A Pilot Study of Symptoms of Neurotoxicity and Injury among Adolescent Farmworkers in Starr County, Texas

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Little is known regarding the relationship between neurotoxicity symptoms and injury, particularly among adolescent farmworkers. This pilot study utilized logistic regression to analyze injury prevalence in relation to self-reported symptoms of neurotoxicity among adolescent farmworkers along the US-Mexico border in Texas. Respondents reporting at least five symptoms had 8.75 (95%CI, 1.89–40.54) times the prevalence of injury compared with those reporting zero or one symptom. Significant associations were observed for six items: trouble remembering things, family noticing memory loss, making notes, irritated for no reason, heart pounding, and tingling. This pilot study suggests a relationship between symptoms of neurotoxicity and injury among adolescent farmworkers, supporting the need for more rigorous investigations. *Key words*: farmworkers; adolescents; pesticides; neurotoxicity; Neurotoxicity Symptoms Questionnaire (Q16); Texas.

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INTRODUCTION

In the United States, the rates of non-fatal and fatal injuries experienced by workers in the agricultural industry surpass those associated with many other industries.[1,2] For example, in 2008, the rate of recordable non-fatal injuries among workers involved in crop production was 5.0 per 100 full-time equivalents (FTEs) compared to 4.0 per 100 FTEs among workers in all industries.[1,2] The rates of non-fatal injury from population-based research studies focused only on migrant and seasonal farmworkers suggest that the rates may be even higher with estimates ranging from 9.3 per 100 to 12.5 per 100 FTEs.[3,4] Based on the National Agricultural Workers Survey (NAWS), farmworkers are largely foreign-born (78.0%), Hispanic (83.0%), lacking employer–provided health insurance (77.0%), and economically disadvantaged with an average family income of $15,000 to $17,499.[5] Many farmworkers are also migrants, traveling seasonally from a home base to sites across the United States to work their jobs.

Despite the hazardous nature of farm work, a substantial number of youth are a part of this workforce. Although a precise estimate of the absolute number of farmworker youth is not available, 6% of participants in NAWS were aged 14–17 years.[5] Applying this statistic to the estimated one to four million farmworkers in the United States[6] would result in hundreds of thousands of youth working in agriculture nationally. In terms of their occupational health and safety, young agricultural workers are not afforded the same protections (such as age and task restrictions) governing youth working in other industries. Such disparities, coupled with physical and mental immaturity, could render these youth more vulnerable to injury. Although the number of published studies in this area is increasing, injury among young farmworkers is not well understood.

One posited risk factor for injury among farmworkers is pesticide exposure. Pesticides include many toxicants such as herbicides, insecticides, fungicides, and rodenticides[7] and are commonly used in agriculture. Many of the active ingredients used to formulate the most common pesticides used in agriculture in the United States are known to be neurotoxic, such as atrazine and 2,4-D in herbicides, and malathion and chlorpyrifos in insecticides.[7] Yet only a few epidemiological studies have explored the relationship between pesticide exposure and the specifc outcome of injury among agricultural workers. One study found that Chinese farmers who applied four or more pesticides per week had 16.75 times the odds (95%CI, 4.70–59.70) of agricultural injury compared with those who applied none.[8] Further, a study in Colorado found that farm operators reporting the use of organophosphate pesticides in the previous 12 months had a significantly increased risk (OR, 2.09; 95%CI, 1.09–3.09) of a farmwork-related injury.[9] After adjustment for age and type

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of agricultural activity in the statistical model, the risk to these farm operators was non-significant but elevated (OR, 1.75; 95%CI, 0.91–3.37). Each of the previous studies was conducted among adult farm owners or operators rather than farmworkers, who may experience different, and possibly more intense, agricultural exposures.

Pesticides and other toxicants, such as solvents, that farmworkers may be exposed to on the job may influence injury by decreasing cognitive function. A recent review suggests a positive association between chronic exposure to moderate levels of pesticides and deficits in neurobehavioral performance and increased symptom prevalence.[10] Despite the number of adolescents working in the agricultural industry and their increased sensitivity to toxicants,[11] there is still little evidence of the potential neurotoxic effects of these exposures among youth. Rohlman et al.[12] found that Hispanic youth working in agriculture had significantly poorer performance on a computerized neurobehavioral test than a non-agricultural group, although educational differences between the two groups could provide an alternate explanation. In another study, Rothlein and colleagues[13] found that the overall neurobehavioral performance of Hispanic immigrant farmworkers was lower than that of Hispanic immigrants who do not perform agricultural work. Among the agricultural group, after adjusting for age, gender, and education, there was a significant correlation between levels of urinary organophosphate metabolites and decreased performance on five neurobehavioral tests: selective attention latency ($p = 0.01$), symbol-digit latency ($p < 0.01$), preferred-hand finger tapping ($p = 0.01$), alternating-hand finger tapping ($p = 0.03$), and continuous performance hit latency ($p = 0.04$). Crawford et al.[14] examined the association between self-reported symptoms of neurotoxicity among adult farmworkers and reported a positive association with injury (OR 2.61; 95%CI, 0.92–7.41). They additionally reported a significant trend ($p = 0.02$) of increasing number of symptoms and injury risk.

The purpose of this pilot study is to determine the prevalence of self-reported symptoms of neurotoxicity among adolescent farmworkers. Additionally, this study examines whether self-reported symptoms of neurotoxicity are associated with injury among adolescent farmworkers residing in Starr County, Texas.

METHODS

Study Population

Data for this pilot study were taken from the second year of the cohort study, "A Study of Work Injuries in Farmworker Children" (Centers for Disease Control/National Institute for Occupational Safety and Health Cooperative Agreement #1 U50 OH07541). The objective of the parent study was to estimate the frequency of and identify risk factors for acute, non-fatal, occupational injury among adolescent farmworkers from Starr County, Texas. Starr County is located along the US-Mexico border; in the years 2000, the county's estimated population was 53,597.[15] The county is largely Hispanic (97.5%) and economically disadvantaged in comparison to the total population in the United States.[15] It is also home to approximately 5045 farmworkers.[16] Roma Independent School District is one of the three school districts located in the county and supports one high school (9th to 12th grades). Students from Roma High School participated in the parent study once a year from 2003–2005. Students eligible for this pilot study were enrolled in school, had parental consent, and were present during data collection, a period of two weeks in November 2004. This project was approved by the Texas A&M University Institutional Review Board.

Sampling

In 2004, the sampling frame included all students enrolled in a required social studies course. Using this method ensured that at least 90% of the student body received an invitation to participate. Recruitment consisted of sending parental consent forms home with students ($n = 1376$). Students received a school spirit towel for returning a signed parental consent form (whether or not the parent consented). For their participation, students received a school spirit shirt. The response rate was 87.8%, yielding a sample size of 1208 participants. Of these students, 7.9% ($n = 96$) engaged in farm work during the nine month recall period. Furthermore, 39.6% ($n = 38$) of the farmworkers reported working at a non-farm job in addition to their agricultural work.

Data Collection

Data were collected via a web-based, bilingual, confidential, and self-administered survey. The survey included approximately 46 items soliciting information on demographics, health indicators and behaviors, and occupational exposures and injuries; the survey required less than 45 minutes to complete. The majority of items referred to the period between January 1, 2004 and September 30, 2004 to ensure coverage of the typical migration season for farmworker families from the region. Occupational items were adapted from a prior study of migrant farmworker families.[3] Specifically, these items included dates of employment, type of job, task, crop (if applicable), hazardous exposures, usual days worked per week, usual hours worked per day, type of payment (for example, by piece or by the hour and per family or per individual), and location (that is, state).

TABLE 1 List of Items Included on Q16

1.	Do you have trouble remembering things?
2.	Do your relatives notice that you have trouble remembering things?
3.	Do you have to make notes to remember things?
4.	Do you often have to go back and check things you have done such as turned off the tv?
5.	Do you find it hard to understand the meaning of newspapers, magazines and books?
6.	Do you have difficulty concentrating?
7.	Do you often feel irritated without any particular reason?
8.	Do you often feel depressed without any particular reason?
9.	Are you tired more than usual?
10.	Are you less interested in dating than your friends?
11.	Does your heart pound (or beat really fast) even when you are resting?
12.	Do you sometimes feel tightness in your chest?
13.	Do you sweat without any particular reason?
14.	Do you have a headache at least once a week?
15.	Do you often have painful tingling ("pins and needles") in some parts of your body?
16.	Do you have any trouble buttoning and unbuttoning?*

*Control question.

The survey was developed in English, translated into Spanish, and back translated; any discrepancies between the English and Spanish versions of the survey were adjudicated. Bilingual interviewers proctored the survey in school computer laboratories during regularly scheduled social studies classes. Students provided their consent electronically at the beginning of the survey and chose to take the survey in Spanish or English.

The Neurotoxicity Symptoms Questionnaire (Q16)

Sixteen questions regarding symptoms of neurotoxicity, referred to as the Q16, were included as a part of the self-administered survey. The specific questions are listed in Table 1. The Q16 was initially developed to monitor early neurotoxic effects among solvent-exposed adult workers in Sweden[17] and has since been applied to other working populations[14,18–21] and children.[22,23] Further, the ability of the Q16 to distinguish between exposed and unexposed groups has been demonstrated.[24] Because the questionnaire was originally developed for use among adult working populations, we modified a few of the questions to be more relevant to our adolescent population. For example, question 10 was originally: "Are you less interested in sex than your friends?" We modified the question to: "Are you less interested in dating than your friends?" Additionally, item 16 on the questionnaire serves as a control question. Although individuals suffering very severe neurotoxicity may have trouble with buttoning, positive responses to this question are more likely indicative of false reporting.[17]

Independent and Dependent Variables

The independent variable in this analysis was students' responses to the Q16. Responses to individual questions were recorded as yes/no. A combined Q16 score was computed as the sum of positive responses to individual questions. The possible values for the combined Q16 score ranged from 0 to 16. This variable was categorized into three categories according the number of positive symptoms (0–1; 2–4; and > 5) and treated as a categorical variable in analyses. We decided on these three categories after examining the distribution of Q16 symptoms among farmworkers.

The dependent variable was dichotomous and defined as the most severe, acute, non-fatal occupational injury (farm or non-farm) experienced between January 1, 2004 and September 30, 2004. Farmworkers reported their most severe farmwork injury and their most severe non-farmwork injury. We included non-farm injuries experienced by adolescent farmworkers because we were interested in the prevalence of any injury and self-reported symptoms of neurotoxicity, not just farm-related injuries. We cannot rule out that farm-related exposures to neurotoxic agents, particularly if they are chronic in nature, may also influence injury risk outside of that job. In a prior study with migrant farmworker families, the use of a more restrictive definition (that is, loss of consciousness, medical treatment, or loss of more than four hours of time from work) resulted in a gross underestimate of events.[3] Nevertheless, minor injuries (such as cuts not requiring a bandage) were excluded from the present analysis. Additional variables needed to characterize the injuries were also collected and included approximate date of injury, injury type, body part, medical treatment, loss of time from work or usual activities, location, and crop/task (if applicable).

We had data regarding neurotoxic agents other than pesticides. Specifically, we examined the consumption of alcohol and the use of inhalants (defined as sniffing glue, breathing the contents of aerosol spray cans, or inhaling any paints or sprays with the intention of becoming intoxicated) as well as the use of gasoline or other solvents to clean hands or the use of insect repellents at work. We treated these variables as well as age as potential confounders. However, we found that the inclusion of each of these variables did not affect our results and therefore did not include them in the final models.

Statistical Analysis

Data were analyzed using Intercooled STATA, version 9.0.[25] The prevalence of neurotoxicity symptoms was calculated. Logistic regression analyses were conducted to explore the relationship between responses to individual Q16 questions and injury as well as between the

total Q16 score, categorized into three categories, and injury. Prevalence odds ratios (POR) and 95% confidence intervals (95% CI) were computed.

RESULTS

Of the 96 farmworkers, 88 (91.7%) completed the entire Q16 inventory. We have partial information from an additional four (4.2%) farmworkers; eight (8.3%) farmworkers have missing Q16 data. The mean age of farmworking adolescents included in this pilot study was 15.8 years (Table 2). The majority of farmworkers were male and over one-third were born in Mexico. The majority of farmworkers worked on farms for less than four years in their lifetime. Nearly 20% of the farmworkers spent five to 10 years working on a farm and 8% had done farm work for more than 10 years. Farmworkers from the Texas-Mexico border typically report working a wide variety of crops and performing an array of tasks in various locations within the United States.[3] The majority of farmworkers (80.2%) migrated for their employment. Job sites were located primarily in California, Colorado, Texas, New Mexico, Washington state, and Wisconsin. The most commonly worked crops in this study were corn, cotton, melon, peanuts, and potato. The most common tasks were cleaning, clearing, cutting, defoliating, harvesting from the ground, hoeing, and weeding (data not shown).

Twenty farmworkers reported a total of 25 occupational injuries that occurred during the nine-month recall period (data not shown). A similar proportion of males (22.8%) and females (22.6%) reported an occupational injury. Eleven of the injured farmworkers were under age 16 while nine were 16 years or older. The types of injuries (n = 25) were as follows: major scrape or cut (n = 10), torn ligament/muscle (n = 3), heat exhaustion (n = 3), broken bone/fracture (n = 2), bruise/crush (n = 2), eye or skin problems due to pesticides (n = 2), sprain/strain (n = 1), dislocated joint (n = 1), and mangled body part (n = 1). A variety of body parts were affected, but the most common included the face, eye, hand, foot, and leg/thigh. Of the 25 reported injuries, four were treated by a medical professional, 12 were treated by a family member or friend, nine were self-treated, and three were untreated. Of the 25 injuries, 18 occurred at a farm job while seven occurred at a non-farm job. The most common location was a farm/ranch field, but the crops worked and tasks performed at the time of injury were very diverse.

In terms of exposure to potential toxicants, working with or around pesticides/other chemicals or pesticide/chemical sprayers was reported by 27.1% and 34.1% farmworkers, respectively. Using insect repellent or gasoline/solvents as cleaning agents at work was reported by 30.1% and 15.3% of the farmworkers, respectively (Table 2). We also had data regarding two non-occupational neurotoxicants that could affect adolescents' responses to the Q16 items: use of alcohol in the previous nine months and ever-use of inhalants. Just over one-third of our sample reported having used alcohol in the past nine-month period (37.9%) and only five individuals reported ever using inhalants, accounting for just 5.8% of the sample. Table 3 shows the prevalence of these self-reported chemical-related exposures classified by Q16 categories. Several of the chemical-related exposures are higher among farmworkers within the highest Q16 category compared with those in the lowest category. Compared with the lowest group, adolescent farmworkers ranked in the highest group had at least double the prevalence of: using insect repellents at work (45.5% vs. 21.1%), using gasoline or solvents to clean hands (36.6% vs. 7.9%), or working near plants as tall or taller than their face (63.6% vs. 31.6%). Working near plants as tall or taller than the face may be an indicator of dermal or inhalation exposure since this would increase the opportunity for contact to any insecticide used on the plants. The prevalence of alcohol use in the prior nine months and lifetime inhalant use each appear to be lower among adolescent farmworkers with higher cumulative Q16 scores.

Table 4 presents the results from the analysis of neurotoxicity symptoms and injury among farmworkers. Thirteen of the 16 individual items on the Q16 questionnaire revealed at least a 50% increase in injury prevalence associated with a positive response. One of the items not associated with injury was the control question, having trouble buttoning and unbuttoning. Only one individual responded positively to this ques-

TABLE 2 Demographic Characteristics of Adolescent Farmworkers in Starr County, Texas 2004

	Farmworkers (n = 88)
Mean age, years (SD)	15.8 (1.2)
Males	64.8%
Born in Mexico	38.6%
Number of years doing farmwork (lifetime)	
< 1	19.3%
1–4	55.7%
5–10	17.1%
> 10	8.0%
Other characteristics	
Working with or around pesticides/other chemicals*	27.1%
Working with or around fertilizer/pesticide sprayers*	34.1%
Working around plants as tall as your face or taller*	43.5%
Using insect repellent at work*	30.1%
Exposure to gasoline or other solvents to clean hands*	15.3%
Alcohol use (ever in prior 9 months)**	37.9%
Inhalant use (ever in life)**	5.8%

*n = 85; **n = 87

TABLE 3 Prevalence of Chemical-Related Exposures Classified by Q16 Categories

Exposure	Q16 Category		
	Low 0–1 Positive Responses	Medium 2–4 Positive Responses	High ≥ 5 Positive Responses
Working with or around pesticides/other chemicals	21.1%	31.3%	36.4%
Working with or around fertilizer/pesticide sprayers	23.7%	40.7%	36.4%
Using insect repellent at work	21.1%	34.4%	45.5%
Using gasoline or other solvents to clean hands	7.9%	15.6%	36.6%
Any chemical exposure listed above	47.4%	53.1%	72.7%
Working around plants as tall as your face or taller	31.6%	53.1%	63.6%
Alcohol use (ever in prior 9 months)	38.5%	43.5%	28.6%
Inhalant use (ever in life)	7.7%	8.7%	0.0%

tion, indicating that most likely, this study did not have an issue with overestimation. Statistically significant associations were observed for having trouble remembering things (POR, 5.56; 95%CI, 1.60–19.30), relatives noticing loss of memory (POR, 4.43; 95%CI, 1.24–15.79), having to make notes (POR, 4.69; 95%CI, 1.40–15.68), being irritated for no reason (POR, 5.56; 95%CI, 1.60–19.30), heart pounding (POR,4.43; 95%CI, 1.13–17.40), and tingling (POR, 12.44; 95%CI, 2.82–55.02). Although we attempted to adjust for age, gender, alcohol use, inhalant use, insect repellent use on the job, and use of gasoline as a cleaner on the job, none of these variables were significant in the models and their inclusion did not change the interpretation of the primary variables of interest.

Farmworking adolescents responding positively to five or more of the Q16 questions had 8.75 (95%CI, 1.89–40.54) times the injury prevalence of those responding positively to zero or one of the questions. We observed a significantly increasing trend ($p = 0.005$) when we examined injury prevalence grouped by low, medium, and high Q16 categories. Because we changed the wording on item Q10 from "less interested in sex" to "less interested in dating," this question may not have measured the same construct in adolescents as in adults. However, when we dropped this item from the Q16 score and reran this analysis, the interpretation of the results did not change.

DISCUSSION

The results of this pilot study are suggestive of a potential association between self-reported symptoms of neurotoxicity and injury prevalence among Hispanic farmworker adolescents in Starr County, Texas. Because this was a pilot study, further investigations using more sophisticated methods of exposure assessment are needed to confirm our findings. Our results are similar to a previous study using a modified version of the Q16 to explore symptoms of neurotoxicity and agricultural injury among adult farmers.[18] Of the 11 items corresponding with our questionnaire, Atrubin et al. report eight which were positively associated with injury, four which were statistically significant. Additionally, for nine of the 11 corresponding items, we report stronger PORs than Atrubin et al. We also found that, compared with their counterparts with less than one positive symptom, adolescent farmworkers reporting five or more symptoms had more than double the prevalence of three exposures: using gasoline or other solvents to clean their hands, using insect repellents at work, and working near plants as tall or taller than their face. Although the absolute number of farmworkers reporting exposure to these items was small (13, 26, and 37, respectively), these results may give some indication as to toxicants potentially responsible for the associations observed between symptoms of neurotoxicity and injury.

Because this was a pilot study, we were restricted by a small sample size, as evidenced by the wide confidence intervals around our point estimates. Our data are cross-sectional. Adolescents were asked about their current symptoms of neurotoxicity and injury (within the past 9 months) at the same time. Although we cannot establish temporality through these data, the majority of the adolescents in our sample had been working farm jobs for more than one year, while the reported injury occurred during the previous nine months. Therefore, the opportunity for exposure to neurotoxic agents is greater than the recall period. We cannot rule out the possibility that a past injury may have preceded and influenced a subject's likelihood of reporting symptoms of neurotoxicity because we cannot account explicitly for timing. However, because the majority of injuries experienced by this population are cuts or scrapes, it is unlikely that these types of injuries would cause an individual to respond positively to items on the Q16 up to nine months after the time of the injury. Therefore, although it is possible, it is improbable that our results may be explained by reverse causality.

Our analysis may also be limited by unmeasured or unknown confounders that may result in the reporting of symptoms that are similar to those measured by the Q16 and that also increase the risk of injury. Reliance on self-reported neurotoxicity symptoms is an additional limitation since using more objective indicators

TABLE 4 Prevalence Odds Ratios (PORs) and 95% Confidence Intervals (95%CI) for the Association Between Q16 Items and Injury among Farm Workers

	Injury #/Total	No Injury #/Total	POR	95%CI Lower	95%CI Upper
Q1. Trouble remembering things	7/20	6/68	5.56	1.60	19.30
Q2. Relatives notice trouble remembering things	6/20	6/68	4.43	1.24	15.79
Q3. Have to make notes	7/20	7/68	4.69	1.40	15.68
Q4. Go back and check things	6/20	9/68	2.81	0.86	9.20
Q5. Hard to understand meaning of media	6/20	15/68	1.51	0.50	4.62
Q6. Difficulty concentrating	6/20	8/68	1.19	0.40	3.57
Q7. Often feel irritated	7/20	6/68	5.56	1.60	19.30
Q8. Often feel depressed	6/20	7/68	3.73	1.09	12.85
Q9. More tired than usual	4/19	14/67	1.01	0.29	3.52
Q10. Less interested in dating	8/19	16/67	2.32	0.80	6.76
Q11. Heart Pounding	5/19	5/67	4.43	1.13	17.40
Q12. Tightness in Chest	4/19	5/67	3.31	0.79	13.83
Q13. Sweat for no reason	4/19	6/67	2.71	0.68	10.84
Q14. Headaches	9/19	25/67	1.51	0.54	4.23
Q15. Painful tingling	7/19	3/67	12.44	2.81	55.02
Q16. Trouble buttoning	1/19	0/67	—	—	—
Q16 Categories***					
Low (0-1 positive responses)	4/19	35/65	1.00	—	—
Medium (2-4 positive responses)	9/19	24/65	3.28	0.91	11.89
High (≥ 5 positive responses)	6/19	6/65	8.75	1.89	40.54

***p-value for trend = 0.005

Note: Sample sizes may not sum to 88 for all variables. Two injured and two uninjured farmworkers did not complete the entire Q16.

[a]Final odds ratios are not adjusted for covariates because inclusion of covariates in the logistic regression models did not meaningfully change the results.

such as in-depth test batteries may be more valid indicators of neurotoxicity.[24] However, more elaborate diagnostic measures were beyond the scope of this preliminary study.

Although this study is preliminary in nature, there are several strengths. There is little available information regarding the effects of neurotoxicity and injuries among farmworker youth. This is the first study of its kind among farmworker adolescents. Further, the population of Hispanic farmworker youth living along the US-Mexico border is a historically understudied and particularly vulnerable group. Our study results are comparable to the results of similar study of adult farmworkers.[18] Finally, we utilized a standardized instrument widely used in working populations worldwide and which is beginning to find use among adolescent workers.[22,23] However, although this instrument has been validated in working adult populations,[17] it has yet to be validated among adolescent populations, a limitation which should be addressed by future investigations.

The results of this pilot support the need for additional, more rigorous investigations into the relationship between neurotoxicity and injury among adolescent farmworker populations. A study designed to assess pesticide exposures in more detail and to determine its relationship to objective measures of neurotoxicity and injury is needed. Future studies should plan to assess the timing of onset of symptoms in relation to injury as well. A separate analysis[26] of data from the parent study suggests that less than a quarter of farmworker youth in this population are ever provided pesticide safety training, which may have dramatic impacts on pesticide exposures and indirectly, injury.

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