Acute Pesticide-Related Illnesses Among Working Youth, 1988-1999

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Objectives. The goal of this study was to describe acute occupational pesticide-related illnesses among youths and to provide prevention recommendations.

Methods. Survey data from 8 states and from poison control center data were analyzed. Illness incidence rates and incidence rate ratios were calculated.

Results. A total of 531 youths were identified with acute occupational pesticide-related illnesses. Insecticides were responsible for most of these illnesses (68%), most of which were of minor severity (79%). The average annual incidence rate among youths aged 15 to 17 years was 20.4 per billion hours worked, and the incidence rate ratio among youths vs adults was 1.71 (95% confidence interval=1.53, 1.91).

Conclusions. The present findings suggest the need for greater efforts to prevent acute occupational pesticide-related illnesses among adolescents. (*Am J Public Health.* 2003;93:605–610)

Work is a common aspect of youths' lives. In fact, the vast majority of young people are, at some time, employed while they are in school. Many of the hazards faced by working youths are receiving increasing attention.[1–3] Although concerns have been raised about pesticide exposures among working youths,[2,4,5] few data are available to support these concerns.

To address the need for more information about the effects of occupational pesticide exposures among young people, we examined the magnitude, incidence, and nature of acute pesticide-related illnesses among working youths. We also compared the rate of such illnesses among youths with the corresponding rate for adults. In this article, in addition to describing the results of our analyses, we provide recommendations for prevention of these illnesses. To our knowledge, ours is the first study to provide population-based estimates of the occurrence of acute occupational pesticide-related illness among young people.

METHODS

Data were obtained on individuals 17 years or younger who developed acute pesticide-related illnesses while working. We excluded cases involving nonoccupational exposures, attempted suicides, intentional malicious use (e.g., attempted homicide), or exposure for a psychotropic effect. In addition, cases caused by disinfectants were excluded, because such cases are not tracked in many states.

Information on cases was provided by the Toxic Exposure Surveillance System (TESS), the California Department of Pesticide Regulation, the California Department of Health Services, the Texas Department of Health, the Washington State Department of Health, the Oregon Department of Human Services, the New York State Department of Health, the Florida Department of Health, the Louisiana Department of Health and Hospitals, and the Arizona Department of Health Services. TESS, maintained by the American Association of Poison Control Centers, collects poisoning reports submitted by approximately 85% of US poison control centers.[6]

Each of the state agencies that contributed data on cases maintains its own surveillance system for acute pesticide-related illness and injury. It should be noted that 4 states neither have poison control centers that participate in TESS nor have in place a state-based surveillance system (Maine, Mississippi, South Carolina, and Vermont).

The periods for which acute pesticide-related illness and injury surveillance data were available varied by agency. TESS data were available for 1993 through 1998. Surveillance data from Texas are considered complete as of 1987; Oregon, as of 1988; New York and Washington State, as of 1991; Arizona and Louisiana, as of 1992; Florida, as of 1998; and California, as of 1989. Data from state agencies were collected through 1999.

The information collected by TESS and the state agencies includes date of illness, information on the ill individual (sex, age, signs, and symptoms), whether the illness occurred as a result of workplace exposures, and the pesticide or pesticides that produced the illness. Additional information collected by the state agencies but not by TESS includes race/ethnicity, occupation, industry, activity of the individual during the exposure, type of exposure (e.g., drift, direct spray, or exposure to a spill or leaking container), and whether personal protective equipment was used. For the present analysis, we defined use of personal protective equipment as use of goggles, face shields, gloves, or respirators.

The Environmental Protection Agency (EPA) acute toxicity category was sought for all pesticides responsible for illness. EPA classifies pesticide products into 1 of 4 acute toxicity categories based on established criteria. Pesticides having the highest toxicity are placed in category I, and those having the lowest are included in category IV. In the case of the present analyses, the acute toxicity category of the pesticide product responsible for causing an illness was often provided by the contributing state agency. When not provided, information on acute toxicity category was retrieved from a data set made available by EPA.

Information on illness severity was sought for all eligible cases. Except for Washington State and Louisiana, state agencies did not determine severity levels for the cases they identified. TESS criteria were used to assign severity levels to the cases provided by TESS and the other state agencies.[6] *Minor effects* consisted of minimally bothersome health effects that generally resolved rapidly. *Moderate effects* consisted of non–life-threatening health effects that were more pronounced or prolonged than minor effects or of a systemic nature. *Major effects* consisted of life-threatening health effects or those resulting in "significant residual disability or disfigurement."

To avoid repeated inclusion of the same case, we compared cases provided by each state agency with cases included in TESS. Cases that matched each other in terms of year and state of exposure, age, sex, and pesticide active ingredient were assumed to involve the same individual. Such individuals were included in the state agency totals only.

Case Definition

Cases were included only if health effects developed subsequent to pesticide contact and these effects were evaluated by poison control or state surveillance professionals as consistent with the known toxicology of the pesticide product. TESS relies on the experience and judgment of poison control center specialists managing specific cases to determine whether the affected individuals have symptoms and signs consistent with the pesticide exposure. No standardized criteria are used to make this determination. A full description of the standardized case definition used by each state agency is beyond the scope of the present article, but this information is available elsewhere.[7]

Data Analysis

SAS software (SAS Institute Inc, Cary, NC) was used for data management and in conducting χ^2 analyses to examine categorical data. Incidence rates among subjects aged 15 to 17 years were calculated for the period 1993 through 1998. The numerator was the total number of illness cases; the denominator was obtained from estimates of hours worked derived from the 1993 through 1998 administrations of the Current Population Survey.[8,9] The Current Population Survey does not provide data on workers younger than 15 years. In calculating incidence rates for young workers, it is preferable to use hours worked rather than employment counts.[9] The reason is that youths work fewer hours per week, and fewer weeks per year, than adults. Using employment counts would underestimate the risk of acute pesticide-related illnesses among young people.

Average annual incidence rates were calculated for young people employed in agricultural (Bureau of the Census industry codes 010–030) and nonagricultural (all other Census Bureau industry codes) industries. Because information on industry was not available from TESS, the assumption was made that the proportion of TESS cases involving individuals employed in agriculture was equal to the proportion found among the cases reported by state agencies. Male and female incidence rates and rates for each of 4 US regional areas were also calculated.

We calculated risks of acute pesticide-related illness among individuals aged 15 to 17 years by comparing rates among these youths with those among adults aged 25 to 44 years.[10] The data on adults were obtained from the same agencies that provided the data on youths, with the same exclusions applied. The age range of the adult comparison group was chosen a priori and was based on methodology used previously in examinations of occupational fatalities.[11] We calculated the incidence rate ratio as the youth–adult ratio of number of acute pesticide-related illnesses per hour worked. A ratio greater than 1 would suggest that youths have a higher risk of acute pesticide-related illnesses than adults. Confidence intervals (CIs) were calculated according to methods described by Rothman.[10]

RESULTS

During 1988 to 1999, 531 youths were identified with acute occupational pesticide-related illnesses. Of these individuals, 428 were identified by TESS and 103 by state agencies (9 cases were identified by both TESS and a state agency). The median age among these young people was 16 years (range: 6–17 years), and 122 (23%) were 13 years or younger; 68% were male. Information on race and ethnicity was available for 42 of the patients identified by state agencies (TESS does not collect this information). All 42 were White, and 21 of these individuals (51%) also reported Hispanic ethnicity. Of the 524 cases for which month of illness was known, 368 (70%) occurred between May and August.

Between 1993 and 1998, the average annual incidence rate among youths aged 15 to 17 years was 20.4 per billion hours worked (Table 1). Incidence rates have decreased in recent years (Table 2). The incidence rate was much higher among those employed in agriculture (196.9/billion hours worked) than among those not so employed (7.0/billion hours worked), and the rate was higher among male (27.9/billion hours worked) than among female (11.5/billion hours worked) youths. The rate was highest among those working in Western-region states (Table 3).

The risk of acute occupational pesticide-related illness was higher in youths than in adults (Tables 1 and 2). Overall, the incidence rate ratio among working youths compared with adults was 1.71; the ratio was lower among young people employed in agriculture (0.74). Results showed that incidence rate ratios were highest in the Midwest and lowest in the West (Table 3).

Information on the pesticides responsible for illnesses is provided in Table 4. Insecticides were responsible for 68% of the illnesses. Among the insecticides, organophosphates (142 cases) and pyrethroids (57 cases) were most commonly responsible. Specific organophosphate insecticides included chlorpyrifos (40 cases), diazinon (23 cases), and malathion (12 cases). Among the specific pyrethroids associated with illnesses were cypermethrin (14 cases) and cyhalothrin (12 cases). Glyphosate (33 cases) and 2,4-dichlorophenoxyacetic acid (16 cases) were the specific herbicides most commonly associated with youth illnesses.

Information on EPA acute toxicity category was available for 432 (81%) of the affected individuals. Of these youths, 51 (12%) were exposed to acute toxicity category I pesticides, 90 (21%) were exposed to category II pesticides, and 291 (67%) were exposed to category III pesticides. The percentage of individuals exposed to category I and category II pesticides was higher among those employed in agricultural industries (67%; 44 of 66 cases) than among those employed in nonagricultural industries (41%; 12 of 29 cases; $P=.02$).

TABLE 1—Total Numbers of Cases of Acute Occupational Pesticide-Related Illness, Estimates of Hours Worked, Incidence Rates, and Incidence Rate Ratios, by Industrial Sector, 1993–1998

	Working Youths Aged 15–17 Years			Working Adults Aged 25–44 Years			
Industrial Sector (Bureau of the Census Codes)	No. (%) With Acute Occupational Pesticide-Related Illnesses	Estimated Total No. of Hours Worked[a]	Incidence Rate[b]	No. (%) With Acute Occupational Pesticide-Related Illnesses	Estimated Total No. of Hours Worked[a]	Incidence Rate[b]	Incidence Rate Ratio (95% Confidence Interval)[c]
All	333 (100)	16328	20.4	9599 (100)	804785	11.9	1.71 (1.53, 1.91)
Agriculture (010–030)	213 (64)[d]	1082	196.9	5367 (56)	20261	264.9	0.74 (0.65, 0.85)
Nonagriculture (all other codes)	107 (32)[d]	15246	7.0	4232 (44)	784524	5.4	1.30 (1.07, 1.58)

[a]In millions of hours.
[b]Per billion hours worked.
[c]Compares the risk of an acute occupational pesticide-related illness among working youths with that among adults in the same industrial sector.
[d]A total of 4% of working youths had no information on industry, and these individuals were not included in analyses stratified by industrial sector.

TABLE 2—Numbers of Cases of Acute Occupational Pesticide-Related Illness, Estimates of Hours Worked, Incidence Rates, and Incidence Rate Ratios, by Year, 1993–1998

	Working Youths Aged 15-17 Years			Working Adults Aged 25–44 Years			
Year	No. With Acute Occupational Pesticide-Related Illnesses	Estimated Total No. of Hours Worked[a]	Incidence Rate[b]	No. With Acute Occupational Pesticide-Related Illnesses	Estimated Total No. of Hours Worked[a]	Incidence Rate[b]	Incidence Rate Ratio (95% Confidence Interval)[c]
1993	46	2366	19.4	1504	133066	11.3	1.72 (1.28, 2.31)
1994	51	2636	19.3	1571	131774	11.9	1.62 (1.23, 2.14)
1995	74	2752	26.9	1809	132993	13.6	1.98 (1.57, 2.50)
1996	60	2794	21.5	1697	134419	12.6	1.71 (1.32, 2.21)
1997	49	2800	17.5	1535	136483	11.2	1.56 (1.17, 2.07)
1998	53	2980	17.8	1483	136050	10.9	1.63 (1.24, 2.14)
Total	333	16328	20.4	9599	804785	11.9	1.71 (1.53, 1.91)

[a]In millions of hours.
[b]Per billion hours worked.
[c]Compares the risk of an acute occupational pesticide-related illness among working youths with that among working adults.

Most of the cases of acute occupational pesticide-related illness among youths were of minor severity (418 of 531; 79%). Severity was moderate in 20% of the cases and major in 1% (Table 4). No fatalities were identified. Proportions of cases within a given severity category were similar across the pesticide functional classes (P=.48) and EPA acute toxicity categories (P=.38). A total of 236 (44%) patients were evaluated and treated in a health care facility; 13 (3%) were hospitalized, 5 of whom were treated in an intensive care unit. When all pesticides were combined, the most commonly observed effects involved the gastrointestinal system (28% of youths reported health effects involving this system), followed by dermal effects (23%).

We also identified job tasks associated with illness. Seventy-one percent of subjects (70 of 99) were employed in agriculture (industry and occupation were available for only 99 of the cases identified by state agencies and for none of the TESS cases). Of the 70 agricultural workers affected, 15 (21%) were exposed while directly handling pesticides (i.e., applying [n=13], disposing of [n=1], or mixing and loading [n=1] pesticides), and 55 (79%) were exposed while doing routine work that did not involve direct handling of pesticides.

Only 3 youths appeared to be working in violation of the Fair Labor Standards Act (FLSA). These 3 youths were younger than 16 years, were employed on farms not owned or operated by their parents, and were applying or handling EPA acute toxicity category I or II pesticides. Among the 55 agricultural workers not handling pesticides, 33 (60%) were exposed while handling plant products previously sprayed with pesticides, 9 (16%) were exposed to drift from pesticides applied to the fields where they

TABLE 3—Numbers of Cases of Acute Occupational Pesticide-Related Illness, Estimates of Hours Worked, Incidence Rates, and Incidence Rate Ratios, by US Region, 1993–1998

	Working Youths Aged 15–17 Years			Working Adults Aged 25–44 Years			
US Region	No. With Acute Occupational Pesticide-Related Illnesses	Estimated Total No. of Hours Worked[e]	Incidence Rate[f]	No. With Acute Occupational Pesticide-Related Illnesses	Estimated Total No. of Hours Worked[e]	Incidence Rate[f]	Incidence Rate Ratio (95% Confidence Interval)[g]
Midwest[a]	89	5220	17.0	1167	194783	6.0	2.83 (2.28, 3.51)
Northeast[b]	28	2589	10.8	938	150048	6.3	1.71 (0.93, 3.16)
South[c]	125	5379	23.2	2743	284187	9.7	2.39 (2.00, 2.86)
West[d]	88	3140	28.0	4688	175767	26.7	1.05 (0.66, 1.66)
Total[h]	333	16328	20.4	9599	804785	11.9	1.71 (1.53, 1.91)

[a]Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin.
[b]Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont.
[c]Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, West Virginia.
[d]Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming.
[e]In millions of hours.
[f]Per billion hours worked.
[g]Compares the risk of an acute occupational pesticide-related illness among working youths with that among working adults.
[h]The sum of the number with acute pesticide-related illnesses is less than the total because 3 youths and 63 adults had no information on state of residence.

TABLE 4—Numbers of Youths With Acute Occupational Pesticide-Related Illnesses, by Functional Class of Pesticides and Severity, 1988–1999

Pesticide Functional Class	Minor Severity, No. (%)	Moderate Severity, No. (%)	Major Severity, No. (%)	Total, No. (%)
Insecticides	286 (80)	68 (19)	5 (1)	359 (68)
Herbicides	89 (78)	23 (20)	2 (2)	114 (21)
Fungicides	16 (73)	6 (27)	0 (0)	22 (4)
Insect and moth repellents	15 (79)	4 (21)	0 (0)	19 (4)
Fumigants	7 (70)	3 (30)	0 (0)	10 (2)
Rodenticides	5 (71)	2 (29)	0 (0)	7 (1)
Total	418 (79)	106 (20)	7 (1)	531 (100)

worked, and 8 (15%) were exposed to off-target drift from pesticides applied to neighboring fields.

The remaining 29 youths were not employed in agriculture. Five (17%) of these youths were applying pesticides at the time they were exposed, and they were employed as general laborers or in maintenance, suggesting that pesticide application was not their primary job activity. An additional 12 (41%) youths were employed as clerks or stock workers in the retail sector. Three of these young people were exposed while cleaning up pesticides that had spilled from a store shelf, and one was exposed while changing a canister in an automatic insecticide dispenser. The remaining 13 (45%) youths were employed in a variety of sectors.

Information on use of personal protective equipment was available for only 70 (68%) of the 103 cases reported by state agencies. Such equipment was used by 16% of the youths involved in these episodes. Proportions of young people using protective equipment did not differ significantly according to EPA acute toxicity category ($P=.59$). Nineteen percent (9 of 48) of youths employed in agriculture used protective equipment, as compared with 10% (2 of 21) of youths employed elsewhere ($P=.34$). Only 25% of those who directly handled pesticides used personal protective equipment.

DISCUSSION

The higher risks of acute occupational pesticide-related illnesses among youths than adults observed in this study suggests that current regulations may offer insufficient protection for working youths. There are several potential explanations for these higher risks. Young people are generally less experienced and assertive than adults, and thus they may not question assignments that place them at risk for pesticide exposure.[2] Youths also are often involved in part-time and seasonal work and, as a result, may receive less training. In addition, they may be more sensitive to pesticide toxicity and may manifest acute illnesses at lower exposure thresholds.[12] Because these acute illnesses affect young people at a time before they have reached full developmental maturation, there is also concern about unique and persistent chronic effects.

Youths employed in agriculture appear to have far greater incidence rates of acute occupational pesticide-related illnesses than youths employed elsewhere. These higher rates may be partly explained by the high usage of pesticides in the agriculture industry. In 1996–1997, the agriculture industry used 77% of the total US volume of active pesticide ingredients.[13] In contrast, agricultural employment was responsible for only 7% of total hours worked by individuals aged 15 to 17 years (Table 1).

The risk of pesticide poisoning in the agricultural sector was lower among youths than among adults. However, this risk comparison and the others provided should be interpreted with caution, because they represent crude estimates. For example, in terms of our denominator, we do not know how many of the hours worked involved pesticide exposure. We assumed that adults and young people have the same probability of pesticide exposure per hour worked. Unfortunately, we have no data to support or refute this assumption, because the number of pesticide-exposed workers and the duration of their exposure are unknown. This lack of information also precludes our identifying the specific industries and occupations involving the greatest risks.

Among the 99 youths for whom information was available on industry, occupation, and activity at the time of pesticide exposure, only 3 appeared to be working in violation of the FLSA. On the basis of this finding that 97% of the young people affected were engaged in legal activities under the FLSA, we recommend that the act be strengthened to prevent such acute illnesses. According to the FLSA, 16 years is the minimum age at which individuals can be employed in an agricultural job that involves handling or applying acutely toxic agricultural chemicals. Exempted from these prohibitions are youths younger than 16 years who are employed by and working on farms owned or operated by a parent or guardian. In addition, youths are not explicitly prohibited from nonagricultural employment that involves handling or applying pesticides.

To protect young farmworkers, the Worker Protection Standard may also need to be strengthened and better enforced. Among the provisions of this standard are restrictions on individuals' entering a pesticide-treated field before expiration of the restricted entry interval (the period required to elapse before one can reenter a field without personal protective equipment) and requirements for training of workers on the hazards associated with pesticides. We found that among the ill youths employed in the agricultural industry, 33 were exposed through contact with treated surfaces, most commonly by entering farm fields recently sprayed with pesticides (n=30). Three of these cases resulted from violations of restricted entry interval requirements, whereas 18 cases occurred despite compliance with these requirements; this latter finding suggests that longer intervals may be required to protect youths. The unique susceptibility of children was not considered in the establishment of restricted entry intervals. In comparison with adults, young people's greater relative body surface area to body mass ratio can lead to more absorption of pesticides.[14]

Our data and analysis involve several potential limitations. The illness rates we observed are probably underestimates, because a large number of cases among youths are not ascertained. Many cases are never identified because the youths affected neither seek medical care nor contact appropriate authorities (e.g., poison control centers). Furthermore, because the signs and symptoms of acute pesticide-related illnesses are not pathognomonic, many youths who seek medical care may not be correctly diagnosed and thus are not classified as having such illnesses.

Although 30 states require reporting of occupational pesticide-related illnesses, many cases, even those occurring among young people who are correctly diagnosed, are not reported.[7] One reason is that only 8 states have surveillance programs for these illnesses, and the fact that 7 of these 8 states are located in the West or South region helps to explain their higher incidence rates. However, even in these 8 states cases are underreported. For example, when we compared state agency and TESS data from these states, only 14% of the TESS cases were also included in the state agency data (i.e., for the years 1993–1998, among those younger than 18 years or aged 25 to 44 years). In the remaining 42 states, only TESS data are available to obtain counts of occupational pesticide-related illnesses.

Reliance on poison control center data can also lead to underascertainment. Because reporting is voluntary, many poisoning cases do not result in calls to the poison control center. The literature suggests that fewer than one third of poisoning cases treated in health care facilities are reported to poison control centers.[15,16] In addition, we found that in states with availability of both TESS data and data from a state agency, TESS identified only 10% of the cases identified by the state agencies (this comparison was made according to the parameters just described).

Finally, we suspect that some working youths may provide misleading information about their age. For example, one individual who became ill after entering a carbofuran-treated field before the expiration of the restricted entry interval initially reported his age as 19 years. Only later did he concede that his true age was 13 years. Therefore, the data we provide should be considered as representing minimum estimates of the true magnitude of the problem.

A related limitation is that incidence rate ratios may be affected by reporting bias if there is differential reporting of cases among youths relative to adults. We found that the elevated risk observed among youths in comparison with adults was confined to cases identified by TESS (incidence relative risk [IRR]=2.18; 95% CI=1.94, 2.45). Among cases reported by state agencies, the rate among youths was similar to that among adults (IRR=0.94; 95% CI=0.71, 1.24). This difference in risk may be due to biased reporting, either to poison control centers (i.e., these centers may be receiving fewer adult reports than child reports) or to state agencies (i.e., the risks observed in the TESS data may be closer to the true values, and state agencies may see greater underreporting of pediatric cases). That there is less underreporting to poison control centers of pediatric poisoning deaths than adult poisoning deaths suggests that TESS may be susceptible to reporting bias.[6] Conversely, the fact that 27% of the pediatric TESS cases occurred among youths younger than 14 years, as compared with only 6% of state agency cases, suggests that state agencies may be hampered in their ability to identify cases among working children.

A final limitation is that information on industry and occupation was not available for TESS cases. Use of different assumptions about the proportion of TESS cases in which the affected individuals are employed in agriculture can lead to different incidence rates by industry. For example, our analysis of youths aged 15 to 17 years who were included in both the TESS and the state agency data (n=9) revealed that 4 (44%) of these young people were employed in agriculture, 3 (33%) were employed in nonagricultural industries, and 2 (22%) had missing employment information. When these percentages were assigned to the TESS cases, the incidence rates for working youths in agricultural and nonagricultural industries were 146.0 and 7.2 per billion hours worked, respectively. These findings suggest that, relative to the incidence rates presented in Table 1, rates may be lower among those employed in agriculture and higher among those employed in nonagricultural industries.

In conclusion, recognizing that many occupational pesticide-related illnesses can be prevented, we offer the following recommendations:

- Improvements in surveillance are needed to overcome the limitations of underreporting. It would be useful if each state conducted surveillance of acute pesticide-related illnesses and injuries.
- The Bureau of Labor Statistics should improve collection of youth employment data, which would provide more accurate denominator data for calculating injury and illness rates.
- Because the signs and symptoms of acute pesticide-related illnesses may be difficult to link to pesticide exposure, health care professionals should be reminded to consider environmental and occupational exposures.
- Information on child labor laws and adolescent occupational hazards should be more effectively disseminated to students, parents, school officials, and employers.
- The FLSA and the Worker Protection Standard should be reviewed and appropriately revised to ensure that workers younger than 18 years are protected against toxic pesticide exposures. ■

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Contributors

G.M. Calvert was the primary author and took the lead on data analysis and writing the article. The remaining authors assisted in data acquisition and interpretation and provided critical revisions of the article.

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Human Participant Protection

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