females among farmworker illness and injury cases is confined to female non-handlers. Nationally, 23% of all those employed as non-handler farmworkers are female, but 39% of the non-handler farmworkers affected by pesticides were female. Affected female non-handler farmworkers were more likely to be working on fruit and nut crops (especially small fruits), exposed by drift from the application site and exposed to fungicides and fumigants compared to affected male non-handler farmworkers.

It is not clear why female non-handler farmworkers working on fruit and nut crops, especially small fruits, had a higher risk. Among non-handler farmworkers, regardless of gender, the proportion who were affected while working on fruits and nuts was higher than the NAWS proportion of farmworkers who are estimated to work on these crops, suggesting that working on fruits and nuts poses an elevated risk for acute pesticide-related illness and injury. Female non-handler farmworkers accounted for most cases affected while working with small fruits and male non-handler farmworkers accounted for most cases affected while working with tree fruits. Among non-handler cases, a higher percentage of females were exposed due to pesticide drift, and were involved in multi-person exposure events compared to males. It is possible that female farmworkers have different patterns of exposure, and different pesticide exposures (i.e., functional and chemical class) due to working on different crops than males. Other studies have shown that men and women typically perform different tasks in agricultural operations, which can lead to different levels of pesticide exposure [Blair and Zahm, 1995; Settimi et al., 1999; Coronado et al., 2004; Quandt et al., 2006; Villarejo and McCurdy, 2008; Keogh, 2009]. Compared to male farmworkers, a higher proportion of females may be involved with activities with direct exposure to crops because they are less likely to operate machinery [Villarejo and McCurdy, 2008] and are more likely to be involved with cutting, sorting, and harvesting than males [Mills et al., 2005].

TABLE III. Circumstances and Contributing Factors for Pesticide Exposure Among Farmworkers With Acute Pesticide-Related Illness and Injury, by Gender, 1998–2007

	All farmworkers				Farmworker non-handlers[a]			
	Females (n = 757)		Males (n = 1,777)		Females (n = 723)		Males (n = 1,119)	
	N	%	N	%	N	%	N	%
Event size								
One person	215	28.4	1,057	59.5	187	25.9	425	38.0
Two or more persons	542	71.6	720	40.5	536	74.1	694	62.0
Handling pesticides at time of exposure?[a]								
Yes	29	3.8	640	36.0				
No	723	95.5	1,119	63.0	723	100.0	1,119	100.0
Unknown	5	0.7	18	1.0				
Type of exposure[b]								
Drift from application site	464	61.3	554	31.2	461	63.8	546	48.8
Contact with treated surface	223	29.5	479	27.0	219	30.3	468	41.8
Exposed during targeted application	29	3.8	379	21.3	15	2.1	31	2.8
Leak/Spill	16	2.1	229	12.9	5	0.7	32	2.9
Indoor air	16	2.1	20	1.1	14	1.9	10	0.9
Other[c]	63	8.3	274	15.4	58	8.0	121	10.8
Unknown	7	0.9	88	5.0	4	0.6	15	1.3
Crop[d]								
Fruits and nuts	422	55.7	831	46.8	419	58.0	618	55.2
Small fruit	347	45.8	373	21.0	346	47.9	318	28.4
Tree fruit	74	9.8	454	25.5	72	10.0	298	26.6
Other fruit	1	0.1	4	0.2	1	0.1	2	0.2
Vegetables	71	9.4	185	10.4	68	9.4	150	13.4
Ornamental plants	59	7.8	76	4.3	54	7.5	37	3.3
Grain	16	2.1	126	7.1	14	1.9	89	8.0
Weeds	2	0.3	78	4.4	0	0.0	0	0.0
Soil	1	0.1	40	2.3	0	0.0	0	0.0
Other	42	5.5	145	8.2	31	4.3	34	3.0
Not applicable	44	5.8	116	6.5	42	5.8	74	6.6
Unknown	100	13.2	180	10.1	95	13.1	117	10.5
Contributing factors[e]								
Contributing factor information available	595	100.0	1,179	100.0	575	100.0	844	100.0
Drift	464	78.0	554	47.0	461	80.2	546	64.7
Early re-entry[f]	58	9.7	159	13.5	58	10.1	158	18.7
PPE factors	20	3.4	199	16.9	13	2.3	22	2.6
Failure to use required PPE	7	1.2	143	12.1	5	0.9	13	1.5
Failure to use PPE/Inadequate or unknown requirement	13	2.2	47	4.0	8	1.4	9	1.1
PPE in poor repair	0	0.0	9	0.8	0	0.0	0	0.0
Use in conflict with label-other and unspecified	28	4.7	134	11.4	27	4.7	126	14.9
Notification/Posting lacking or ineffective	55	9.2	63	5.3	55	9.6	62	7.3
Oral notification of pesticide application not provided	32	5.4	26	2.2	32	5.6	26	3.1
Application site not posted/notification posters incorrect	23	3.9	37	3.1	23	4.0	36	4.3
Unsafe equipment/Equipment failure	9	1.5	106	9.0	4	0.7	13	1.5
Hazard communication or other OSHA violation	21	3.5	56	4.7	21	3.7	52	6.2
Non-handler in treated area during application	42	7.1	50	4.2	42	7.3	50	5.9
Training factors	8	1.3	39	3.3	7	1.2	19	2.3

(*Continued*)

TABLE III. (*Continued*)

	All farmworkers				Farmworker non-handlers[a]			
	Females (n = 757)		Males (n = 1,777)		Females (n = 723)		Males (n = 1,119)	
	N	%	N	%	N	%	N	%
Training not provided or inadequate	8	1.3	38	3.2	7	1.2	18	2.1
Worker not told of health effects caused by pesticides	0	0.0	1	0.1	0	0.0	1	0.1
Decontamination inadequate	3	0.5	44	3.7	3	0.5	39	4.6
Transport for care not provided	1	0.2	15	1.3	1	0.2	12	1.4
FIFRA-other and unspecified	4	0.7	6	0.5	2	0.3	0	0.0
Other/Unspecified worker protection standard violation	5	0.8	7	0.6	4	0.7	4	0.5
Inadequate record keeping	1	0.2	5	0.4	1	0.2	1	0.1
None identified	20	3.4	114	9.7	18	3.1	52	6.2
Unknown	162	27.2	598	50.7	148	25.7	275	32.6

[a]Pesticide handler status was determined by activity at time of exposure. If a farmworker was applying pesticide, mixing and loading pesticide, transporting or disposing of pesticide, repairing or maintaining pesticide application equipment, or performing any combination of these activities, he or she was considered a pesticide handler. All other farmworkers were considered non-handlers.
[b]Because cases had more than one type of exposure, the sum of the percentages exceeds 100%.
[c]"Other" was coded if the type of exposure was known but did not fit into any of the above categories (e.g., fumes generated from mixing chemicals, smoke from burning chemicals, etc.).
[d]Refers to the crop the worker was tending at the time of exposure.
[e]Multiple contributing factors may have been involved.
[f]Agricultural pesticides have a restricted entry interval (REI) that defines how soon after an application workers can enter the treated area. If workers are required to enter the treated area before the REI has expired, they must wear the appropriate PPE. In cases of early re-entry, workers entered the treated area before the REI expired with no or insufficient PPE.

Non-handler farmworkers may not know the potential for exposure to pesticides and may be less likely to take appropriate precautions [Miligi et al., 2003]. Hagan and Moraga-McHaley [2009] found that female farmworkers in New Mexico are much less likely to receive pesticide exposure prevention training than males (32% vs. 57%), and found that farmworkers who received this training had greater knowledge of measures to reduce pesticide exposure and were more likely to engage in those behaviors (92% of the survey respondents were non-handlers). In contrast, NAWS data suggest that 77% of female and male non-handler farmworkers receive annual pesticide training. However, additional training of non-handler farmworkers may not prevent many of the cases identified by SENSOR/CDPR. Non-handler farmworkers have little or no control over the four contributing factors responsible for the largest proportion of illness and injury cases: drift; early re-entry into pesticide-treated fields; use of pesticides in conflict with the label; and, being present in the treated area at the time of the application.

The 1999 NAWS data also showed gender differences in pesticide illness and injury but the findings were equivocal. Overall, female crop farmworkers were less likely to experience pesticide illness and injury compared to males, but were more likely than males to report that exposure resulted in symptoms. The NAWS findings also suggest that the magnitude of pesticide illness and injury among farmworkers is much higher than that found by SENSOR/CDPR (SENSOR/CDPR found that 0.13% of female farmworkers and 0.06% of male farmworkers experienced pesticide illness or injury per year between 1998 and 2007, compared to the NAWS finding of 0.77% of female farmworkers and 1.6% of males in 1999). These NAWS findings are limited by the fact that the 1999 NAWS survey has a relatively small sample size which does not permit stable estimates, and did not ask about contact with pesticide-treated surfaces, which is an important source of pesticide exposure.

Physiological differences between men and women may result in females' increased susceptibility to adverse effects from pesticides and other environmental toxins [McDuffie, 1994; Silvaggio and Mattison, 1994; Paolini et al., 1996, 1999; Pozzetti et al., 1999; Sierra-Santoyo et al., 2000; Gandhi et al., 2004; Soldin and Mattison, 2009]. However, the gender distribution among affected handlers compared to the national gender distribution among handlers (according to NAWS; Fig. 1) does not support the hypothesis that females are physiologically predisposed to higher rates of pesticide illness and injury.

While females may be experiencing higher rates of illness because they are more likely to work with crops and engage in activities at higher risk of pesticide exposure, it is also possible that the difference is due to higher reporting rates among female workers than male workers.

TABLE IV. Frequency and Characteristics of Pesticides to Which Farmworkers With Acute Pesticide-Related Illness and Injury Were Exposed, by Gender, 1998–2007

	All farmworkers				Farmworker non-handlers[a]			
	Females (n = 757)		Males (n = 1,777)		Females (n = 723)		Males (n = 1,119)	
	N	%	N	%	N	%	N	%
Pesticide functional class[b]								
Insecticide	509	67.2	1,103	62.1	500	69.2	814	72.7
Insecticide only	158	20.9	467	26.3	152	21.0	337	30.1
Fungicide	293	38.7	541	30.4	286	39.6	382	34.1
Fungicide only	40	5.3	101	5.7	35	4.8	69	6.2
Herbicide	60	7.9	293	16.5	54	7.5	76	6.8
Herbicide only	36	4.8	224	12.6	30	4.1	42	3.8
Fumigant	108	14.3	154	8.7	106	14.7	107	9.6
Other	222	29.3	456	25.7	211	29.2	299	26.7
Product chemical class[c]								
AChE inhibitors	227	30.0	643	36.2	219	30.3	485	43.3
Inorganic compounds	225	29.7	346	19.5	219	30.3	226	20.2
Dithiocarbamates	134	17.7	170	9.6	132	18.3	140	12.5
Pyrethrins/Pyrethroids	89	11.8	205	11.5	88	12.2	151	13.5
Other	456	60.2	1,018	57.3	436	60.3	587	52.5
Toxicity category								
I	319	42.1	765	43.1	308	42.6	499	44.6
II	213	28.1	439	24.7	206	28.5	295	26.4
III/IV	213	28.1	518	29.2	200	27.7	310	27.7
Unknown	12	1.6	55	3.1	9	1.2	15	1.3

[a]Pesticide handler status was determined by activity at time of exposure. If a farmworker was applying pesticide, mixing and loading pesticide, transporting or disposing of pesticide, repairing or maintaining pesticide application equipment, or performing any combination of these activities, he or she was considered a pesticide handler. All other farmworkers were considered non-handlers.
[b]Because cases were exposed to more than one functional class, the sum of the functional classes exceeds the total number of cases. Categories "Insecticide," "Herbicide," and "Fungicide" include all cases exposed to pesticide product in that functional class. As such, these categories include cases exposed to the functional class of interest only as well as cases exposed to mixtures containing that and other functional classes. In the rows labeled "only," cases were exposed only to pesticides belonging to the functional class of interest.
[c]Cases may have been exposed to the chemical class of interest only or to mixtures that included pesticides belonging to the chemical class of interest along with pesticides from another chemical class.

Female workers may report illness more frequently because they are more perceptive about their symptoms and more likely to seek health care, which has been observed in previous studies [Corney, 1990; van Wijk and Kolk, 1997; Koopmans and Lamers, 2007; Keogh, 2009; Soldin and Mattison, 2009]. For example, male workers may be more likely than females to ignore low-severity illness and only seek care for illnesses of moderate or high severity. However, our finding of little difference in illness severity between genders does not support this hypothesis. Female farmworkers also may have reported illness more frequently because they were often involved in multi-person events, and their awareness of other ill co-workers may have increased their desire and courage to report.

If differences in rates of acute pesticide-related illness also reflect differences in overall pesticide exposures among female farmworkers, our findings may also have implications for increased risks of chronic conditions. For example, studies suggest that female agricultural workers experience a disproportionate risk for leukemia. A study of a California farmworker labor union cohort found that females consistently experienced higher odds ratios for leukemia than males [Mills et al., 2005]. In another study of farmers and pesticide applicators that used National Health Interview Survey data, female workers had a higher risk ratio for leukemia than male workers (age-adjusted RR 2.2, 95% CI = 1.5–3.2) [Fleming et al., 2003].

Limitations

This study has several limitations. First, this study was limited by incomplete information for some cases. Eleven cases lacked information on gender and were thus excluded from analysis. Missing information could lead to

TABLE V. Acute Pesticide-Related Illness and Injury—Characteristics and Report Sources for Farmworkers by Gender, 1998–2007

	All farmworkers				Farmworker non-handlers[a]			
	Females (n = 757)		Males (n = 1,777)		Females (n = 723)		Males (n = 1,119)	
	N	%	N	%	N	%	N	%
Severity								
Low	672	88.8	1,541	86.7	648	89.6	1,003	89.6
Moderate	80	10.6	224	12.6	71	9.8	113	10.1
High	5	0.7	10	0.6	4	0.6	3	0.3
Fatal	0	0.0	2	0.1	0	0.0	0	0.0
Symptoms[b]								
Neurological	479	63.3	895	50.4	470	65.0	638	57.0
Gastrointestinal	381	50.3	630	35.5	375	51.9	450	40.2
Ocular	264	34.9	659	37.1	256	35.4	375	33.5
Dermatological	272	35.9	618	34.8	248	34.3	366	32.7
Respiratory	314	41.5	526	29.6	303	41.9	362	32.4
Cardiovascular	49	6.5	109	6.1	48	6.6	57	5.1
Renal/Genitourinary	15	2.0	19	1.1	14	1.9	15	1.3
Report source[c]								
Workers' compensation documents	179	23.6	617	34.7	169	23.4	305	27.3
Government report	188	24.8	415	23.4	179	24.8	288	25.7
Poison control center	58	7.7	282	15.9	52	7.2	86	7.7
Physician report	24	3.2	86	4.8	22	3.0	44	3.9
Other	361	47.7	563	31.7	352	48.7	478	42.7

[a]Pesticide handler status was determined by activity at time of exposure. If a farmworker was applying pesticide, mixing and loading pesticide, transporting or disposing of pesticide, repairing or maintaining pesticide application equipment, or performing any combination of these activities, he or she was considered a pesticide handler. All other farmworkers were considered non-handlers.
[b]Cases may have experienced symptoms in multiple organ systems, and therefore the sum of the percentages exceeds 100.
[c]Because cases may have been reported through multiple sources, the sum of the sources exceeds the total number of cases. "Other" report sources include self reports, news reports and obituaries, death certificates, reports from a friend or relative, etc.

misclassification of severity or to inappropriate inclusion or exclusion of the case. Second, rates of pesticide illness and injury may have been distorted by inaccurate estimations of the farmworker population. This group is poorly defined and difficult to characterize due to the transiency of much of the population and tendency to avoid government contact [Villarejo, 2003]. It is possible that estimates of female farmworkers are less accurate than those for males, leading to inaccurate estimates of the true incidence rates of acute pesticide illness and injury among females. In developing countries, women tend to occupy the most marginal positions in both the formal and informal work forces [London et al., 2002]. Factoring in that farmworkers often have undocumented US immigrant status, it may be possible that female farmworkers who are precariously employed may be more reluctant to participate in government surveys used to generate employment statistics. Finally, the cases captured by SENSOR/CDPR may not be representative of all cases of acute pesticide illness or injury among farmworkers. Because some Western states have stronger protections for agricultural workers and more robust pesticide illness and injury surveillance programs, case estimates may have been more accurate in the Western region than in others. For example, both California and Washington state give farmworkers the right to organize and bargain collectively, require cholinesterase monitoring for some pesticide handlers, and have larger numbers of surveillance program staff [Calvert et al., 2010; Liebman and Augustave, 2010]. These protections may make farm workers less hesitant to seek medical care for pesticide illness, and better staffed surveillance programs may improve the odds of cases being identified.

Recommendations

The most common type of exposure reported for both male and female farmworkers was off-target drift. As such, regulations which deal specifically with drift merit closer attention. EPA recently released a draft pesticide registration (PR) notice on improved pesticide drift labeling [US EPA, 2009]. It is intended to provide pesticide users, pesticide registrants and regulatory officials with more detailed guidance to better control drift hazard and assist enforcement activities with clearer and more enforceable instructions. Applicators should use drift management measures and equipment that are best at reducing drift exposure, including new validated drift reduction technologies as they become available [US EPA, 2009]. Additionally, EPA recently enacted several regulations addressing drift from soil fumigation, including making all soil fumigants restricted use, requiring that good agricultural practices be specified on the label, lowering maximum application rates, implementing new handler protections (including enhanced respiratory protection), adopting tarp puncture and removal restrictions, extending worker re-entry restrictions (generally at least 5 days), and requiring detailed fumigant management plans to be prepared by the fumigant users [US EPA, 2010].

Farmworkers have little or no control over many of the contributing factors that led to pesticide illness or injury. As has been recommended elsewhere, our findings suggest that improved grower and applicator compliance with existing pesticide regulations may prevent many cases of farmworkers who were acutely affected by pesticides [Arcury et al., 2001; Calvert et al., 2008; Liebman and Augustave, 2010]. Enhanced enforcement is also needed to bolster compliance with existing pesticide regulations. Additionally, reduced-risk pest control measures such as integrated pest management (IPM) should be adopted, which can achieve reductions in pesticide exposure and misuse [National Research Council, 2000]. Finally, existing surveillance systems should be strengthened to improve capture of cases of pesticide illness and injury, and additional measures should be undertaken to promote diagnostic capability, such as providing both better training for clinicians to recognize pesticide illness and injury and better laboratory testing to confirm pesticide exposures.

CONCLUSIONS

Surveillance data from the SENSOR-Pesticides program and CDPR show that the risk of acute pesticide illness or injury is twice as high among females as among males. The over-representation of females among farmworker illness and injury cases appears to be confined to female non-handlers. Female non-handler farmworkers who were affected were more likely to be working on fruit and nut crops (especially small fruits), to be exposed by drift from the application site, and to be exposed to fungicides and fumigants compared to affected male non-handler farmworkers. Although females have a greater risk of acute pesticide illness or injury, the absolute number of farmworkers with acute pesticide-related illness and injury is higher among males than females because approximately 84% of farmworkers are male. Farmworkers have little or no control over many of the contributing factors that led to pesticide illness or injury. Farmworkers need additional protection from pesticide drift exposure. Furthermore, improved compliance with and enforcement of existing pesticide regulations may prevent many cases of acute pesticide illness and injury among farmworkers. Finally, IPM practices should be adopted to reduce pesticide use, and existing surveillance systems should be strengthened to better capture acute pesticide illness and injury.

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