Patterns of Pesticide Use and Their Determinants Among Wives of Farmer Pesticide Applicators in the Agricultural Health Study

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Pesticide exposure among farmers' wives is poorly characterized. Using questionnaire data from a cohort study of licensed pesticide applicators and their spouses, we investigated patterns of pesticide use among farmers' wives (n = 31,173). Wives reported a wide range of pesticide use: 36% never used pesticides during their lifetimes, whereas the heaviest pesticide users (10%) reported lifetime use of 3 or more agricultural pesticides plus commonly used residential pesticides. We identified 5 ordinal pesticide-use categories and studied factors associated with each category through polytomous logistic regression. Engaging in field work and household hygiene practices that could increase exposure were associated with pesticide use, and associations appeared to strengthen with increasing pesticide use category. Farm women reporting the heaviest pesticide use could exacerbate their exposure by engaging in practices that could increase pesticide contact. (J Occup Environ Med. *2004;46:856–865*)

Farmers' wives could be exposed to pesticides and other hazardous agents if they engage in field work, mix or apply pesticides, live in close proximity to farming operations, or if their husbands carry home contamination on their work clothes. This wide range of opportunity for exposure to pesticides among farmers' wives has been documented,[1,2] but pesticide exposure levels are poorly characterized in this population. Because their exposure could be higher than the general population, the need to include farm women in epidemiologic investigations of pesticides is widely recognized.[3–5] Women with agricultural exposures exhibit excesses of non-Hodgkin's lymphoma, leukemia, multiple myeloma, soft tissue sarcoma, and cancers of the breast and ovary.[5–10] Pesticides have been linked to spontaneous abortion among wives of pesticide applicators[4,11] and to childhood cancer and birth defects in offspring of exposed couples.[12–15]

A number of recent studies have quantified residential pesticide exposure from sources, including carry-home contamination by agricultural workers, spray drift from nearby fields, and home or lawn application.[16–21] Pesticide exposure to farmers' wives while they mix or apply pesticides, which is potentially higher than their residential exposure, continues to be understudied. To address this gap in knowledge, we investigated patterns and deter-

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DOI: 10.1097/01.jom.0000135521.15169.3e

minants of pesticide use (ie, mixing and application) reported by farm wives using data from the Agricultural Health Study (AHS).

The AHS is a long-term prospective study following farm families in Iowa and North Carolina designed to evaluate the health of men and women with agricultural exposures.[5] In a previous analysis of AHS data, Gladen et al. found that approximately one half of farm wives reported that they worked in the fields during the previous growing season,[2] and more than half the wives reported that they mixed or applied pesticides for residential or agricultural use. We extended these previous findings by defining ordinal pesticide use categories that incorporated both toxicity information and information on the total number of pesticides used over the wives' lifetimes. We identified determinants of membership in each pesticide use category as well as behavioral factors such as hygiene practices that were correlated with pesticide use among farmers' wives enrolled in the AHS.

Methods

The AHS, a follow-up study of licensed pesticide applicators and their spouses, has been described elsewhere.[22] In short, those who applied for a license to buy restricted-use pesticides (RUPs) in Iowa and North Carolina between 1993 and 1997 were asked to participate in the study. Approximately 52,000 private applicators who typically worked as farmers, 82% of those eligible, were enrolled. Of those applicators enrolled, 81% were currently married, and we enrolled 76% of their eligible spouses. Spouses of private applicators who did not own or work on a farm ($n = 996$) and male spouses ($n = 178$) were excluded. A total of 31,173 husband and wife pairs, in which the husband was the sole licensed pesticide applicator, constituted the final study population.

We used data collected with 2 questionnaires. Most data came from a take-home spouse questionnaire that was largely self-administered and returned by mail. A fraction of the spouses who did not return their questionnaire by mail (19%) completed it during a telephone interview. Wives were first asked how many days per year and how many years during their lifetimes they personally mixed or applied any pesticide for either residential or agricultural purposes. They were next asked if they ever mixed or applied 50 specific pesticides during their lifetimes. The pesticides queried included common herbicides, insecticides, fungicides, fumigants, and some products that are no longer sold such as organochlorine pesticides. Information to estimate exposure intensity and duration for specific pesticides was not collected for the farm wives and residential versus agricultural use not distinguished. In a separate section of the questionnaire, wives were asked if they usually personally treat their own home or lawn for pests but were not asked to specify the pesticide.

The spouse questionnaire was also the source of information on factors potentially associated with pesticide use, including age, race, education, employment off the farm, engaging in field work, and household hygiene practices (removing work boots before entering the house and mixing pesticide-contaminated work clothes with the family wash). A second self-administered questionnaire completed by the applicator at the time of enrollment, provided information on other factors thought to influence pesticide use, including the presence of young children in the home, farm size, and farm products. Both questionnaires can be found at www.aghealth.org.

We used the August 2, 2003, release of the AHS phase I dataset for all analyses to identify patterns of pesticide use among farm wives. First, we ranked pesticides by prevalence of use among the wives and evaluated their relative toxicity by applying a 4-level scale used by the U.S. Environmental Protection Agency (US EPA) to summarize the acute toxicity of pesticides on product labels.[23] We also determined the total number of pesticides mixed or applied during each farm wife's lifetime and the proportion of wives reporting all combinations of pesticides. Finally, we determined the proportion of women using a specific pesticide given that their husband also used the pesticide, as well as the proportion of women using a pesticide given that their applicator husbands did not. The ratio of these 2 measures serves as an estimate of relative prevalence comparing wives whose husbands use the pesticide with wives whose husbands do not.

We defined 5 pesticide use categories to encapsulate the broad exposure patterns that were identified (see "Results"). To determine factors potentially associated with the pesticide use categories, we used polytomous logistic regression models fitted with PROC CATMOD in SAS version 8.2 (Cary, NC). Because the exposures modeled as dependent variables were not rare (ie, $<10\%$), odds ratios (ORs) should be interpreted as measures of association, not estimates of relative risk. Potential determinants of pesticide use were grouped and modeled together as follows: 1) personal characteristics of the wife, 2) field work activities, and 3) farm characteristics. The correlations between household hygiene factors known to increase residential contamination and pesticide use categories were also explored through polytomous regression analyses. We conducted stratified analyses to determine whether associations varied by state. Final models were adjusted for age and state of residence. The reference group for most of the analyses presented was wives who never used pesticides; however, for analyses restricted to pesticide users, wives who reported using only commonly used pesticides served as the referent.

To evaluate the potential for selection bias, we compared ever-married male applicators whose wives did not participate in the study with those with participating wives on

TABLE 1
Factors Potentially Associated With Pesticide Use, AHS Farm Wives, Iowa and North Carolina, 1993 to 1997

	AHS Farm Wives (n = 31,173) Number (%)	
	Iowa (n = 21,498)	North Carolina (n = 9,675)
Age, years		
median (range)	45 (19–88)	49 (17–96)
Child in the last 9 years	6202 (30)	1767 (20)
Race		
White	20885 (99)	8581 (94)
Other*	202 (<1)	541 (6)
Education		
<high school	538 (3)	927 (11)
High school	7485 (40)	4509 (42)
>high school	10708 (57)	3973 (47)
Never worked off the farm	2332 (11)	921 (10)
Household hygiene practices		
Leave work boots on in house	6956 (33)	3875 (44)
Mix contaminated clothes with family wash	1470 (7)	1076 (12)
Farm size		
<5 acres	210 (1)	1484 (21)
5–49 acres	362 (2)	2151 (26)
50–199 acres	3187 (15)	1949 (23)
200–499 acres	7402 (36)	1351 (16)
500–999 acres	6089 (29)	811 (10)
≥1000 acres	3515 (17)	683 (8)
Type of crops/animals		
Cotton	0 (0)	1225 (13)
Fruits and vegetables†	7097 (33)	3856 (40)
Grains‡	20794 (97)	6066 (63)
Livestock§	15608 (73)	3589 (37)
Poultry and eggs	593 (3)	682 (7)
Tobacco	0 (0)	4127 (43)
Farm activities reported by spouse, last growing season		
Apply chemical fertilizer	1448 (7)	1853 (21)
Apply natural fertilizer	1949 (9)	1512 (17)
Drive combines/harvesters	2935 (14)	337 (4)
Hand pick crops	3635 (17)	3918 (44)
Plant	3327 (16)	3833 (43)
Till soil	5977 (29)	1267 (14)

* African Americans, Native Americans, Asian/Pacific Islanders, and other races.
† Apples, blueberries, grapes, peaches, strawberries, watermelon, cabbage, sweet corn, cucumbers, green peppers, potatoes, sweet potatoes, and tomatoes.
‡ Alfalfa, popcorn, seed corn, hay oats, sorghum, soybeans, and wheat.
§ Cattle, sheep, hogs, and other farm animals.

demographic factors and pesticide use patterns. In addition, participating wives who did not provide information on pesticide use (and were thereby excluded from the polytomous logistic regression analyses) were compared with those who did provide this information. Finally, the potential impact of missing values was explored by recoding variables to indicate "missing-ness" (ie, 1 = missing, 0 = not missing) and determining the association between missing values and pesticide use categories. We also evaluated the sensitivity of OR estimates to missing values by replacing them with arbitrary values at the extremes of the observed range and noting the change in the estimates.

Results

Our sample was limited to wives of married private applicators enrolled in the AHS. Although a large proportion of wives participated in the study (76%), wives who did not participate were more likely to be from North Carolina (51% vs. 31%) and to be married to men who did not finish high school (15% vs. 9%). Applicators whose wives participated were similar to those whose wives did not with respect to age, days per year of pesticide use, and lifetime days of pesticide use. A total of 2279 (7%) women provided no information on pesticide use or did not specify the pesticide(s) they used, and consequently, were excluded from regression analyses. These women were similar with respect to race, age, education, and husband's pesticide use to women who did provide personal information on pesticide use. More women from Iowa than North Carolina (69% vs. 65%) provided information on pesticide use.

The personal characteristics of the farm wives in this sample (n = 31,173) differed somewhat between North Carolina and Iowa (Table 1). Overall, the age of the wives ranged from 17 to 96 years (median = 46 years). Wives from North Carolina were older with fewer young children at home compared with the wives from Iowa. A larger proportion of wives from North Carolina never finished high school. Hygiene practices that could increase exposure such as wearing dirty work boots in the house and mixing contaminated work clothes with the family wash were reported more frequently by wives in North Carolina. Farm size, types of crops and animals produced on the farm, and field work activities conducted by the wife varied by state. Iowa farmers, whose farms are larger on average, grew more grain and livestock, whereas farmers in North Carolina grew cotton and tobacco, which are not produced in Iowa. When asked about activities during the last growing season, a larger proportion of women in North Carolina reported hand-picking crops, whereas wives

TABLE 2
Prevalence and Toxicity Information for the 25 Most Commonly Reported Pesticides by Farmers' Wives in the AHS (of 50 Pesticides Included in the Questionnaire), 1993 to 1997

Description	Wife Prevalence (%)	Applicator Prevalence (%)	Applicator Prevalence Ranking	Wife's Conditional Prevalence (%)		US EPA Regulatory Status and Acute Toxicity Category[38]	
				Given Applicator Uses	Given Applicator Does Not Use	Restricted Use	Toxicity Class*
Glyphosate†‡	34	76	2	64	49	No	III–IV
Carbaryl†	31	56	7	64	43	No	I–III
Malathion†‡	19	73	4	38	26	No	III–IV
2,4-D†‡	15	80	1	30	15	No	III
Diazinon†	10	32	20	26	15	Yes§	II–III
Trifluralin‡	5	57	6	14	4	No	III
Atrazine‡	5	76	3	10	4	Yes	III
Alachlor	4	58	5	11	5	Yes	III
Chlordane	4	28	23	15	5	Yes	II
Dicamba†	4	56	8	11	4	No	III
Chloropyrifos†	4	44	14	10	5	No	II–III
Petroleum oil distillate	4	51	9	8	6	No	N/A
DDT	4	28	22	15	4	Yes	N/A
Metolachlor	3	50	10	10	4	No	III
Permethrin (poultry)	3	14	35	16	5	Yes	II–III
Imazethapyr	3	48	11	10	2	No	III
Terbufos	3	43	15	9	3	Yes	I
Cyanazine	3	46	13	8	3	Yes	II
Dichlorvos	3	12	37	14	4	Yes	I
Pendimethalin‡	2	47	12	7	3	No	III
Captan	2	11	38	7	3	No	IV
Phorate	2	37	19	7	2	Yes	I
Permethrin (crops)	2	14	36	8	3	Yes	III
Fonofos	2	24	24	8	2	Yes	I
Carbofuran	2	30	21	6	3	Yes	I–II

* EPA toxicity categories: I, LD50 ≤ 200 mg/kg (high); II, LD50 = 200–2,000 mg/kg (moderate); III, LD50 = 2,000 to 20,000 mg/kg (slight); IV, LD50 > 20,000 mg/kg (practically none).

† Among the 10 most common active ingredients found in pesticides used in the home and garden market sector, 1998 to 1999[24].

‡ Among the 10 most common active ingredients found in pesticides used in the agricultural market sector, 1998 to 1999[24].

§ Some formulations of Diazinon were restricted in 1988 due to avian toxicity.

in Iowa reported driving combines and harvesters more frequently than their North Carolina counterparts.

Table 2 lists the 25 pesticides most commonly used by farmers' wives, of the 50 pesticides included on the spouse questionnaire, sorted by prevalence of use. The pesticides frequently reported by the wives overlap substantially with those frequently reported by the applicator. Glyphosate, malathion, and 2, 4-D are listed among the 10 most commonly used pesticides in both the agricultural and home and garden market sectors.[24] The proportion of wives who reported using the 5 most common products (glyphosate, carbaryl, malathion, 2, 4-D, and diazinon) when their husband did not use the product is relatively large, ranging from 15% to 49%. With the exception of diazinon, these pesticides are classified as general use pesticides (ie, a pesticide applicator license is not required to mix or apply them). Although most wives who reported using pesticides used 1 or 2 during their lifetimes, even wives who reported up to 5 pesticides most often used a combination of these 5 products and nearly all wives who used pesticides used at least 1 of these products.

Based on our analyses of wives' pesticide use patterns, we used the following reasoning to establish 5 pesticide use categories (Table 3). First, we established a reference group to indicate wives who never used or mixed pesticides during their lifetime (category 1). We created a second category to indicate wives who reported personally applying pesticides to their home or garden but did not specify the pesticide or report using pesticides for agricultural purposes (category 2). A third category was established for wives using the 5 most frequently reported pesticides (category 3). Although wives classified in this group could apply pesticides to crops, the fact that a relatively large proportion of wives report using the product when their applicator husband did not could indicate that many women are

TABLE 3
Proportion of AHS Farm Wives in Each Pesticide-Use Category, Iowa and North Carolina, 1993 to 1997

	Number (%)	
	Iowa	North Carolina
Pesticide use category		
(1) None	6334 (32)	4099 (46)
(2) Home and lawn only*	2064 (10)	702 (8)
(3) Commonly used†	6563 (33)	2343 (26)
(4) 1–2 additional agricultural‡	2872 (14)	1096 (12)
(5) ≥3 additional agricultural§	2191 (11)	630 (7)

* Information on specific pesticide not provided.
† Glyphosate, 2,4-D, malathion, diazinon, and carbaryl.
‡ One to two predominantly agricultural pesticides in addition to the commonly used products.
§ Three or more predominantly agricultural pesticides in addition to the commonly used products.

TABLE 4
Comparison of Pesticide Use Reported by Applicator and Wife, Wives Who Engage in Pesticide Mixing or Application, AHS 1993 to 1997

	Applicator	Wife
Lifetime days of mixing or applying pesticides		
Median (range)	225 (0–7000)*	50 (2.5–7000)
Number of pesticides applied during lifetime		
Median (range)	14 (0–50)*	2 (1–40)
Percent of mixing performed, N (%)		
None	540 (3)	4827 (38)
Less than 50%	3401 (21)	4842 (38)
More than 50%	12204 (76)	3099 (24)
Percent of application performed, N (%)		
None	225 (1)	887 (7)
Less than 50%	2966 (18)	6426 (50)
More than 50%	12941 (80)	5418 (43)

* A small fraction (<1%) of licensed applicators reported never mixing or applying pesticides.

using residential formulations. Users of the remaining pesticides were divided between 2 categories indicating the use of predominantly agricultural pesticides. Wives who used 1 to 2 of these agricultural pesticides in addition to category 3 pesticides were grouped together (category 4). Wives who used 3 or more agricultural pesticides in addition to category 3 pesticides formed another grouping (category 5).

Overall, the prevalence of ever using pesticides was lower among North Carolina wives (68% vs. 54%) with a greater percentage reporting that they never mixed or applied pesticides (Table 3). Among the wives who reported having mixed or applied pesticides, the median lifetime days reported was higher in North Carolina than Iowa (56 vs. 39 days). The median number of pesticides used during a lifetime was 7 times higher for the applicators than for their wives (Table 4). In addition, the median number of lifetime days reported for mixing or applying pesticides was 4.5 times higher for the applicators than for their wives, whereas the range was similar. Many wives reported applying pesticides but not mixing them.

The associations of wives' personal characteristics with pesticide use categories were evaluated in the same regression model (Table 5). Compared with age greater than 56 years, younger age (<39 years) was inversely associated with pesticide use among the users of agricultural pesticides (OR = 0.7, 95% confidence interval [CI] = 0.6–0.8), whereas middle age (47–56 years) was positively associated with pesticide use in most categories (OR = 1.6, 95% CI = 1.4–1.8, for the heaviest users). Having a baby in the last 9 years was inversely associated with the heaviest pesticide use category (OR = 0.7, 95% CI = 0.6–0.8), after adjustment for age. The wife never working off the farm was only weakly associated with using only residential pesticides as well as the heaviest pesticide use category (OR = 1.2, 95% CI = 1.1–1.4).

Several factors linked to increased pesticide contact at home were associated with pesticide use categories (Table 6). Wearing of work boots inside the home and mixing pesticide-contaminated clothing with the family wash were up to 1.5 times more likely among the heaviest pesticide users. Odds ratios appeared to increase slightly with increasing pesticide use category but CIs overlapped. Higher frequency of pesticide use by the applicator, which could be related to home contamination if pesticides are tracked inside the home, was associated with the heaviest pesticide use by the wife. Although CIs overlapped, an increasing trend with days per year the applicator mixed or applied pesticides was suggested (ORs for the heaviest users: 1.2–1.5).

Engaging in agricultural field work was associated with wives' pesticide use (Table 7). Odds ratios were highest among women who drove combines, planted crops, or applied fertilizer (ORs for the heaviest users: 2.5–3.7) and increased with increasing pesticide use category. Farm products (fruits and vegetables, grain, livestock, and poultry) were modeled with small farm size (<50 acres) and adjusted for age and state of residence (not shown). Only livestock production was significantly associated with wife's pesti-

TABLE 5
Personal Characteristics of AHS Farm Wives and Their Association With Pesticide Use Categories*

	Home or Lawn		Commonly Used		1–2 Agricultural		≥3 Agricultural	
Characteristic	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
North Carolina	0.5	(0.4, 0.6)	0.6	(0.6, 0.7)	0.6	(0.6, 0.7)	0.5	(0.4, 0.5)
Iowa (reference)	1.0		1.0		1.0		1.0	
Age of Wife								
≤38 years	1.0	(0.9, 1.2)	0.9	(0.8, 1.0)	0.7	(0.6, 0.8)	0.6	(0.5, 0.8)
39–46 years	1.2	(1.0, 1.3)	1.2	(1.1, 1.3)	1.2	(1.0, 1.3)	1.2	(1.1, 1.4)
47–56 years	1.0	(0.9, 1.2)	1.3	(1.2, 1.4)	1.3	(1.2, 1.5)	1.5	(1.4, 1.7)
≥57 years (reference)	1.0		1.0		1.0		1.0	
Minority race†	1.2	(0.9, 1.5)	0.6	(0.5, 0.7)	0.5	(0.4, 0.7)	0.6	(0.4, 0.8)
White	1.0		1.0		1.0		1.0	
Education								
<high school	1.2	(1.0, 1.4)	0.6	(0.5, 0.8)	0.8	(0.6, 1.0)	0.6	(0.5, 0.8)
>high school	0.9	(0.8, 0.9)	1.2	(1.1, 1.2)	1.2	(1.1, 1.3)	1.0	(0.9, 1.1)
High school	1.0		1.0		1.0		1.0	
Baby in the last 9 years								
Yes	0.9	(0.8, 1.0)	1.0	(0.9, 1.1)	0.8	(0.7, 0.9)	0.7	(0.6, 0.8)
No	1.0							
Wife never worked off-farm								
Yes	1.2	(1.0, 1.3)	0.9	(0.8, 1.0)	0.9	(0.8, 1.0)	1.2	(1.1, 1.4)
No	1.0		1.0		1.0		1.0	

* Personal characteristics were modeled together, ie, odds ratios are mutually adjusted.
† African Americans, Native Americans, Asian/Pacific Islanders, and other races.

TABLE 6
Household Hygiene Factors of AHS Farm Wives Related to Residential Contamination and Their Association With Pesticide Use Categories*

	Home or Lawn		Commonly Used		1–2 Agricultural		≥3 Agricultural	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Family members leave on work boots when entering home								
Yes	1.3	(1.2, 1.4)	1.3	(1.2, 1.3)	1.4	(1.3, 1.5)	1.5	(1.4, 1.6)
No	1.0		1.0		1.0		1.0	
Contaminated clothing mixed with the family wash								
Yes	1.3	(1.1, 1.5)	1.2	(1.1, 1.3)	1.4	(1.2, 1.6)	1.5	(1.3, 1.7)
No	1.0		1.0		1.0		1.0	
Frequency husband mixes or applies								
5–9 d/y	1.0	(0.8, 1.1)	1.1	(1.0, 1.2)	1.1	(0.9, 1.2)	1.2	(1.1, 1.4)
10–19 d/y	0.9	(0.8, 1.1)	1.2	(1.1, 1.3)	1.1	(1.0, 1.2)	1.4	(1.2, 1.6)
20–39 d/y	1.0	(0.9, 1.2)	1.2	(1.1, 1.4)	1.1	(0.9, 1.2)	1.5	(1.3, 1.7)
40 or more d/y	0.9	(0.7, 1.1)	1.1	(1.0, 1.3)	1.0	(0.9, 1.2)	1.4	(1.2, 1.7)
<5 d/y (reference)	1.0		1.0		1.0		1.0	

* Pesticide hygiene factors were modeled together, ie, odds ratios are mutually adjusted.
† Odds ratios adjusted for age and state of residence. Indicator variables were specified for age as follows: ≤38 years; 39–46 years; 47–56 years; and ≥57 years (reference).

cide use (OR = 1.4, 95% CI = 1.3–1.6, for the heaviest users). Because a higher proportion of women from North Carolina in this cohort who live on small farms have been observed to engage in field work,[2] the association between farm size and pesticide use was explored further. The model described here was run separately for each state but no effect modification was observed. The analyses were then restricted to wives who reported using or mixing pesticides with those using only the 5 most common pesticides serving as the reference group. In this model, a weak association between farm size less than 50 acres and pesticide use categories was observed (OR = 1.3, 95% CI = 1.1–1.6, for the heaviest users).

The mean and median days spent mixing or applying all pesticides increased with increasing pesticide use category (Fig. 1). We did not have lifetime days for wives who reported only home and lawn use of pesticides

TABLE 7
Farm Activities and Their Association With Pesticide Use Categories*

	Home or Lawn		Commonly Used		1–2 Agricultural		≥3 Agricultural	
Field Work	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Drive combines or harvesters								
Yes	1.3	(1.1, 1.5)	1.2	(1.0, 1.3)	1.6	(1.4, 1.8)	2.5	(2.2, 2.9)
No	1.0		1.0		1.0		1.0	
Apply fertilizer (chemical)								
Yes	1.0	(0.8, 1.3)	1.8	(1.6, 2.1)	2.4	(2.0, 2.7)	3.6	(3.1, 4.3)
No	1.0		1.0		1.0		1.0	
Apply fertilizer (natural)								
Yes	2.1	(1.8, 2.6)	1.4	(1.2, 1.6)	2.1	(1.8, 2.4)	3.4	(2.9, 3.9)
No	1.0		1.0		1.0		1.0	
Hand pick crops								
Yes	0.9	(0.7, 1.0)	1.4	(1.3, 1.6)	1.9	(1.7, 2.1)	1.3	(1.1, 1.4)
No	1.0		1.0		1.0		1.0	
Plant crops								
Yes	1.3	(1.1, 1.5)	1.5	(1.4, 1.6)	2.1	(1.9, 2.3)	3.7	(3.3, 4.1)
No	1.0		1.0		1.0		1.0	
Till the field								
Yes	0.9	(0.7, 1.0)	1.3	(1.2, 1.5)	1.0	(0.9, 1.2)	1.0	(0.9, 1.2)
No	1.0		1.0					

* Farm activities were modeled together, ie, odds ratios are mutually adjusted.

† Odds ratios adjusted for age and state of residence. Indicator variables were specified for age as follows: ≤38 years; 39–46 years; 47–56 years; and ≥57 years (reference).

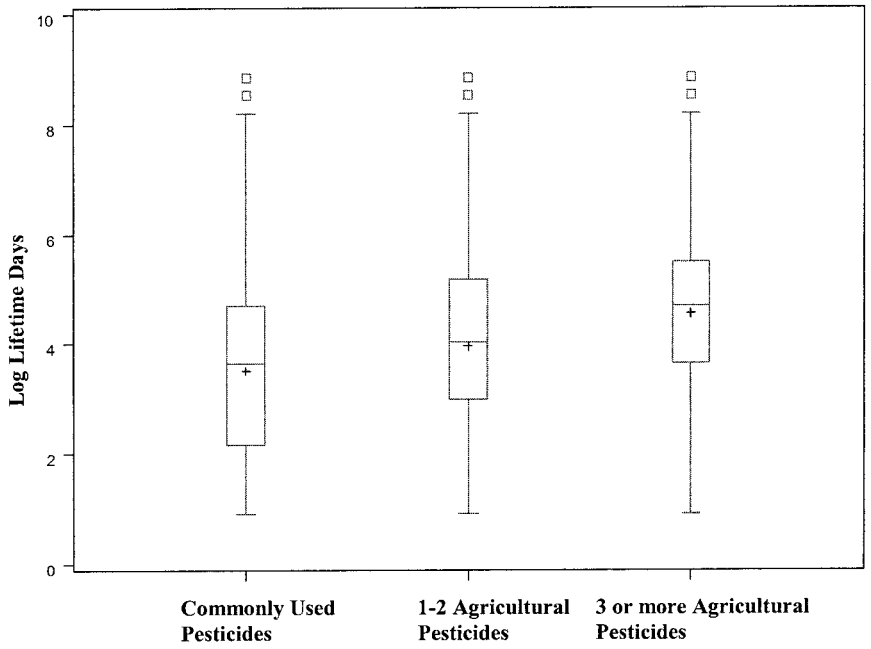

Fig. 1. Log lifetime days of pesticide use by pesticide use category, AHS farm wives 1993–1997.

and thus this category is not pictured. The median number of lifetime days of pesticide use reported by wives in the heaviest pesticide use category was 109 days, twice the median lifetime days for all women who mixed or applied pesticides. The 75th percentile of lifetime days among the wives in the heaviest use category (245) approximately corresponds to the median number of lifetime days (225) for the certified pesticide applicators. The median number of pesticides used during the wives' lifetime in the heaviest pesticide use category (9) was comparable to the median number of pesticides reported by the applicator (14).

Discussion

The AHS was designed, in part, to bridge the gap in our current knowledge of pesticide exposure to farm families.[5] The magnitude of pesticide exposure and its effect on the health of farm women is poorly understood. In an earlier analysis of AHS data, Gladen et al. documented a broad range of opportunities for pesticide exposure to farmers' wives.[2] Many farm wives reported direct contact with pesticides while mixing or applying these products or engaging in field work. Even women who did not use pesticides themselves were potentially exposed if their homes or drinking water wells were located near areas where pesticides were mixed or applied or if pesticides were tracked inside their homes. The present analyses focused on women with direct contact with pesticides (ie, those who mix or apply pesticides themselves). We found a wide variation in pesticide use

among wives of farmer pesticide applicators. Overall, most women had less direct contact than their applicator husbands. The women who used pesticides, particularly the heaviest users, were more likely to engage in field work and live in households where hygiene practices could increase their pesticide contact.

Farm wives perform a wide range of farm work.[1,25] However, little has been published on the nature of their work and how it relates to their health. One national survey of women's involvement in agriculture (n = 2059) conducted in 1981[26] found that only 17% of the women applied fertilizers, herbicides, or insecticides. This proportion is much lower than our estimate of 64% for farm wives enrolled in the AHS. This difference could be the result of geographic variation, the way in which respective survey questions were structured (residential use was included in the AHS questionnaire), changing trends over time, or selective participation in the AHS by women who use pesticides. Nevertheless, our finding that many farmers' wives engage in farm work is consistent with reports by other investigators. Results from the national survey indicate that as many as 55% of U.S. farm women are responsible for the daily operations of the farm and perform many types of farm work such as plowing, planting, disking, cultivation, harvesting, or running machinery or trucks.[1,25] A study of farm residents in Colorado (n = 761), recruited from 1992—1997, found that approximately 83% of farm women are involved in farm work in some capacity.[27] Researchers on this study also found that 187 women living on 424 farms (approximately 44%, assuming 1 adult woman per farm) applied herbicides to crops (Beseler C, personal communication, March 1, 2004).

The bulk of the heaviest pesticide users in our study appeared to be a small subset of women who also who engage in field work, including the operation of heavy farm equipment. The association between the frequency of pesticide work performed by the applicator and heavy pesticide use by the wife suggested that many wives might be doing this work along with their husbands rather than as their substitutes. Although not currently licensed pesticide applicators, the wives who were the heaviest users and reported the highest number of lifetime days of exposure could have similar exposure to some male applicators.

We observed an inverse association between young age and pesticide use and a positive association between middle age and pesticide use. Older women could have had more opportunity for pesticide use and therefore report using more pesticides than younger women. In this cohort, however, pesticide use peaks for wives in the 40s and early 50s,[2] suggesting that wives over 60 years old might have done less pesticide work during their lifetime, on average, than younger women. Also, the inverse association of having young children with the heaviest pesticide use category, after adjustment for age, suggested mothers with young children could do less pesticide work. The variable indicating the presence of young children at home could have been prone to misclassification, however, because applicators were asked if they fathered a child in the last 9 years, not if that child currently lived with them.

Farm families, including those enrolled in the AHS, have been reported to use more nonagricultural pesticides than nonfarm families in the United States.[28] The proportion of AHS farm wives reporting the use of pesticides on their home or lawn (86%) was comparable to the proportion reported in other studies of farm families (88–91%).[29,30] Within the cohort of AHS farm families, wives who used more agricultural pesticides were more likely to also apply pesticides to their home or lawn. Our observation that the wives who used pesticides were also engaged in household hygiene practices that could increase their pesticide contact and used more pesticides at home suggests that some women who use pesticides on the farm could take fewer precautions with pesticides generally.

The few epidemiologic studies of disease patterns among farmers' wives have defined exposure broadly without capturing the wide variation in exposure that we have delineated within this population. In general, wives of licensed pesticide applicators and farmers or women who live on farms have been compared with the general or rural populations.[7,8,13,15,31] Also, pesticide exposure in women has been defined by job title in case-control[32] and cancer-mortality studies.[6] Classifying exposure so broadly is likely to have amalgamated subgroups of subjects in different risk groups, causing the associations between pesticide exposure and the health outcomes studied to be shifted toward the null value. Also, women who work on farms but do not list their occupation as farmer are likely to be missed in occupational studies based on job title, reducing the external validity of results.

Our pesticide use categories were designed to distinguish gradations in pesticide use among the wives. We observed that the median lifetime days increased with increasing pesticide use category. In addition, the likelihood of engaging in field work, the frequency of applicator pesticide use, and hygiene practices that could increase pesticide contact also increased with pesticide use category. These findings suggest that these categories are ordered with regard to pesticide exposure and could serve as a practical exposure metric in future AHS analyses.

Although our results suggested that the pesticide use categories are ordered, individuals at different levels of risk could be grouped within 1 exposure category. We observed a great deal of variation in total lifetime days of exposure and other factors within pesticide use categories.

Women classified in pesticide use category 3, ie, users of the 5 most commonly reported pesticides, could have mixed or applied pesticides for residential or agricultural purposes, experiencing different exposure scenarios with different health consequences. Agricultural pesticide formulations are typically more toxic than residential formulations. In addition, pesticides in the predominantly agricultural groupings were not distinguished based on their toxicity. However, the most acutely toxic pesticides (level I) were used by a small proportion of women most often classified in the predominantly agricultural use pesticide categories. There was also variation in the percent of time spent mixing versus applying pesticides within categories of pesticide use. Mixing pesticides could be a risk factor for a high-exposure event[33] and the consequences of such an exposure would be more severe for highly toxic pesticides.

Major strengths of this study include its large sample size, the largest to date of farm women, and the breadth of data collected from participants allowing for a detailed examination of work habits among farm women. Because all data were self-reported, our results could have been influenced by poor recall, particularly among the older participants. Farmers, however, have been shown to provide accurate information with respect to pesticide use and duration[34,35] as well as lifestyle and agricultural factors.[36] Although a large amount of data was missing for some variables considered in the regression analyses (up to 13% of observations), a separate sensitivity analysis suggested that our results were not substantially impacted.

Pesticide exposure to women is an important public health concern. A wide array of health effects have been linked to pesticide exposure and hormonally active pesticides, and those that target the reproductive system could affect women differently than men.[37] The variation in exposure within and between different populations of women engaged in farm work should be considered in future studies. Studies evaluating the relationship between self-reported determinants of exposure, both occupational and environmental, and quantitative measures of exposure would be particularly valuable.

Acknowledgments

The authors are grateful to S. Long for programming assistance, and to Drs. C. Parks and B. Gladen for their comments on an earlier version of this article. This work was supported by intramural research funds of the National Institute of Environmental Health Sciences, National Institutes of Health, Department of Health and Human Services.

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