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Agricultural Injury Risk Among Rural California Public High School Students: Prospective Results

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Objectives *To characterize prospective agricultural injury experience among rural California Central Valley public high school students enrolled in agricultural sciences curriculum.*

Methods *The University of California, Davis Youth Agricultural Injury Study (UCD-YAIS) examined prospective farm-work injury among students from 10 California Central Valley public high schools.*

Results *Of eligible subjects, 882 (62.5%) completed at least one annual follow-up survey. Of these, 489 reported farm work in the previous year, including 40 (8.2%) with at least one farm work-related injury. Fractures were the most common injury, especially among girls. Girls were more likely to suffer animal-related injury and boys injury from motor vehicles, machinery, or tool use. Prospective injury risk was strongly associated with prior-year farm injury (OR 8.53; 95% CI 4.02, 18.1) and farm work hours. After adjustment for farm work hours, grade level, and sex, risk was significantly associated with machinery operation, applying chemicals, number of hazardous tasks performed, riding motorcycles or mopeds, riding in back of an uncovered pick-up truck, and smoking. Risky attitude toward farm safety was associated prospectively with injury in stepwise fashion.*

Conclusions *Adolescents are at risk for serious farm-work injuries. Although limitations on hazardous tasks and farm work hours are likely to be the most efficacious means for reducing injury, education will play an important role. Education should include inculcating safety-related attitudes and habits and focus on hazardous tasks, such as those involving animals (for girls) and motor vehicles and machinery (for boys), especially among youth with prior farm injury.* Am. J. Ind. Med. 55:631–642, 2012.

KEY WORDS: injury; agriculture; youth; farm; risk behavior

INTRODUCTION

Agriculture is exceptional among US industries in three major respects that increase the burden of work injuries among youth: farms and ranches often serve as both workplace and home, increasing exposure to injury hazards; a high participation of youth labor; and a relatively lax regulatory regime governing youth labor. There were approximately 1.1 million youth aged 20 years and younger resident on U.S. farms in 2006; 590,000 of these youth worked on the farms, and an additional 307,000 were hired to work [NIOSH 2009]. The Fair Labor Standards Act (FLSA) of 1938 bars youth below age 14 from most paid labor. In agriculture, by contrast, children as young

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as 12 can engage in paid labor [Foster et al., 1997]. Moreover, the FLSA does not apply to children working on their family farms, for which there are effectively no legal regimens regulating work by children.

Youth working in agriculture, including on family farms, often put in long hours, perform dangerous tasks, and suffer a heavy burden of injury [NIOSH 2009]. There were 22,648 injuries among persons younger than 20 years of age who lived, worked, or visited a farm or ranch in 2001, representing a cumulative 1-year injury incidence of 12.7/1,000 among household and hired youth [US Department of Agriculture, 2004]. Prevention efforts have focused on educational interventions, including school-based programs [Chapman et al., 1995; Reed et al., 2001; Reed et al., 2003; Teran et al., 2008], service organizations such as the National Future Farmers of America (FFA), 4-H (Head, Heart, Hands, and Health), and ''on-the-job'' learning from family members [Lee et al., 1997, 2004].

The University of California, Davis Youth Agricultural Injury Study (UCD-YAIS) is a longitudinal study of California rural public high school students enrolled in a state-approved agricultural studies program. We reported earlier the cross-sectional results based on the initial survey, showing a strong association between work injury and hours worked and risk-taking behavior (manifest as riding in the back of an uncovered pickup truck and non-use of seatbelts) and documented an association between injury and a three-question agricultural safety attitude risk index [McCurdy et al., 2011]. We report here the results of the prospective injuries occurring in the year following the initial survey.

MATERIALS AND METHODS

Study Design Overview

The UCD-YAIS is a longitudinal cohort study of farm-work injury comprising an initial cross-sectional survey with annual follow-up among California Central Valley public high school students enrolled in the state-approved agriculture curriculum during the 2002–2005 school years. Ten high schools were selected from a list provided by the California Department of Education based on their location in agricultural communities and participation in the state's agriculture education curriculum. Study personnel visited each school to obtain input from students and teachers regarding the focus of the study, perceptions on farm work and hazards, and for questionnaire development. During the data collection phase, study personnel again visited each school to describe and promote the study among students. English and Spanish parental consent and student assent forms were distributed following the presentations. Study personnel then revisited each school, typically within a week of the initial presentation, to administer the questionnaires to those with parental consent to participate. Subjects received as participation incentive gift certificates worth $5 redeemable through local food vendors, as recommended by student focus groups. Subjects were identified on the questionnaire only by an assigned subject identification number. Study personnel administered the questionnaire during class time with the consent of the instructor; the questionnaire required approximately 45 min to complete.

Survey Questionnaire

Where possible, we used previously validated questions from standardized questionnaires (e.g., National Health Interview Survey and National Health and Nutrition Examination Survey). The questionnaire addressed demographic characteristics, health status and habits, sources of agricultural health and safety information, attitudes toward agricultural work, safety habits, smoking and respiratory history, work history, and agricultural injury history.

A qualifying agricultural injury was defined as an injury event in the preceding year occurring with farm work and associated with at least one of the following: (a) professional medical attention, (b) loss of at least one-half day of school or work, or (c) reduction of work or usual activity for at least one-half day. We excluded cases for which no narrative descriptive information was provided. Where multiple injuries occurred, we considered the most recent. Nature and external cause of injury were categorized by nosologists at the University of California Davis Medical Center based on the ICD-9 classification system [World Health Organization, 1977]. Body parts affected by injury were categorized using the Occupational Injury and Illness Classification Manual [US Department of Labor, 2007]. A composite safety attitude risk index comprised the numerical values associated with Likert-scale responses to three safety-related questions: (1) ''No matter how hard you try to prevent them, serious injuries are going to occur on a farm or ranch,'' (2) ''Safety precautions are important and necessary, even if they slow the job,'' and (3) ''I am less likely to be injured doing farm work than other people my age doing the same work.'' Subjects answered, ''Strongly agree,'' ''Agree,'' ''Disagree,'' or ''Strongly disagree.'' Responses were scored numerically 0–3 such that high values indicated risky attitudes. The scores were then summed as a composite safety attitude risk index ranging from 0 to 9. Variables relating to acreage or hours worked were categorized using approximate tertile or quartile groupings. Farm crops or commodities were assigned to grain, row, tree, small animal, large animal, or ''other'' categories. Smoking status (current/former/never) was determined based on historic and current smoking experience.

Data Management and Analysis

We used a scannable questionnaire with the Teleform (Cardiff, Vista, CA) data processing program and the Stata (StataCorp LP, College Station, TX) statistical software package for data management and analysis. We summarized continuous variables with mean and standard deviation (for normal distributions) and median and percentile score (for nonnormal distributions). We summarized categorical variables as percentages within each category. We conducted initial two-way tabular analysis to identify variables associated with injury, followed by stratification to evaluate for potential confounding. We utilized multivariable logistic regression analysis to assess independent associations with injury for important variables while adjusting for hours per year of farm labor (0–300/301–600/601–1,500/1,501+), school grade, and sex.

Institutional Review

The UC Davis Institutional Review Board initially approved an active (opt-in) consent process requiring parental permission and student assent for participation. During the first two annual cycles of data collection this process an average participation rate of 39.5% of students present on the survey day. The UCD IRB subsequently approved a passive (opt-out) consent process, in which students were allowed to participate unless the parent or guardian provided a written statement prohibiting participation. The passive process was used for the remaining 2 years of data collection and yielded participation from approximately 100% of students present on the survey day. The passive informed consent group (n = 669) contained a higher percentage of boys (75.0% vs. 67.4%, $P < 0.01$), a lower likelihood of working on a farm or ranch in the preceding year (48.8% vs. 60.1%, $P < 0.001$), and a lower 1-year cumulative incidence of injury (3.8% vs. 8.2%, $P < 0.01$) compared to the active informed-consent group (n = 1,114). The two groups appeared otherwise comparable and were therefore combined. Exploratory inclusion of the consent process in subsequent modeling did not significantly alter odds ratios for other variables and was not included in final analyses.

Study Sample

Subjects (1,783) completed an initial survey. Of these, 1,410 were not seniors or in the last year of the study and thus were potentially available for at least one annual follow-up survey; 882 (62.5%) of these completed a second survey. Of all those completing a second survey, 510 were not then high school seniors or in the last year of the study, and 120 (23.5%) of these completed a third survey. Of the 120 persons completing a third survey, 46 were not then seniors or in the last year of the study, and 6 (13.0%) of these persons completed a fourth survey.

The 120 subjects completing three or four annual surveys differed from the 1,663 persons completing only one or two with respect to sex, ethnicity, and likelihood of working on a farm. In view of this and because the retention ratios for completing three or four annual surveys were much lower than for completing a second survey, we elected to limit further prospective analysis to the second survey. In keeping with our approach for the cross-sectional analysis of the initial survey [McCurdy et al., 2011], we further limited analysis to the 489 subjects who reported working on a farm during the second year of the study because agricultural injuries occurred exclusively in this group.

RESULTS

Demographic and Farm Work Characteristics

The 489 subjects working on a farm or ranch in the second year of the survey were similar to the inception cohort of 946 persons reported earlier (Tables I and II). More than two-thirds were White, and more than 95% were born in the U.S. Over half of subjects lived on a farm, and the most commonly reported main crops or commodities were large animals and tree crops (Table II). Subjects working on a farm or ranch in Year 2 were comparable to the inception cohort with respect to ownership of the farm or ranch at which the worked, hours per year spent in farm work (median 780; interquartile range 273–2,560), and tasks performed (Table III).

Injury Experience and Risk Factors

There were 40 (8.2%) farm work-related injuries among the 489 persons working on a farm or ranch in the preceding year (Year 2). Injury risk was significantly directly associated in step-wise fashion with school grade level (OR 2.73, 95%CI 1.16, 6.43 for 12-graders compared to 9th-graders; Table I) and annual hours worked on the farm or ranch (OR 5.09, 95% CI 1.61, 16.1 for 1,501+ compared to 0–300 hr/year; Table III). After adjustment for these two covariates and sex, total injury risk was significantly associated with operating heavy machinery other than tractors (OR 3.19; 95%CI 1.21, 8.40), application of chemicals (OR 2.50; 95%CI 1.20, 5.21), and increasing number of selected tasks performed (OR 2.60, 95%CI 0.67, 10.1 for 7+ compared to 0–2 tasks; $P < 0.05$, test for trend; Table III).

A composite safety attitude risk index based on three questions, completed on the initial Year 1 survey, was prospectively predictive for injuries in Year 2. Persons

TABLE I. Selected Demographic Characteristics and Agricultural Injury Risk During Study Among 489 Rural California High School Students Working on a Farm or Ranch

Characteristic	Frequency [n (%)]			Cumulative 1-year injury incidence [n (%)]	Adjusted odds ratio for injury[a] (95% confidence interval)
	Entire sample (Year 1; n = 1,783)	Farm work in past year (Year 1; n = 946)	Farm work in past year (Year 2; n = 489)		
Sex					
Male	1,287 (72.2)	721 (76.2)	363 (74.2)	29 (8.0)	1.00 (reference)
Female	496 (27.8)	225 (23.8)	126 (25.8)	11 (8.7)	1.61 (0.74, 3.48)
Age at interview					
[Mean + SD years]	M: 15.7 ± 1.28	M: 15.8 ± 1.26	M: 16.2 ± 0.92	—	—
	F: 15.3 ± 1.21	F: 15.2 ± 1.19	F: 15.8 ± 0.83		
Grade at interview[b]					
9th	567 (31.8)	279 (29.5)	—	—	—
10th	488 (27.4)	263 (27.8)	203 (41.5)	11 (5.4)	1.00 (reference)
11th	342 (19.2)	194 (20.5)	176 (36.0)	14 (8.0)	1.61 (0.68, 3.77)
12th	373 (20.9)	207 (21.9)	110 (22.5)	15 (13.6)	2.73 (1.16, 6.43)
Not stated	13 (0.7)	3 (0.3)	—	—	—
Ethnicity					
White	997 (55.9)	625 (66.0)	341 (69.7)	35 (10.3)	1.00 (reference)
Hispanic	600 (33.7)	212 (22.4)	95 (19.4)	0 (0.0)	—
Other	162 (9.1)	98 (10.4)	52 (10.6)	5 (12.5)	0.69 (0.23, 2.09)
Not stated	24 (1.4)	11 (1.2)	1 (0.2)	0 (0.0)	—
Place of birth					
USA	1,590 (89.2)	865 (91.4)	466 (95.3)	40 (8.6)	1.00 (reference)
Mexico	161 (9.0)	67 (7.1)	20 (4.1)	0 (0.0)	—
Other	18 (1.0)	9 (1.0)	3 (0.6)	0 (0.0)	—
Not stated	14 (0.8)	5 (0.5)	—	—	—
Parents with 4-year college degree					
Neither	961 (53.9)	474 (50.1)	232 (47.4)	21 (9.1)	1.00 (reference)
One	326 (18.3)	206 (21.8)	109 (22.3)	9 (8.3)	0.93 (0.40, 2.17)
Both	161 (9.0)	107 (11.3)	52 (10.6)	3 (5.8)	0.57 (0.16, 2.05)
Not sure	321 (18.0)	152 (16.1)	96 (19.6)	7 (7.3)	1.13 (0.44, 2.91)
Not stated	14 (0.8)	7 (0.7)	—	—	—

[a] Adjusted for hours per year of farm labor (0–300/301–600/601–1,500/1,501 +), sex, and grade (as continuous variable) in the preceding year.
[b] $P < 0.05$, test for trend (Year 2).

scoring 6 or more on the 9-point index had an adjusted odds ratio of 2.82 (95%CI 1.03, 7.75) compared to persons scoring 0–3, and the index manifested a significant trend with injury risk ($P < 0.05$, test for trend; Table IV). The strongest association with injury was for prior injury: persons reporting an injury on the initial survey (Year 1) were at more than eightfold increased odds for injury in Year 2 (OR 8.53, 95%CI 4.02, 18.1; Table V). Smoking also showed a significant step-wise increased odds for injury for former (OR 2.19, 95%CI 0.67, 7.14) and current (OR 4.98, 95%CI 1.95, 12.7) smokers compared to never smokers. Among safety-related habits, there was a strong and statistically significant trend of increasing odds for injury for riding in the back of an uncovered pickup truck (OR 6.24, 95%CI 1.70, 22.9 for 16+ times per year compared to "never" group; $P < 0.01$, test for trend), and riding a motorcycle or moped in the past year was associated with increased odds for injury (OR 3.02; 95%CI 1.11, 8.17; Table V). There was a trend for increasing injury with less frequent use of seatbelts and helmet use when riding a motorcycle or moped, but these did not reach statistical significance.

Description of Injuries

Contusions, fractures, and sprains were the most common injuries, together comprising nearly two-thirds of all injuries (Table VI). Among girls, all but one injury were

TABLE II. Selected Farm or Ranch Characteristics and Agricultural Injury Risk During Study Year 2 Among 489 Rural California High School Students Working on a Farm or Ranch

Characteristic	Frequency [n (%)]		Cumulative 1-year injury incidence[a] [n (%)]	Adjusted odds ratio for injury[a] (95% confidence interval)
	Farm work in past year (Year 1; n = 946)	Farm work in past year (Year 2; n = 489)		
Live on a farm or ranch				
No	432 (45.7)	214 (43.8)	10 4.7)	1.00 (reference)
Yes	509 (53.8)	275 (56.2)	30 (10.9)	2.08 (0.93, 4.62)
Not stated	5 (0.5)	—	—	—
Years lived on farm or ranch[b]				
Mean + SD	11.3 ± 5.2	12.2 ± 4.9		1.07 (0.98, 1.18)
Median	14.0	15.0		
Size of home farm or ranch[b] (acres)				
1–15	162 (31.8)	3 (1.1)	2 (66.7)	36.3 (2.18, 605.3)
16–45	106 (20.8)	63 (22.9)	7 (11.1)	0.87 (0.28, 2.72)
46–145	86 (16.9)	56 (20.4)	5 (8.93)	0.82 (0.23, 2.84)
146+	113 (22.2)	67 (24.4)	8 (11.9)	1.00 (reference)
Not stated	42 (8.3)	86 (31.3)	8 (9.3)	—
Main crop or commodity at home farm or ranch[b]				
Grain crops	48 (9.4)	43 (15.6)	7 (16.3)	1.00 (reference)
Row crops	114 (22.4)	46 (16.7)	2 (4.4)	0.20 (0.04, 1.08)
Tree	119 (23.4)	62 (22.6)	4 (6.5)	0.27 (0.07, 1.06)
Small animal	11 (2.2)	6 (2.2)	1 (16.7)	1.18 (0.11, 12.6)
Large animal	147 (28.9)	84 (30.6)	13 (15.5)	0.67 (0.23, 1.98)
Other	28 (5.5)	14 (5.1)	2 (14.3)	0.47 (0.08, 2.95)
Not stated	42 (8.3)	20 (7.3)	1 (3.3)	—

[a]Adjusted for hours per year of farm labor (0–300/301–600/601–1,500/1,501 +), sex, and grade (as continuous variable) in the preceding year.
[b]Analysis limited to subjects who reported living and working on a farm or ranch in the preceding year (n = 509 for Year 1 and 275 for Year 2).

in these three categories, and fractures were most common, representing more than one-third of injuries. The foot and ankle, wrist and hand, and head were the most common body parts involved (Table VII). Injuries to wrist and hand occurred exclusively among boys. The most common external causes of injury were animals, striking or being struck by an object, and machinery or hand tools (Table VIII). Animal-related causes represented nearly one-third of injuries; of these, nine were caused by cattle and the remaining three by horses. Animal-related injuries predominated in girls, for whom they comprised almost two-thirds of injuries (five related to cattle and two with horses). Machine or hand tool and motor vehicle injuries occurred uniquely among boys and represented over one-quarter of injuries in this group. Three injuries (two fractures and a sprain) involved tractors.

The most common qualifying criterion for injury was the need for at least ½ day of light duty at work (n = 23, 57.5% of injuries, median 4 days), followed by missing at least ½ day of school or work (n = 21, 52.5% of injuries, median 0 days) and need for medical care (n = 20, 50.0% of injuries); no subjects incurred an overnight hospital stay. Two (5.0%) injuries eventuated in chronic sequelae (ongoing shoulder pain and light sensitivity following an eye injury). The most frequently cited contributing factor was personal carelessness (n = 13, 32.5% of injuries), followed by boredom (n = 10, 25.0% of injuries), and distraction (n = 9, 22.5% of injuries).

DISCUSSION

We report here the prospective results of the UCD-YAIS, a cohort study of farm work-related injury among rural California public high school students enrolled in an agricultural studies program. Our results are similar to those reported earlier for initial cross-sectional results [McCurdy et al., 2011]. Overall injury risk is quantitatively comparable (8.2% vs. 10.3%), as is the spectrum of conditions, including the predominance of animal-related injuries among girls. Both prospective and cross-sectional results identified several risk factors for injury risk, including hours spent on farm work, number of hazardous tasks

TABLE III. Selected Farm Work Characteristics and Agricultural Injury Risk During Study Year 2 Among 489 Rural California High School Students Working on a Farm or Ranch

Characteristic	Frequency [n (%)]		Cumulative 1-year injury incidence[a] [n (%)]	Adjusted odds ratio for injury[a] (95% confidence interval)
	Farm work in past year (Year 1; n = 946)	Farm work in past year (Year 2; n = 489)		
Ownership of farm or ranch worked				
Family	569 (60.2)	296 (60.5)	30 (10.1)	1.00 (reference)
Non-family	258 (27.3)	146 (29.9)	8 (5.5)	0.67 (0.29, 1.56)
Farm labor contractor	47 (5.0)	11 (2.3)	1 (9.1)	1.16 (0.13, 10.1)
Other	57 (6.0)	29 (5.9)	1 (3.5)	0.64 (0.08, 5.37)
Not stated	15 (1.6)	7 (1.4)	0 (0.0)	—
Hours worked per year[b]				
0–300	200 (21.1)	116 (23.7)	4 (3.5)	1.00 (reference)
301–600	190 (20.1)	71 (14.5)	4 (5.6)	1.60 (0.38, 6.73)
601–1,500	247 (26.1)	141 (28.8)	13 (9.2)	2.74 (0.85, 8.87)
1,501+	202 (21.4)	118 (24.1)	18 (15.3)	5.09 (1.61, 16.1)
Not stated	107 (11.3)	43 (8.8)	1 (2.3)	—
Tasks performed				
Operate a tractor	632 (66.8)	348 (71.2)	32 (9.2)	0.87 (0.34, 2.21)
Operate other heavy machinery	474 (50.1)	261 (53.4)	31 (11.9)	3.19 (1.21, 8.40)
Mix chemicals	269 (28.4)	150 (30.7)	20 (13.3)	1.83 (0.89, 3.76)
Apply chemicals	342 (36.2)	189 (38.7)	25 (13.2)	2.50 (1.20, 5.21)
Feed large animals	678 (71.7)	355 (72.6)	36 (10.1)	2.48 (0.84, 7.37)
Feed small animals	740 (78.2)	400 (81.8)	36 (9.0)	1.34 (0.44, 4.10)
Harvest by hand	278 (29.4)	152 (31.1)	16 (10.5)	1.35 (0.68, 2.68)
Welding	522 (55.2)	309 (63.2)	32 (10.4)	2.00 (0.72, 5.60)
Number of selected tasks (above) performed[c]				
0–2	173 (18.3)	85 (17.4)	4 (4.7)	1.00 (reference)
3–4	264 (27.9)	139 (28.4)	6 (4.3)	0.62 (0.15, 2.49)
5–6	256 (27.1)	129 (26.4)	13 (10.1)	1.50 (0.40, 5.58)
7–8	157 (16.6)	98 (20.0)	16 (16.3)	2.60 (0.67, 10.1)
Not stated	96 (10.2)	38 (7.8)	1 (2.6)	—

[a]Adjusted for hours per year of farm labor (0–300/301–600/601–1,500/1,501+), sex, and grade (as continuous variable) in the preceding year.
[b]$P < 0.01$, test for trend (Year 2).
[c]$P < 0.05$, test for trend (Year 2).

performed, and riding in the back of an uncovered pickup truck. There was also increased prospective risk for injury associated with riding a motorcycle or moped in the past year, operating heavy machinery, and applying chemicals. A composite safety attitude risk index was significantly associated with the initial cross-sectional results and is validated here with the prospective risk for injuries reported in the subsequent year on the follow-up survey. As for the cross-sectional results, the severity of the prospective injuries is striking, with fractures the most common diagnosis, representing nearly one-quarter of all cases, and many events holding potential for fatality.

The most important correlates of prospective injury risk were prior-year farm injury (OR 8.53, 95%CI 4.02, 18.1) and the number of hours spent in farm work each year (OR 5.09, 95%CI 1.61, 16.1 for 1,501+ compared to 0–300 hr/year). Increased risk for persons with previous injuries has been noted in other agricultural populations [Zhou and Roseman, 1994; Lewis et al., 1998], including in a similar population of farm youth involved in a school-based agricultural education program [Westaby and Lee, 2003]. Subjects working in agriculture reported a median of 780 hr per year (approximately 15 hr/week), comparable to reports by other authors [Bonauto et al., 2003; Chapman et al., 2009]. The approximately one-quarter of subjects working at least 1,500 hr in the preceding year demonstrated over fivefold increased odds for injury compared to subjects working 300 or fewer hours. This

TABLE IV. Sources of Agricultural Safety Information and Attitudes and Agricultural Injury Risk During Study Year 2 Among 489 Rural California High School Students Working on a Farm or Ranch

Characteristic	Frequency [n (%)]		Cumulative 1-year injury incidence[a] [n (%)]	Adjusted odds ratio for injury[a] (95% confidence interval)
	Farm work in past year (Year 1; n = 946)	Farm work in past year (Year 2; n = 489)		
Number of agricultural courses taken from 7th–12th grade				
0–1	370 (39.1)	117 (23.9)	9 (7.7)	1.00 (reference)
2–4	490 (51.8)	321 (65.6)	25 (7.8)	1.04 (0.45, 2.37)
5+	86 (9.1)	51 (10.4)	6 (11.8)	1.17 (0.37, 3.64)
Member, FFA[b]				
No	141 (14.9)	120 (25.4)	6 (5.0)	1.00 reference)
Yes	788 (83.3)	367 (75.1)	34 (9.3)	1.72 (0.69, 4.29)
Not stated	17 (1.8)	2 (0.4)	0 (0.0)	—
Member, 4-H[b]				
No	821 (86.8)	430 (87.9)	31 (7.2)	1.00 (reference)
Yes	106 (11.2)	53 (10.8)	9 (17.0)	2.13 (0.91, 5.01)
Not stated	19 (2.0)	6 (1.2)	0 (0.0)	—
Acknowledged as "very important" source of agricultural safety information versus "not important at all"				
Father	572 (60.5)	307 (62.8)	22 (7.2)	0.55 (0.06, 4.79)
Mother	438 (46.3)	231 (47.2)	17 (7.4)	0.42 (0.14, 1.27)
Other relative	295 (31.2)	155 (31.7)	12 (7.7)	0.50 (0.16, 1.58)
High school teachers	369 (39.0)	178 (36.4)	14 (7.9)	0.50 (0.17, 1.45)
FFA[b]	334 (35.3)	202 (41.3)	15 (7.4)	1.15 (0.31, 4.28)
4-H[b]	134 (14.2)	87 (17.8)	12 (13.8)	2.13 (0.88, 5.17)
Other source	97 (10.3)	40 (8.2)	8 (20.0)	—
Composite safety attitude risk index from initial (Year 1) survey[c]				
0–3	223 (23.6)	122 (25.0)	7 (5.7)	1.00 (reference)
4–5	554 (58.6)	282 (57.7)	20 (7.1)	1.00 (0.40, 2.51)
6–9	163 (17.2)	80 (16.4)	12 (15.0)	2.82 (1.03, 7.75)
Not stated	6 (0.6)	5 (1.0)	1 (20.0)	—

[a]Adjusted for hours per year of farm labor (0–300/301–600/601–1,500/1,501+), sex, and grade (as continuous variable) in the preceding year.
[b]FFA (National Future Farmers of America) and 4-H (Head, Heart, Hands, and Health) are national agricultural youth organizations.
[c]$P < 0.05$, test for trend (Year 2).

exceeds the 2.2-fold increased odds for injury associated with working 30–40 hr per week observed by Larson-Bright et al. [2007] in a sample of Midwestern farm children.

The major strengths of this study include a large number of participants, high participation at inception, and consistency of the initial cross-sectional and follow-up results reported here. The most important limitation is the reliance on recall, which is likely to be weakest for less severe injuries. Other limitations include limited power due to a relatively small number of prospective injuries, the focus on California Central Valley public high school students enrolled in an agricultural sciences curriculum, and attrition of subjects through the four annual cycles of data collection. In view of the small number of subjects and injuries in the third and fourth data collection cycles and evidence of demographic differences between that population and the inception cohort, we elected to limit study of prospective injuries to those reported in the second round of data collection.

National data demonstrate reduced risk for youth farm injury in recent decades, with a 36% decline between 1998 and 2006 [Hendricks and Hendricks, 2010]. Although the reasons for this remain unclear, increasing attention from the Centers for Disease Control and Prevention, including NIOSH, non-governmental organizations such as Farm Safety 4 Just Kids, and researchers may contribute. The National Children's Center for Rural Agricultural Health and Safety efforts to develop and promote the North American Guidelines for Children's Agricultural Tasks (NAGCAT) and Creating Safe Play Areas on Farms may also play an important role [National

TABLE V. Selected Safety Habits and Agricultural Injury Risk During Study Year 2 Among 489 Rural California High School Students Working on a Farm or Ranch

Characteristic as Reported on Initial Interview	Frequency [n (%)]		Cumulative 1-year injury incidence [n (%)]	Adjusted odds ratio for injury[a] (95% confidence interval)
	Farm work in past year (Year 1; n = 946)	Farm work in past year (Year 2; n = 489)		
Prior-year injury (history of agricultural injury in Year 1)				
Yes	97 (10.3)	51 (10.4)	18 (35.3)	8.53 (4.02, 18.1)
No	849 (89.7)	438 (89.6)	22 (5.0)	1.00 (reference)
Smoking status[b]				
Never Smoker	773 (81.7)	405 (82.8)	26 (6.4)	1.00 (reference)
Former Smoker	43 (4.6)	27 (5.5)	4 (14.8)	2.19 (0.67, 7.14)
Current Smoker	64 (6.8)	33 (6.8)	9 (27.3)	4.98 (1.95, 12.7)
Not stated	66 (7.0)	24 (4.9)	1 (4.2)	—
Use chewing tobacco				
No	821 (86.8)	422 (86.3)	30 (7.1)	1.00 (reference)
Yes	99 (10.5)	57 (11.7)	10 (17.5)	2.30 (0.99, 5.36)
Not stated	26 (2.8)	10 (2.0)	0 (0.0)	—
Ridden in back of uncovered pickup truck in past 12 months[b]				
Never	207 (21.9)	123 (25.2)	3 (2.4)	1.00 (reference)
1–5 times	399 (42.2)	197 (40.3)	13 (6.6)	2.57 (0.70, 9.39)
6–15 times	122 (12.9)	67 (13.7)	7 (10.5)	4.46 (1.08, 18.5)
16+ times	207 (21.9)	101 (20.7)	17 (16.8)	6.24 (1.70, 22.9)
Not stated	11 (1.2)	1 (0.2)	0 (0.00)	—
Seatbelt use				
Always	437 (46.2)	248 (50.7)	18 (7.3)	1.00 (reference)
Nearly always	252 (26.6)	118 (24.1)	7 (5.9)	0.75 (0.29, 1.90)
Sometimes	163 (17.2)	73 (14.9)	8 (11.0)	1.26 (0.49, 3.27)
Seldom/Never	84 (8.9)	48 (9.8)	7 (14.6)	1.85 (0.69, 4.94)
Not stated	10 (1.1)	2 (0.4)	0 (0.0)	—
Ridden motorcycle or moped in past year				
No	307 (32.5)	148 (30.3)	5 (3.4)	1.00 (reference)
Yes	581 (61.4)	313 (64.0)	33 (10.5)	3.02 (1.11, 8.17)
Do not recall	44 (4.7)	27 (5.5)	2 (7.4)	—
Not stated	14 (1.5)	1 (0.2)	0 (0.0)	—
Helmet use when riding motorcycle or moped	(n = 581)	(n = 313)		
Always	202 (34.8)	98 (31.3)	7 (7.1)	1.00 (reference)
Nearly always	106 (18.2)	57 (18.2)	5 (8.8)	1.32 (0.39, 4.52)
Sometimes	118 (20.3)	70 (22.4)	7 (10.0)	1.39 (0.45, 4.32)
Seldom/never	149 (25.6)	85 (27.2)	13 (15.3)	2.18 (0.79, 6.03)
Not stated	6 (1.0)	3 (1.0)	1 (33.3)	—
Ridden all-terrain vehicle (ATV) in past year				
No	223 (23.6)	99 (20.5)	3 (3.0)	1.00 (reference)
Yes	657 (69.5)	368 (75.3)	36 (9.8)	3.01 (0.88, 10.3)
Do not recall	50 (5.3)	20 (4.1)	1 (5.0)	—
Not stated	16 (1.7)	2 (0.4)	0 (0.0)	—
Helmet Use when riding ATV	(n = 657)	(n = 368)		
Always	159 (24.2)	81 (22.0)	7 (8.6)	1.00 (reference)
Nearly always	106 (16.1)	65 (17.7)	6 (9.2)	1.08 (0.33, 3.48)
Sometimes	128 (19.5)	78 (21.2)	6 (7.7)	0.87 (0.27, 2.79)
Seldom/Never	259 (39.4)	143 (38.9)	17 (11.9)	1.27 (0.49, 3.32)
Not stated	5 (0.8)	1 (0.3)	0 (0.0)	—

[a]Adjusted for hours per year of farm labor (0–300/301–600/601–1,500/1,501 +), sex, and grade (as continuous variable) in the preceding year.
[b]$P < 0.01$ for trend (Year 2).

TABLE VI. Nature (Primary Diagnosis) of Injury Among 40 Rural California High School Students Reporting an Agricultural Injury[a] in the Preceding Year

		Frequency [n, (column %)]		
ICD9 code[b]	Primary diagnosis	Boys	Girls	Total
800–829	Fracture	5 (17.2)	4 (36.4)	9 (22.5)
836.5	Other dislocation of knee, closed	0 (0.0)	1 (9.1)	1 (2.5)
840–848, 884.9	Sprain	4 (13.8)	2 (18.2)	6 (15.0)
850	Concussion	3 (10.3)	0 (0.0)	3 (7.5)
873.4, 876	Open wound of face, back	1 (3.4)	0 (0.0)	1 (2.5)
876, 880–887	Open wound, upper limb	2 (6.9)	0 (0.0)	2 (5.0)
879.2	Open wound, abdominal wall	1 (3.4)	0 (0.0)	1 (2.5)
921.9	Contusion, eye	1 (3.4)	0 (0.0)	1 (2.5)
922.1–924.8, 992.31	Contusion	4 (13.8)	3 (27.3)	7 (17.5)
930.9	Foreign body, eye	1 (3.4)	0 (0.0)	1 (2.5)
943–946	Burn	2 (6.9)	0 (0.0)	2 (5.0)
959.01	Unspecified head injury	1 (3.4)	1 (9.1)	2 (5.0)
989.5	Toxic effect of substance	1 (3.4)	0 (0.0)	1 (2.5)
	Other	3 (10.3)	0 (0.0)	3 (7.5)
	Total	29 (100)	11 (100)	40 (100)

[a]Injury occurred while working in agriculture and caused the subject to seek medical attention or lose at least one-half day of work or school time or have at least one-half day of restricted activity.
[b]Ninth revision, International Classification of Diseases [World Health Organization, 1977].

Children's Center for Rural Agricultural Health and Safety, 1998; Esser et al., 2003]. Most importantly, this finding may indicate a cultural shift occurring among farm owners and parents to end unsafe traditions involving farm work and children.

Safety attitudes, as measured by a simple three-question index, were strongly associated with injury risk, with a nearly threefold increase in odds of prospective injury for persons with the highest index value. This trend was also seen for the cross-sectional prior-year injuries in the initial survey, as reported earlier [McCurdy et al., 2011]. The importance of safety attitudes for injury risk has been reported in other similar populations. Westaby and Lee [2003] working with a sample of FFA members

TABLE VII. Injured Body Part Among 40 Rural California High School Students Reporting an Agricultural Injury[a] in the Preceding Year

		Frequency [n, (column %)]		
Body part classification code[b]	Body part injured	Boys	Girls	Total
010–039 (exclude 032)	Head (except eye)	4 (13.8)	1 (9.1)	5 (12.5)
032	Eye	2 (6.9)	0 (0.0)	2 (5.0)
210–256 (exclude 230)	Trunk (except back and spine)	1 (3.4)	1 (9.1)	2 (5.0)
230	Back and spine	1 (3.4)	2 (18.2)	3 (7.5)
310, 340, 380	Upper extremity and shoulder (except hand and wrist)	1 (3.4)	1 (9.1)	2 (5.0)
320, 330	Wrist and hand	5 (17.2)	0 (0.0)	5 (12.5)
410, 411	Hip and thigh	1 (3.4)	0 (0.0)	1 (2.5)
412, 413	Knee and lower leg	1 (3.4)	1 (9.1)	2 (5.0)
420, 430, 440	Foot and ankle	6 (20.7)	2 (18.2)	8 (20.0)
800	Multiple body regions	4 (13.8)	2 (18.2)	6 (15.0)
	Other	3 (10.3)	1 (9.1)	4 (10.0)
	Total	29 (100)	11 (100)	40 (100)

[a]Injury occurred while working in agriculture and caused the subject to seek medical attention or lose at least one-half day of work or school time or have at least one-half day of restricted activity.
[b]Body parts affected by injury were categorized using the Occupational Injury and Illness Classification Manual [US Department of Labor, 2007].

TABLE VIII. External Cause of Injury Among 40 Rural California High School Students Reporting an Agricultural Injury[a] in the Preceding Year

		Frequency [n, (column %)]		
ICD9 E-code[b]	External cause of injury	Boys	Girls	Total
E818–E825.1	Injury related to motor vehicle	2 (6.9)	0 (0.0)	2 (5.0)
E828	Injury related to animal ride	1 (3.4)	2 (18.2)	3 (7.5)
E829	Other road vehicle accidents	1 (3.4)	0 (0.0)	1 (2.5)
E844.9, E880–E888	Injury related to fall	2 (6.9)	2 (18.2)	4 (10.0)
E906.8	Specified injury caused by animal	4 (13.8)	5 (45.4)	9 (22.5)
E91–E917	Injury by striking	7 (24.1)	1 (9.1)	8 (20.0)
E919	Injury by machine or hand tool	6 (20.7)	0 (0.0)	6 (15.0)
E920	Cutting and piercing instruments or objects	1 (3.4)	0 (0.0)	1 (2.5)
E924, E898	Injury by burn	2 (6.9)	0 (0.0)	2 (5.0)
E927	Overexertion from sudden strenuous movement	2 (6.9)	1 (9.1)	3 (7.5)
	Other	1 (3.4)	0 (0.0)	1 (2.5)
	Total	29 (100)	11 (100)	40 (100)

[a]Injury occurred while working in agriculture and caused the subject to seek medical attention or lose at least one-half day of work or school time or have at least one-half day of restricted activity.
[b]Ninth Revision, International Classification of Diseases [World Health Organization, 1977].

in high schools in several states, reported that safety consciousness and risk taking were the strongest predictors of injury risk in the cross-sectional component of their study. Consistent with Westaby and Lee's findings, we also noted that risk taking, manifest in our study as riding in the back of an uncovered pick-up truck, was associated with both cross-sectional and prospective injury risk. The associations with smoking and of having a previous injury may also be indicators of risk-taking behavior.

The frequency and severity of injuries reported here and from other studies of youth working in the agricultural industry underscore the importance of prevention. Efforts to reduce agricultural injury have traditionally focused around engineering improvements, regulatory enforcement, and education [Aherin et al., 1992]. Among youth, emphasis has been on education, although systematic literature reviews have failed to identify reductions in injury experience related to educational interventions [Murphy et al., 1996; DeRoo and Rautiainen, 2000; Reed and Claunch, 2000; Rautiainen et al., 2008]. A large national study among youth FFA members showed no significant effect for educational interventions [Lee et al., 2004]. However, educational interventions have been successful in improving knowledge level and safety attitudes. Reed and co-workers, using a quasi-experimental cross-over design, showed that high school students working on farms and participating in educational sessions addressing agricultural safety demonstrated improved safety attitudes and intent to change behavior [Reed et al., 2001]. A subsample of these students received a follow-up farm site visit showing that over three-quarters of the subsample had made positive changes in farm work behaviors [Reed et al., 2003].

In view of the paucity of evidence for effectiveness of education for reducing injury risk, some authors have suggested limitations in hours and tasks for farm youth [Zentner et al., 2005; Marlenga et al., 2007]. However, there is substantial countervailing sentiment in the agricultural community, and many farm parents believe that farm work is a positive and character-building experience [Lee et al., 1997]. In the absence of a clear regulatory regime, NAGCAT provides voluntary guidelines for 62 farm tasks [National Children's Center for Rural Agricultural Health and Safety 1998]. Work by Gadomski et al. [2006] shows that approximately one-half of injuries occurred during tasks contrary to NAGCAT recommendations and, of these, approximately half were potentially preventable. Our data and those of other investigators should inform the health and safety conversation in the agricultural community, including consideration of stronger regulatory regimes, perhaps incorporating NAGCAT guidelines or strengthening Department of Labor (DOL) Hazardous Orders and authority to regulate youth work hours and tasks, and social norm change toward reducing hazards for farm youth.

The DOL Hazardous Orders, part of the FLSA (1938) governing child labor, are meant to prohibit or limit youth engagement in various hazardous employment activities. The Act's provisions apply to children under 18 in nonagricultural industries, but only to children under 16 in agriculture. Of the 28 Hazardous Orders, 11 relate to agriculture, and these have historically been less stringent

than standards in nonagricultural industries. In early September 2011, the DOL Wage and Hour Division published a Notice of Proposed Rulemaking for updating the agricultural child labor provisions with the intent of bringing these more closely into line with those for nonagricultural industries. NIOSH has provided specific recommendations for the proposed revision, the first since 1970 [NIOSH, 2002].

DOL's proposed revisions relate to tractor safety (all tractors used by 14- and 15-year-old student learners must have ROPS and seatbelts; increased training requirements for 14–15-year old to operate tractors and farm implements); other farm machinery (expansion of the list of prohibited machinery and equipment); work with animals (prohibiting certain work with livestock, such as in feedlots, exchanges, and similar operations); pesticides (prohibiting work as a pesticide handler); work at heights (reducing the maximum allowed work height from 20 to 6 feet); work with storage facilities for raw materials (prohibiting work with grain elevators, grain bins, and silos); and would prohibit use of electronic devices such as cell phones while operating power-driven machinery, including automobiles.

Whereas, bringing the agricultural Hazardous Orders into closer alignment with those for nonagricultural industries is appropriate, these measures will apply only to employed children younger than 16 years who are not working on their family farm, leaving unaddressed a large population of youth at risk. Nevertheless, they will cover youth under 16 years of age employed on farms and can serve as a guide for employers and parents when working with youth technically not covered by the Act.

CONCLUSIONS

The prospective farm work-related injuries among rural California public high school students are similar quantitatively and qualitatively to our earlier report of the initial cross-sectionally reported injuries and underscore the high risk and severity of injuries among farm youth. The strongest correlates of prospective injury risk were prior farm injury and the annual number of farm-work hours. Safety attitudes, as indicated in a three-question index, and risk-taking behavior, manifest here as smoking, riding motorcycles or mopeds, and riding in the back of an uncovered pick-up truck, were also associated with injury risk. These factors may be useful for identifying youth at increased risk. Potential interventions include focused educational efforts and limitations on farm work hours and tasks. The challenge for the agricultural community is to define the amount and character of farm work appropriate for children, and the means of assuring such limitations, so that children benefit from work without excessive risk.

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