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Hired crop worker injury risks on farms in the United States during three different periods between 2002 and 2015

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Abstract

Background: Hired crop workers have high incidence of work-related injuries, but little has been documented about potential risks at the national level.

Methods: Data were obtained from a national probability sample of hired crop workers in the United States (U.S.) during 2002–2004 (period I), 2008–2010 (period II), and 2014–2015 (period III). Multivariable logistic regression models of work-related injury were constructed using an occupational exposure adjustment for weeks worked in the previous year.

Results: Hired crop workers reporting that their employer did not provide clean drinking water and disposable cups every day were estimated to be at greater odds of injury during all three periods. Having at least some English-speaking ability was associated with increased odds of injury in two periods, while owning a dwelling in the U.S. showed greater injury risk during period II but was associated with lower risk during period III. Other items significantly associated

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AUTHOR CONTRIBUTIONS

Larry Layne and Carlos Siordia are the authors responsible for the design, analysis and interpretation, writing, and final approval, and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

John Meyer declares that he has no conflict of interest in the review and publication decision regarding this article.

ETHICS APPROVAL AND INFORMED CONSENT

All work was performed at NIOSH and NCIPC. All work was classified as routine and ongoing public health surveillance by the NIOSH Human Subjects Review Board and was conducted consistent with applicable federal law and CDC policy (see, e.g., 45 C.F.R. part 46, 21 C.F.R. part 56; 42 U.S.C. §241(d); 5 U.S.C. §552a; 44 U.S.C. §3501 et seq.).

DISCLAIMER

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health (NIOSH) and the National Center for Injury Prevention and Control (NCIPC), Centers for Disease Control and Prevention (CDC). Through an Interagency Agreement with the U.S. Department of Labor, Employment and Training Administration (USDOL/ETA), NIOSH receives NAWS research files with restricted access requirements. Research for this document was conducted by NIOSH and NCIPC using these restricted access files. In addition, citations to websites external to NIOSH and NCIPC do not constitute NIOSH and NCIPC endorsement of the sponsoring organizations or their programs or products. Furthermore, NIOSH and NCIPC are not responsible for the content of these websites. All web addresses referenced in this document were accessible as of the publication date.

with injury during at least one of the study periods in the final multivariable logistic models included being a direct-hire, a migrant worker, U.S.-born, receiving public aid, and having a health condition.

Conclusions: Hired crop workers are an extremely marginalized population of workers in the U.S. Innovative intervention methods must extend beyond traditional occupational models to focus on the overall health of hired crop workers, including increasing healthcare access, ending agricultural exceptionalism to provide equal regulatory protections afforded to workers in other industries, and adequate enforcement of existing regulations. These findings contribute to the understanding of correlates related to increased work-related injury among hired crop workers, and have implications in fields of prevention, intervention, and policy.

Keywords

farm worker; Hispanic; injury; migrant

1 | INTRODUCTION

It has long been documented that the agricultural industry is one of the most hazardous in the United States (U.S.) with a fatality rate in crop operations of 20.8 per 100,000 full-time equivalents (FTE) in 2020 compared to the overall civilian work-related fatality rate of 3.4.[1] The nonfatal injury rate for crop operations was 4.6 per 100 FTE compared to a rate of 2.9 across all industries in 2020.[2] Even with the higher rates shown in agricultural, it is believed that agricultural industry has the largest undercount of injuries compared to other industries.[3] Leigh et al.[3] estimated that the published number of nonfatal injuries on crop operations was a 73.7% undercount of the true nonfatal injury burden.[3] The primary reasons for such a large undercount were the exclusion of employees on small farms and the exclusion of farm families.[3]

The U.S. agricultural workforce has been steadily undergoing change. Current trends include a loss of small family farms, which declined by 4% between the 2007 and 2012 Census of Agriculture.[4] During this same period, however, there was a 6% increase in the number of farms with 5000 acres or more, and a 33% increase in the number of farms with a total value of sales of $500,000 or more.[4] The number of farms classified as a corporation increased 11% during this same period, with a greater proportion of these corporate farms reporting expenses incurred for hired farm labor (62%) and contract labor (22%).[4] These trends potentially suggest that a greater proportion of total farm labor will be derived from hired and contract labor in the future along with the rise of large, corporate farms.

Manual labor on crop farms can include close human interaction with heavy machinery, exposure to hazardous pesticides, and irregular and long hours of intensive manual labor that can involve harsh weather conditions, such as working in direct sunlight in very high heat.[5] Not only do they face exposure to chemicals and pesticides working in the fields, but take-home contamination has been measured in their residences.[6-9] Hired crop workers face agricultural exceptionalism, in which regulatory protections provided to workers in other industries often do not apply to agricultural workers or are weaker.[8,10,11] A large percent of hired crop workers are undocumented (i.e., lack legal authorization to work in the U.S.).[12]

It has been reported that lack of legal authorization leads to greater fear of job loss and deportation.[13,14] Hired crop workers are also adversely impacted by structural and social determinants of health, including poverty, employment uncertainty, substandard housing, limited access to healthcare, and food insecurity.[14-17] In the U.S., hired crop workers have been described as one of the most marginalized groups of employed workers.[15,16]

The National Agricultural Workers Survey (NAWS) operated by the U.S. Department of Labor/Employment and Training Administration (USDOL/ETA) has been used to collect occupational data for hired farm laborers on crop operations since 1989. Hired farm laborers on crop operations are referred to as hired crop workers throughout this paper. Published data tables of the NAWS 2013–2014 indicate that hired crop workers are predominately Hispanic (80%), foreign-born (73%), with Spanish as their primary language (74%), and are relatively young with an average age of 38 years compared to 42 years for the overall U.S. labor force.[18] The percentage of hired crop workers with authorization to work in the U.S. has increased from 47% to 53% between 2000 and 2014.[12,18] Many of these demographic characteristics, along with this population's socioeconomic characteristics, have been suggested to be related to higher risk of occupational injuries and illnesses among hired crop workers.[18]

The National Institute for Occupational Safety and Health (NIOSH) added a supplemental injury module to the standard NAWS survey through a collaborative effort with the USDOL. The injury supplement was administered during three separate periods based on the availability of funding, including 2002–2004 (period I), 2008–2010 (period II), and 2014–2015 (period III). Two recent NAWS studies conducted descriptive analyses to identify potential injury risks for work-related injuries among hired crop workers.[19,20] Relevant findings included that hired crop workers were at greater odds of an injury when they were hired directly by the farm operator (compared to indirect or labor contractor hired), handled pesticides, or were positive for a health condition, while undocumented crop workers were at lower odds of injury compared to documented workers.[20] What differentiates these findings from those of previous studies is the national probability sampling methodology of NAWS. Many of the previous studies have used information from relatively small natural geographic clusters of farm workers, such as crop workers living in a single community-dwelling or a farm labor camp, a single educational system, migrant health clinics, or included only subgroups of the hired crop worker population.[5,21-27] To address gaps in the literature of potential injury risks among hired crop workers, the current study uses the eight available years of the NAWS injury data from three different time periods to construct multivariable logistic regression models to identify associations between occupational injuries and various demographic characteristics and environmental factors.

2 | METHODS

2.1 | NAWS survey

A total of 8 years of NAWS data from period I (2002–2004), period II (2008–2010), and period III (2014–2015) were analyzed for the current paper. Previous publications detail the NAWS methods and explain that it consists of a nationally representative multistage sample of crop operations in the contiguous U.S. designed to account for regional and

seasonal differences in crop farming.[12,18] The NAWS defines “hired crop workers” as those who perform field work on nursery, cash grain, field crop, fruit and nut, vegetable, and Christmas tree farms in the U.S., including field packers, supervisors, and those hired crop workers who simultaneously hold nonfarm jobs. NAWS does not include hired livestock workers, secretaries, and mechanics.[20,28] Also excluded are those in the H-2A temporary agricultural program that provides entry into the U.S. for seasonal agricultural work based on a shortage of domestic labor.[29] Youth less than 14 years old are not interviewed. Hired crop workers are included in the sample regardless of their worker documentation status (or work authorization status).

The NAWS survey can be administered in either Spanish or English at the preference of the respondent. The hired crop worker is informed that participation is voluntary, and they sign two copies of the consent form, the first for survey requirements and the second copy for them to keep. The interview is conducted during nonwork hours in a place of convenience selected by the respondent. An honorarium of $20 was provided to the crop workers who participated in the NAWS to offset the inconvenience and any expense incurred to participate in the interview. The survey instrument may be obtained in entirety in English or Spanish from the USDOL/ETA website.[30]

The NAWS survey collects demographic characteristics, including age, sex, ethnicity, marital status, country of birth, whether there are youth <18 years of age living in the respondent's home, English proficiency, documentation status, and whether the respondent has a health condition. English proficiency (i.e., “English-speaking ability”) was determined by the question “How well do you speak English?” There were four response categories including: (1) not at all, (2) a little, (3) somewhat, and (4) well. The second and third categories (i.e., “a little’ and ‘somewhat”) were combined due to small cell size for the response “somewhat.” The NAWS variable for “documentation status” (also commonly referred to as work authorization status) contained four response categories, including: (1) citizen, (2) green card, (3) other work authorization, and (4) unauthorized. For this analysis, the two categories of green card and other work authorization were aggregated and referred to as “documented” to create a three-category variable of citizen, documented, and undocumented. The item “health condition” was an aggregation of six conditions and a broad “other” category. The six conditions were comprised of asthma, diabetes, hypertension, tuberculosis, heart disease, and urinary tract infections. The respondent was determined to have a health condition if they were positive for any of the six categories or if information was listed in the narrative text of the “other” category.

In addition to the demographic characteristics, three socioeconomic variables from NAWS were retained for this analysis. Questions asking if the hired crop worker's “family income below the poverty level” and do they “own a dwelling in the U.S.” (i.e., mobile home, single-family home, and duplex or condominium style) were coded as dichotomous variables in the data as yes or no. The third variable, do they “receive any type of public aid” was an aggregate of 13 individual categories. The respondent was asked, “In the last 2 years, have you or anyone in your household received benefits or used the services of any of the following social programs?,” including temporary assistance for needy families (TANF); food stamps; disability insurance; unemployment insurance; Social Security; veteran's

pay; general assistance/welfare; low income housing; public health clinic; Medicaid; WIC (Women, Infants, and Children); disaster relief; legal services; and an open-ended "other" category. If the respondent answered "yes" to one or more of these questions, they were coded positive for the item "receive any type of public aid."

Eight variables related to the hired crop workers' employment characteristics and three additional field sanitation items were retained in this analysis. The number of "years of farm work performed in the U.S." was collected for each respondent. The NAWS variable "migrant type" for this study was defined as a crop worker who performed jobs at least 75 miles apart, or who moved more than 75 miles for farm work during the last 12 months.[18] These are commonly referred to as either shuttle migrants or follow-the-crop migrants. Workers who do not travel for work were referred to as nonmigrant (or settled). The variable "type of hire" describes how the crop worker was hired and differentiates between workers that were recruited by the grower/farmer or his foreman (i.e., direct hire), or whether they were recruited by a farm labor contractor or his foreman (i.e., contractor laborer). 'Wage type' refers to how the hired crop worker is paid, by the piece rate compared to other forms of compensation, including hourly, combination, and salary. The variable to access whether the crop worker has handled pesticides was collected by a dichotomous response of yes or no to the question, "In the last 12 months, have you loaded, mixed or applied pesticides?" For the item "Does the employer pay for needed equipment?," a positive response was created by combining the categories (1) no equipment needed, (2) grower/labor contractor pays all, and (3) grower/labor contractor provides all but worker "prefers" to bring some of his/her own equipment. A negative response included: (1) worker pays for all equipment, (2) a friend or relative pays for some or all equipment, (3) worker pays for some equipment, (4) worker pays for replacement or damaged tools, and (5) grower/labor contractor pays for some but worker "must" bring/buy the rest. "Worker's compensation coverage" was collected from the question "If you are injured at work or get sick as a result of your work, do you get any payment while you are recuperating (i.e., worker's compensation)?" And the item "employer provides health insurance" was collected from the question, "If you are injured or get sick off the job (e.g., at home), does your employer provide health insurance or pay for your health care?" Both of these variables were collected by a dichotomous yes or no response.

Finaly, three variables addressing field sanitation were retained for this analysis. The three questions were collected from the following: "Does your current employer provide EVERY DAY (potable) clean drinking water and disposable cups?… a toilet (EVERY DAY)?… (provide) water to wash hands (EVERY DAY)?" The first variable, "employer provides clean drinking water and disposable cups every day" contained three response categories including no water, no cups; yes water only; and yes water and disposable cups. The first two categories were aggregated into a negative response and compared to the response "yes water and disposable cups." The last two variables for toilets and hand wash were collected in the survey by the dichotomous yes or no response.

2.2 | Injuries

To identify injuries, hired crop workers were asked whether they had incurred an injury during the last 12 months that: (1) occurred on a farm they were working on in the U.S., or while traveling to or from a farm for work in the U.S., and (2) resulted in one or more of the following: rendered the worker unable to work for at least 4 h; rendered the worker unable to work as hard as he or she normally did for at least 4 h; required the worker to seek medical treatment; or required the worker to take strong medicine to keep working (strong medicine is defined as something other than over-the-counter medications). The injury screening question was changed before the start of the period II interviewing process to include examples of common agricultural injuries that were read to the workers to help increase the sensitivity of identifying injuries. The examples included cutting oneself with a sharp tool or knife; strains from lifting heavy objects; falling from a ladder; and getting sick from exposure to the sun, sting or bite of an insect, or from pesticides. Additional changes to the injury screening question are discussed in detail elsewhere.[20] For each injury case, a narrative description of the injury etiology provided by the injured worker was recorded. The injury module was collected separately from the musculoskeletal pain and discomfort module, and the pain and discomfort data were not included in the current injury analysis. The injury module incorporated in the NAWS was determined to be routine and ongoing public health surveillance by the NIOSH Human Subjects Review Board and was conducted consistent with applicable federal law and CDC policy (§see, e.g., 45 C.F.R. part 46, 21 C.F.R. part 56; 42 U.S.C. §241(d); 5 U.S.C. §552a; 44 U.S.C. §3501 et seq).

2.3 | Analysis

Statistical Analysis System (SAS®)[31] SURVEYFREQ, SURVEYMEANS, and SURVEYLOGISTIC procedures were used to account for the complex sampling design of the NAWS. The statistical estimates reported in this paper were derived using multi-year sample weights. Multi-year weights were used to create unbiased sample estimates that account for changes in sampling variances caused by pooling data across multiple years that varied by sample size. A finite correction term was used in period I to adjust the standard errors to account for a larger sample of farms during this study period. A coefficient of variation (CV) ≤ 36% was required for variables to meet data reporting requirements in this study.

Because of the difficulties in defining the true number of hired crop workers in the U.S., national count estimates were not generated from this analysis. Nationally representative percent distributions for the population estimates and injury percent distributions are presented along with adjusted odds ratios and their 95% confidence interval estimates. Estimates with a CV > 36% were excluded from analysis due to unreliability of the estimates.

To calculate the injury rates, employment estimates were derived from the NAWS work history section of the survey. The employment estimates incorporated the number of weeks of farm work during the previous 12 months to serve as a proxy for occupational exposure. These employment estimates are referred to as week-based full-time equivalents (FTE_{WB}).

This methodology was previously used for the calculation of injury rates using NAWS injury data and described in detail elsewhere.[20]

The injury odds ratios were also adjusted to incorporate occupational exposure by dividing the injuries (coded as 1 or 0) by the number of weeks of farm work during the previous 12 months and scaled to ensure all injury values were between 0 and 1. This "calling" of the injuries according to the occupational exposure adjustment results in higher injury values for cases with fewer weeks worked. For example, an injured crop worker reporting only 2 weeks of farm work in the previous 12 months would have an injury value of 0.5 (1 injury/2 weeks worked) compared to a value of 0.02 for someone reporting 50 weeks of work (1 injury/50 weeks worked). We refer to this as an adjusted odds ratio (OR_{ADJ}).[20]

For this study, all potential independent variables considered for use in the multivariable modeling were identified by calculating a bivariate (or univariate) OR_{ADJ} with injury statistically significant at $p \leq 0.20$.[32] Correlation matrices for each of the three periods are presented in Appendix A for variables that were statistically significant with injury at $p \leq 0.20$. Two multivariable logistic regression (MVLR) models were constructed for each period using forward selection. One MVLR model used the traditional significance level of $p \leq 0.05$, and an alternative MVLR model was constructed using $p \leq 0.10$ for determination of significance. This second more liberal MVLR model was constructed for pragmatic purposes, to examine potential differences between models with the inclusion of additional covariates approaching but failing to meet traditional significance level $p \leq 0.05$ that might be important.[33]

The first step in constructing the multivariable models was the selection of the independent variable with the strongest OR_{ADJ} that was statistically significant, then reentering the remaining items one at a time while controlling for the first item entered into the model. After selecting the second largest OR_{ADJ}, the remaining variables were reentered while controlling for the first two variables. This process was repeated until no additional variables had a significant OR_{ADJ}. Finally, all independent variables not included in the final multivariable logistic models were reentered a final time to reexamine significance, or to determine if they had a confounding effect by changing any of the significant adjusted odds ratios by 15% or more. The variables sex, age, and foreign-born, were entered into the final model to determine if they had a confounding effect by changing any of the significant adjusted odds ratios by 5% or more (if not already included in the model based on a statistical significance OR_{ADJ}). If this confounding effect was identified, they were maintained in the final model regardless of significance. This lower level of 5% (compared to the traditional rule of thumb of 15%) was selected as a method for determining whether the final multivariable models would be influenced by the inclusion of these covariates. Otherwise, it can be presumed that these covariates were not statistically beneficial to the final multivariable variable.

3 | RESULTS

3.1 | Demographics

There were 9992 hired crop workers interviewed during period I with 241 of these workers reporting at least one injury. There were 5873 interviews with 141 injuries in period II, and 5657 interviews with 124 injuries in period III. The overall grower (i.e., the farm employer) participation rate was 69% in period I, 66% in period II, and 54% in period III. The response rate among hired crop workers was 94% during periods I and II, and 95% in period III.

Over the three periods of the study, the percentage of females in the workforce increased from 23.5% to 30.2% (Table 1). The median ages of the hired crop workers were 32, 35, and 36 during the three periods, respectively. The median age of males was 32 years in periods I and II and 35 years for females during these two periods. Females had a median age of 37 years during period III compared to 36 years for males. The percentage of hired crop workers reporting Hispanic ethnicity was about 80% over the three periods (Table 1). About three quarters of the hired crop workers self-reported that they were foreign-born, although this percentage dropped steadily (although not significantly) from 75.6% to 73.7% during the study periods (Table 1). “English-speaking ability” and the percentage of workers reporting at least one health condition continually increased across the three periods (Table 1). The percentage of the workforce self-reporting that they “received any type of public aid” doubled during the study periods, increasing from 25.5% in period I to 51.9% in period III.

An examination of the employment characteristics showed that the median “years of farm work in the U.S.” steadily increased from 7 years in period I, to 10 years in period II, and 11 years in period III. Males had higher median years of farm work with 8, 11, and 13 years over the three periods, respectively, compared to 6, 9, and 8 years of farm work for females. The percentage of hired crop workers classified as migrants steadily decreased during the three study periods, while the percentage of hired crop workers self-reporting that they “loaded, mixed, or applied pesticides” steadily increased (Table 1). The items of “worker's compensation” and “health insurance coverage” are difficult to interpret due to a large number of unknown responses (Table 1). The three field sanitation items, “employer provides clean drinking water and disposable cups every day,” “employer provides a toilet,” and “employer provides handwash water,” had high percentages of positive responses for all three periods (Table 1).

3.2 | Injury modeling

The nationally weighted percent of hired crop workers reporting an injury during period I was 2.6% (95% CI 2.1—3.1); 1.9% (95% CI 1.4—2.5) during period II; and 2.0% (95% CI 1.5—2.5) in period III. The overall injury rates were 4.3/100 FTE_{WB} (95% CI 3.5—5.1) in period I; 2.9/100 FTE_{WB} (95% CI 2.0—3.8) in period II; and 3.0/100 FTE_{WB} (95% CI 2.2—3.7) in period III.

Bivariate (or univariate) adjusted odds ratios were calculated for each of the three separate periods for a variety of socioeconomic, workplace demographic, and field sanitation factors collected in the NAWS thought to be potentially related to increased risk of injury or

previously identified in the literature. Table 2 lists these items examined for potential injury risks using the adjusted odds ratios. As previously stated in the methods, items significantly related to injury at $p \leq 0.20$ were maintained for the multivariable modeling. Two items were significantly related to injury (i.e., $p \leq 0.20$) during all three periods: "loaded, mixed, or applied pesticides" and the "employer provides clean drinking water and disposable cups every day." Crop workers who "loaded, mixed, or applied pesticides" were at an increased risk of injury compared to workers who did not, with an increased injury risk that ranged from 1.5 to 2.1 over the three periods of the study (Table 2). Workers who responded in the negative to the question "employer provides clean drinking water and disposable cups every day" were at a 2.1 to 2.5 increased risk of injury over the three periods (Table 2).

Six additional items were significantly (i.e., $p \leq 0.20$) related with injury during two of the three periods. Crop workers reporting a "health condition" were at greater risk of injury during periods I and III. During period III, those positive for a "health condition" were at 4.4 higher risk for injury, which was the largest bivariate injury odds ratio identified in any of the three periods (Table 2). Crop workers reporting speaking English "a little" or "somewhat," and "well" were at increased injury risk with odds ratios ranging from 1.7 to 2.8 compared to those who had no English-speaking ability (Table 2). Additionally, males were at increased risk in periods I and II, workers born in the U.S. or Puerto Rico (i.e., not foreign-born) were at increased risk during periods I and III, and workers who were citizens of the U.S. compared to undocumented were at greater injury risk in periods I and II (Table 2). The variable "own dwelling in the U.S." was significantly related to injury during periods II and III. This relationship however, was reversed between the two periods. Crop workers who owned a dwelling in the U.S. were identified at greater risk of injury during period II, while those who owned a dwelling in the U.S. were at lower risk during period III (Table 2). A closer examination of this item showed that among those injured during period II, 45% reported owning a dwelling in the U.S. compared to only 15% of the injured workers in period III. Eight additional items were found significantly related to injury during at least one of the three periods, including "youth <18 years living in household," "receive any type of public aid," "migrant type," "type of hire," "wage type," "employer pays for all equipment," "employer provides a toilet," and "employer provides handwash water" (Table 2).

3.3 | Multivariable modeling

During period I, there were 13 variables initially considered for the MVLR models based on a significant bivariate odds ratio with injury at $p \leq 0.20$ (Table 2). Two of the covariates of interest, sex and foreign-born, met the inclusion criteria for multivariable modeling based on their bivariate statistical significance, while age was also included as a potential confounder. In the first MVLR model, based on the traditional $p \leq 0.05$, five variables were maintained in the final multivariable model (Table 3A). "English-speaking ability" was the first variable to be entered into the model using forward selection as it had the strongest odds ratio. Once "English-speaking ability" was accounted for in the model, "documentation status" lost significance and was dropped. This was somewhat expected as the Spearman's correlation matrix for this period (Appendix A) showed that the three variables "English-speaking ability," "documentation status," and foreign-born had large Spearman's correlations equal to

or greater than $r = 0.70$ indicating a high probability of confounding effects between them. Following “English-speaking ability,” the items “type of hire,” “employer provides clean drinking water and disposable cups every day,” “migrant type,” and foreign-born loaded significantly in that order (Table 3A). Examining sex and age as possible confounders, the item age increased the OR_{ADJ} of foreign-born by 12%. While Spearman's correlation between age and foreign-born was not high (i.e., 0.13, Appendix A), those foreign-born were younger with a median age of 32 compared to 39 for those born in the U.S. or Puerto Rico. Age also served as a confounder on English-speaking ability “well,” decreasing the OR_{ADJ} by 5% and was maintained in the final model (Table 3A). The third covariate of interest, sex, did not produce any change at the ≥5% level.

The second more liberal MVLR model for period I, based on $p \leq 0.10$, was similar to the first model with the exception of one additional item, “receive any type of public aid,” that was included on the model due to the more relaxed p value (i.e., $p \leq 0.10$) used to determine statistical significance (Table 3B). The confounder age increased the OR_{ADJ} of foreign-born by 11% and decreased the OR_{ADJ} of English-speaking ability “a little or somewhat” by 5%, therefore, it was maintained in the final model (Table 3B).

During period II, there were five variables considered for the MVLR models based on their bivariate odds ratios with injury at $p < 0.20$ (Table 2). Additionally, age and foreign-born were examined as potential confounders, while sex was already included based on its bivariate significance with injury. For the first MVLR model, using the traditional $p \leq 0.05$ for significance, there were two variables incorporated in the final multivariable model. The variable, “employer provides clean drinking water and disposable cups every day” was entered first as the largest bivariate odds ratio, followed by “own dwelling in the U.S.” (Table 3A). With these two variables included in the multivariable model, the items sex and “documentation status” lost significance and were dropped. Two covariates of interest, sex and foreign-born, were incorporated into the final MVLR model (Table 3A) to assess their possible confounding. The covariate sex reduced the strength of the OR_{ADJ} for “employer provides clean drinking water and disposable cups every day” by 5%. The covariate foreign-born reduced the strength of the OR_{ADJ} for the item”own dwelling in the U.S.” by 6%. A higher percentage of females (95.4%) reported that the “employer provided clean drinking water and disposable cups every day” compared to 91.1% among males. For the item “own dwelling in the U.S.,” 44.2% of U.S. and Puerto Rico-born crop workers reported “owning a dwelling in the U.S.” compared to 20.4% of those foreign-born. While “documentation status” was originally considered for the MVLR model based on its bivariate relationship with injury (Table 2), the item lost statistical significance and was dropped. It did, however, serve as a confounder for the item “own dwelling in U.S.” producing a 14% change. While this was approaching the 15% cut-off limit, the ‘documentation status’ item was not included in the model because it contained a relatively large number of missing values. And due to the sensitivity of this item, the non-reporting encountered for this variable was most likely biased.

In the second, more liberal MVLR model using $p \leq 0.10$ for significance during period II, the same two items of “employer provides clean drinking water and disposable cups every day” and “own dwelling in the U.S.” were entered in the model based on statistical

significance (Table 3B). The third variable maintained on the multivariable model—"loaded, mixed, or applied pesticides"—had an $OR_{ADJ} = 1.8$ ($p = 0.11$). Due to the p value being only one hundredth above the cutoff, this item was included in the final model. The covariate sex produced a 7% change on the item "loaded, mixed, or applied pesticides," decreasing the strength of the pesticide item's OR_{ADJ} from 1.8 to 1.6, and increasing p value from $p = 0.11$ to $p = 0.18$ (Table 3B). Among males, 19.9% reported that they "loaded, mixed, or applied pesticides" compared to 4.0% for females. The other covariates of interest, age and foreign-born, had no effect as confounders and were not incorporated into the final multivariable model. And similar to the first model for period II, "documentation status" changed the OR_{ADJ} for "own dwelling in the U.S." by 14% but was not maintained for reasons previously mentioned.

During period III, there were eight variables considered for the MVLR models based on the significance of their bivariate odds ratios, including the covariate foreign-born based on its bivariate significance with injury (Table 2). The variable sex was examined as a possible confounder, but age could not be used due to the failure of some data cells to meet data reporting and disclosure requirements (Table 2). The first MVLR model for period III, based on the traditional $p \leq 0.05$, had three significant variables including "having a health condition," "employer provides clean drinking water and disposable cups every day," and "own dwelling in U.S." (Table 3A). The item of "having a health condition" had an OR_{ADJ} of 4.5, which was the largest OR_{ADJ} identified on all six of the final MVLR models in this study (Table 3A). The covariate foreign-born changed the item "own dwelling in the U.S." by 10%, with the OR_{ADJ} for "own dwelling in the U.S." increasing from 2.2 to 2.4 (Table 3A). The covariate of interest, sex, did not meet the criterion to be included on the final MVLR model.

In the second MVLR model of period III, using $p \leq 0.10$ as the significance value, the same three variables were included in the final model as listed above with the addition of a fourth, "English-speaking ability" (Table 3B). The covariate foreign-born made a 15% difference for speaking English "well," increasing the OR_{ADJ} from 2.6 to 3.0, which was somewhat expected as Spearman's correlation between these two items was 0.68 (see Appendix A). With the addition of "English-speaking ability" in the model, foreign-born no longer served as a covariate for "own dwelling in the U.S.," as was the case in the previous model based on $p \leq 0.05$. Because foreign-born served as a confounder for "English-speaking ability," it was maintained in the final model (Table 3B).

4 | DISCUSSION

4.1 | Findings

In this study, two MVLR models were constructed for each period. The first used the traditional $p \leq 0.05$ to determine statistical significance. A second more liberal MVLR model was constructed based on $p \leq 0.10$. This second model was included in the study primarily for pragmatic purposes, to provide the ability to compare different results for items approaching but failing to meet traditional significance that could potentially be important for the study of injury to this population. Overall, the results of the two models were very

similar with the more liberal *p* value adding only one additional significant variable to the final MVLR models.

All six of the final multivariable logistic models included the field sanitation item showing increased odds of injury when the crop worker responded negatively to the question "employer provides clean drinking water and disposable cups every day." This was the only item that was significantly related to injury during all three time periods. Steege et al.[34] previously reported that the field sanitation items of clean drinking water and disposable cups, handwashing supplies, and access to toilets all declined on farms with fewer farmworkers. Another study that examined access to toilet paper as a proxy for general field sanitation items reported a (statistically insignificant) increase in risk of injury.[22] This study also reported a confounding effect between field sanitation and the type of employer (i.e., grower or labor contractor),[22] an item retained in our multivariable model during period I. Another study using NAWS data found that two field sanitation items (i.e., the employer provides a toilet and provides water to wash hands every day) were significantly related to self-reported back pain and discomfort.[35] Preibisch and Otero[36] found nearly one quarter of farmworkers in Canada lacked hand-washing facilities, increasing exposure to infectious agents and chemicals. Vela-Acosta et al.[37] found that deficient field sanitation conditions were related to greater occupational risks. Gabbard and Perloff[38] suggested that these field sanitation items are a proxy for overall work conditions and are related to whether a hired crop worker is more or less likely to return for future employment. Similar to results presented by Gabbard and Perloff,[38] this variable could potentially be a proxy of the employers' attitude toward prevention of injuries and illness. A qualitative examination of the injury narratives would be warranted to investigate whether lack of water could be related to the types of injuries reported by crop workers. Dehydration may result in mental and physical fatigue, less attention and focus, or balance-related problems, which could predispose the crop workers to illness or injuries. Mizelle et al.[39] reported that hydration status, measured by urine specimens, among North Carolina farmworkers significantly deteriorated to the extent they were dehydrated or severely dehydrated by the end of a workday. And that these farmworkers spent the majority of their shift working in temperatures above the recommended limits for workplace heat exposure.[39] Another farmworker study reported that dehydration was related to decreased kidney function, kidney function significantly decreased between pre- and postharvest, and that pesticide exposure needs to be considered along with dehydration status and heat stress.[40] Relationships between field sanitation, size of employer, type of employer, and occupational exposures collected using walk-through surveys also warrants additional consideration.

The ability to speak at least some English showed an increased odds of injury compared to those who spoke no English in the final multivariable models during periods I and III using the more liberal model based on a *p* value of 0.10. And in period I, it was also significant in the MVLR model based on the more traditional *p* value of 0.05. This finding appears to contrast with some of the literature where language barriers are believed to make farmworker access to, and the conveying of safety information to the hired workers more difficult.[41,42] However, one could hypothesize that English language skills are related to the fear of reporting, leading to an undercount among those with the least English language skills.[36] Fear of job loss and deportation have been documented among

unauthorized workers.[13,14] Limited English is also related to general health care access, with those who speak no English less likely to use any type of health care.[36,43] A previous analysis of NAWS data reported that among foreign-born farmworkers, undocumented individuals had a lower prevalence of both chronic health conditions and musculoskeletal pain and discomfort.[44] Another study using NAWS data examined the relationships between English language writing and speaking ability, education, documentation status, training, job assignment, and tasks performed. In a detailed analysis of pesticide items in NAWS 1989–2006, crop workers who had applied pesticides were more likely to be older men with increased English language skills, greater education, and were also more likely to be documented workers.[45] And crop workers more likely to have received pesticide training included documented workers with increased education and farm work experience.[45] This suggests that language, in addition to education and documentation status, was related to the training provided, job assignment, and tasks performed by the crop workers. In the current study, crop workers who reported that they performed the tasks related to handling pesticides (i.e., “loaded, mixed, or applied pesticides”) were at increased odds of injury on the final multivariable model during period II, although the item lost significance at the $p \leq 0.10$ level when sex was introduced as a control.

In addition to the two items “employer provided clean drinking water and disposable cups every day” and “English-speaking ability,” the only other item that appeared on a final multivariable model during at least two different periods was “own a dwelling in the U.S.” Crop workers who reported owning a dwelling in the U.S. were at greater risk of injury during period II, but this item was associated with lower risk of injury during period III. Owning a dwelling showed no difference during period I. The difference in dwelling ownership between periods II and III is not understood but could potentially be related to the changing demographics of the workforce during the three periods.[46,47] Mexican-born persons comprised between 68% and 72% of the total workforce in NAWS during the three injury study periods (Table 1). Starting with the Great Recession of 2008, however, Mexican-born immigrants leaving the U.S. outnumbered those migrating into the U.S.[48,49] This decline was most notable among undocumented immigrants, resulting from both a lower number migrating to the U.S. and greater numbers of immigrants leaving the U.S. to return to Mexico.[48,50-52] It has been speculated these changes to unauthorized immigration patterns were due to relatively high unemployment in the U.S., increased border enforcement, and improved economic conditions in Mexico.[53] The notable out-migration of undocumented crop workers is one plausible explanation for the increased percent of dwelling ownership observed during period II (Table 1), as those least likely to own a dwelling were most likely to return to Mexico. And as previously mentioned, about three times the proportion of injured workers reported owning a dwelling during period II compared to period III (i.e., 45% in period II compared to only 15% in period III) (Table 2). While it is unknown how changes in immigration patterns and hired crop worker demographics between the three injury study periods influenced injury prevalence patterns, they may be partially responsible not only for the discordant findings for “own a dwelling in the U.S.,” but also for the overall differences observed between the periods.

Finally, the multivariable model during period I identified two additional variables associated with increased odds of injury, being a migrant farmworker and a direct hire

(i.e., hired by the grower). These variables also presented challenges with analyses as the “type of migrant” could not be examined in periods II or III, while the “type of hire” could not be examined in period II, due to the statistical estimates' failure to meet minimum reporting guidelines. The demographic data showed the percentage of hired crop workers classified as migrant (i.e., shuttle and follow-the-crop migrant workers as opposed to nonmigrant/settled) decreased from 36% in period I to 19% in period III. Using more recent NAWS data, Gold et al.[28] found this declining pattern continued as the percentage of migrant workers dropped to 15% in 2019–2020. An examination of injury patterns between migrant and settled farmworkers would be difficult without an increased sample size, or over-sampling of migrant workers as this type of hired crop worker is rapidly decreasing. The finding for “type of hire” being related to injury in period I is partially consistent with McCurdy et al.,[25] who reported a similar protective factor for indirect hire among men but found the opposite effect for women. The findings of the current study and McCurdy et al.,[25] however, are counter to the findings of Cooper et al.,[22] who reported seven times greater risk of injury among indirect hires (i.e., hired by a farm labor contractor). Das et al.[54] reported crop workers in California who were employed by farm labor contractors were less knowledgeable about employment benefits such as worker's compensation and unemployment insurance. Additional work is needed in this area, but the differences in the geographical scope of the samples of these studies could also account for the differences in findings.

Hired crop workers are an extremely marginalized population of workers in the U.S. Developing innovative intervention methodologies must extend beyond traditional occupational models to focus on the overall health of hired crop workers. Baron et al.[55] have noted that low-income workers face hazards from a complex interplay between work and nonwork, and this interplay requires a culturally sensitive, social-ecologic approach to interventions. Intervention strategies for crop workers have ranged from suggesting “community-based strategies”[41] to calling for “system-wide policy changes.”[17] Healthcare access presents significant financial and logistical barriers for immigrant agricultural workers.[17] The strengthening of the Community and Migrant Health Centers with occupational specialists, developing outreach and telehealth, and reducing language and transportation barriers are needed.[17] Agricultural exceptionalism denies crop workers the regulatory protections afforded to workers in other industries and must be eliminated.[10,14,56] And adequate application and enforcement of existing regulations has shown to be deficient.[10,57-62] A multifaceted approach to address these occupational and health disparities among hired crop workers is required yet will be very challenging to implement.

4.2 | Strengths and limitations

The NAWS is a national-level probability survey that collects data via a face-to-face interview format, with the interviews being conducted at a convenient location of the interviewee's preference. The 94% response rates during periods I and II and 95% response rate during period III among hired crop workers selected for an interview demonstrates the acceptability of the survey design among this population of workers. The response rates among growers (i.e., the agricultural employers) were lower than among hired crop workers, with 69%, 66%, and 54% of the growers agreeing to allow workers on their farms

to be interviewed during the three periods, respectively. However, a bias of less than 10% was found when examining differences between grower respondents and non-respondents by geographical region, agricultural industry subsector, and source of information used to construct the samples.[63] This suggests that the overall grower response rates are not the source of a large amount of bias, regardless of the less-than-optimal response rates.[63]

The cultural differences in language and cognitive constructs among international crop workers could lead to lack of clarity for some questions in the survey. Cooper et al.[22] reported that the English phrase “work-related injury” does not have an equivalent in Spanish, although the phrase “lesiones de trabajo” (injury from work) is included on worker's compensation forms. Due to the potential difficulties arising from language translation and cognitive interpretation of work-relatedness, the NAWS injury screening question was modified to include examples of the most common types of injuries to hired crop workers to increase the sensitivity of identifying injuries before the start of period II as reported in Tonozzi and Layne.[20] Additional cognitive testing of the injury screening question should be considered in future studies.

The self-reporting nature of the data collection instrument could lead to several potential problems. Underreporting of injuries due to the 12-month recall period likely produced an undercount in this study, although telescoping (extending beyond the recall period) for a few severe incidents is also possible. Another possible bias in the NAWS is workers providing intentionally misleading responses due to fear of reporting work-related injuries or because questions were perceived to be sensitive.[40] Additionally, crop workers who had incurred a severe injury that prevented them from working during the last 15 days were not eligible to participate in the NAWS. This could lead to an undercount of severe injuries, as workers who had not yet returned to work due to injury would not have been eligible for the sample.

The NAWS does not currently include hired livestock workers, crop workers outside the contiguous U.S., or crop workers classified as H-2A.[29] Still, the NAWS is currently the only national probability sample that provides demographic, employment, and health characteristics for hired crop workers in the continental U.S.[64] The NAWS sampling methodology provides unbiased percentage distributions and injury rate estimates using a sound approach that was validated through an independent study.[65] The definition used in this study for an injury is more stringent than some other studies of migrant crop workers as most minor injuries are excluded. The strengths and limitations of NAWS have been discussed in more detail in previous studies.[19,20,43]

5 | CONCLUSIONS

Hired crop workers are an extremely marginalized population of workers in the U.S. exposed to harsh employment conditions. Hired crop workers who responded negatively to “employer provides clean drinking water and disposable cups every day” were at greater odds of injury during all three periods, suggesting this item may be a proxy for overall work conditions. These injury risks along with the demographic characteristics of this population, point to the need for innovative intervention methodologies that extend beyond traditional occupational models to focus on the overall health of hired crop workers. Access to

healthcare, agricultural exceptionalism, and enforcement of regulatory standards should be addressed. These findings contribute to the understanding of correlates related to increased work-related injury among hired crop workers, and these findings have implications in the fields of prevention, intervention, and policy.

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DATA AVAILABILITY STATEMENT

NIOSH receives NAWS-restricted research files from the USDOL/ETA through an Interagency Agreement. The Interagency Agreement maintains restricted access requirements precluding the release of these files. The NAWS data are available for public download from USDOL/ETA at https://www.dol.gov/agencies/eta/national-agricultural-workers-survey/data.

APPENDIX A

See Tables A1 and A2.

TABLE A1

Spearman's correlation coefficient[a] matrices for independent variables with significant adjusted odds ratios ($p \leq 0.20$) with injury by time period.

Period I													
	Gender	**Foreign-Born**	**English**	**Doc. Status**	**Health**	**Public Aid**	**Migrant**	**Hire Status**	**Wage Type**	**Pesticide**	**Pay Equip.**	**Water Cups**	**Toilet**
Gender	1.00	0.10	0.07	0.09	0.11	0.14	0.14	0.02	0.04	0.15	0.03	0.04	0.08
Foreign-born		1.00	0.72	0.76	0.15	0.07	0.27	0.19	0.16	0.20	0.10	0.02	0.02
English			1.00	0.70	0.14	0.02	0.34	0.19	0.17	0.24	0.10	0.03	0.00
Doc. status				1.00	0.23	0.04	0.32	0.18	0.17	0.23	0.09	0.00	0.01
Health					1.00	0.05	0.11	0.05	0.06	0.07	0.02	0.00	0.01
Public aid						1.00	0.15	0.01	0.01	0.00	0.04	0.02	0.00
Migrant							1.00	0.09	0.16	0.16	0.08	0.06	0.04
Hire status								1.00	0.25	0.16	0.16	0.07	0.00
Wage type									1.00	0.14	0.26	0.03	0.01
Pesticide										1.00	0.07	0.04	0.06
Pay equipment											1.00	0.07	0.05
Water/ cups												1.00	0.34
Toilet													1.00

Period I													
	Gender	Foreign-Born	English	Doc. Status	Health	Public Aid	Migrant	Hire Status	Wage Type	Pesticide	Pay Equip.	Water Cups	Toilet
Age group													

[a] Spearman's correlations presented as absolute values.

[b] Variable not significant ($p \leq 0.20$) with injury but was added to matrix because it was tested as a covariate of interest.

TABLE A2

Spearman's correlation coefficient[a] matrices for independent variables with significant adjusted odds ratios ($p \leq 0.20$) with injury by time period.

Period II							
	Gender	Doc. Status	Dwelling US	Pesticide	Water Cups	Age Group[b]	Foreign-Born[b]
Gender	1.00	0.01	0.05	0.16	0.04	0.01	0.02
Doc. Status		1.00	0.42	0.19	0.02	0.35	0.73
Dwelling US			1.00	0.13	0.03	0.37	0.24
Pesticide				1.00	0.13	0.09	0.17
Water/Cups					1.00	0.03	0.01
Age Group						1.00	0.07
Foreign-Born							1.00

Period III									
	Foreign-Born	English	Youth <18 HH	Health	Dwelling US	Pesticide	Water Cups	Hand Wash	Gender[b]
Foreign-born	1.00	0.68	0.16	0.06	0.12	0.11	0.04	0.01	0.03
English		1.00	0.06	0.07	0.17	0.15	0.04	0.00	0.06
Youth <18 HH			1.00	0.03	0.10	0.02	0.01	0.03	0.22
Health				1.00	0.12	0.06	0.04	0.01	0.06
Dwelling US					1.00	0.09	0.03	0.04	0.05
Pesticide						1.00	0.07	0.04	0.21
Water/cups							1.00	0.31	0.03
Hand wash								1.00	0.01
Gender									1.00

[a] Spearman's correlations presented as absolute values.

[b] Variables not significant ($p < 0.20$) with injury but were added to matrices because they were tested as a covariate of interest.

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TABLE 1

Demographic, economic, and employment characteristics among hired crop workers in the United States: National Agricultural Workers Survey (NAWS), period I (2002–2004), period II (2008–2010), and period III (2014–2015).

	Data collection years								
	Period I: 2002–2004 9,992 Interviews			Period II: 2008–2010 5,873 Interviews			Period III: 2014–2015 5,657 Interviews		
Characteristics	Weighted percent[a]	95% CI[b]		Weighted percent	95% CI		Weighted percent	95% CI	
Demographic characteristics									
Sex * Age (years)									
Female	23.5	20.7	26.3	24.3	21.2	27.4	30.2	25.3	35.2
<25	6.0	4.9	7.2	5.0	3.8	6.2	4.9	3.4	6.5
25–34	7.0	5.8	8.2	5.9	4.8	7.0	8.2	5.9	10.4
35–44	5.6	4.5	6.7	6.2	4.5	7.9	8.4	6.8	10.0
45+	4.9	4.0	5.7	7.2	5.3	9.0	8.7	6.0	11.5
Male	76.5	73.4	79.3	75.7	72.6	78.8	69.8	64.8	74.7
<25	23.4	21.5	25.4	18.0	15.3	20.7	14.4	11.8	17.0
25–34	20.3	18.6	22.0	18.8	16.4	21.3	17.8	15.9	19.8
35–44	17.4	15.9	18.9	16.8	15.1	18.6	14.7	12.6	16.7
45+	15.3	13.9	16.7	22.1	19.4	24.8	22.8	19.8	25.8
Detailed age group (years)									
14–17	3.5	2.7	4.3	2.3	1.2	3.3	2.3	1.3	3.3
18–24	26.0	23.9	28.0	20.7	17.7	23.8	17.1	14.3	19.8
25–34	27.3	25.4	29.2	24.7	22.0	27.4	26.0	23.6	28.3
35–44	23.0	21.5	24.5	23.0	20.3	25.7	23.1	21.0	25.2
45–54	12.7	11.6	13.9	18.7	16.3	21.1	18.0	15.7	20.3
55+	7.5	6.5	8.4	10.6	8.9	12.3	13.5	11.4	15.7
Foreign-born									
Yes	75.6	72.5	78.6	74.5	69.9	79.0	73.7	69.7	77.7
Mexico	72.0	68.7	75.3	69.1	64.4	73.8	68.4	64.5	72.4
No	24.4	21.4	27.4	25.5	21.0	30.1	26.3	22.3	30.3
Hispanic									

Characteristics	Data collection years								
	Period I: 2002–2004 9,992 Interviews			Period II: 2008–2010 5,873 Interviews			Period III: 2014–2015 5,657 Interviews		
	Weighted percent[a]	95% CI[b]		Weighted percent	95% CI		Weighted percent	95% CI	
Yes	82.5	79.7	85.2	79.3	75.4	83.3	81.8	77.9	85.6
No	17.5	14.8	20.3	20.7	16.7	24.6	18.2	14.4	22.1
English-speaking ability									
Not at all	40.1	37.3	43.0	32.7	28.6	36.8	28.5	24.6	32.4
A little, Somewhat	33.9	31.9	36.0	38.3	35.0	41.6	39.8	36.8	42.8
Well	25.9	23.1	28.7	29.0	24.2	33.7	31.7	27.5	36.0
Documentation status									
Undocumented	49.1	45.9	52.4	50.0	44.8	55.3	48.4	44.4	52.5
Documented	23.9	21.4	26.4	20.2	17.4	23.0	21.0	17.9	24.1
Citizen	27.0	24.0	30.0	29.8	25.3	34.3	30.6	26.2	34.9
Marital status * Spouse farmworker									
Not married	41.5	39.5	43.5	39.3	35.7	43.0	42.1	38.5	45.7
Married	58.5	56.5	60.5	60.7	57.0	64.3	57.9	54.3	61.5
Spouse is a farm worker	17.0	14.8	19.2	19.0	14.0	24.1	18.7	15.8	21.6
Spouse is NOT a farm worker	41.5	39.2	43.8	41.6	37.6	45.6	39.2	35.8	42.6
Youth <18 years old living in household									
Yes	34.7	32.2	37.2	40.1	36.0	44.3	44.3	40.9	47.6
No	65.3	62.8	67.8	59.9	55.7	64.0	55.7	52.4	59.1
Health condition									
No	82.7	80.9	84.5	81.1	78.7	83.5	77.0	73.9	80.2
Yes	17.3	15.5	19.1	18.9	16.5	21.3	23.0	19.8	26.1
Economic characteristics									
Family income below poverty level									
Yes	22.0	20.0	24.1	20.1	17.5	22.7	31.8	27.6	35.9
No	55.1	52.2	58.1	66.1	62.7	69.4	67.6	63.5	71.7
Unknown/missing	22.8	20.6	25.1	13.9	11.5	16.3	0.6	0.2	1.1
Receive any type of public aid									
Yes	25.5	23.2	27.8	36.1	31.8	40.4	51.9	48.1	55.7

Characteristics	Data collection years								
	Period I: 2002–2004 9,992 Interviews			Period II: 2008–2010 5,873 Interviews			Period III: 2014–2015 5,657 Interviews		
	Weighted percent[a]	95% CI[b]		Weighted percent	95% CI		Weighted percent	95% CI	
No	74.5	72.2	76.8	63.9	59.6	68.2	48.1	44.3	51.9
Own dwelling in U.S.									
Yes	21.8	19.7	23.9	26.5	22.5	30.5	21.2	18.3	24.0
No	78.2	76.1	80.3	73.5	69.5	77.5	78.8	76.0	81.7
Employment characteristics									
Years of farm work in U.S.									
< 24 months	24.0	21.7	26.2	15.9	12.7	19.2	13.6	11.2	16.1
2-5 years	19.5	18.0	21.1	15.8	13.8	17.9	15.1	12.5	17.8
6-10 years	15.3	13.9	16.7	20.1	17.3	23.0	18.7	15.9	21.5
11-20 years	21.6	20.1	23.1	21.0	18.5	23.5	24.9	22.5	27.3
21+ years	19.5	17.7	21.4	27.3	24.0	30.3	27.6	24.5	30.8
Migrant type									
Migrant	35.8	32.3	39.4	26.4	21.9	30.9	19.1	15.5	22.7
Nonmigrant/settled	64.2	60.6	67.7	73.6	69.1	78.1	80.9	77.3	84.5
Type of hire									
Contract laborer	18.7	15.2	22.1	13.4	9.2	17.6	17.8	12.6	23.0
Grower direct hire/other	81.3	77.9	84.8	86.6	82.4	90.8	82.2	77.0	87.4
Wage type									
Piece rate	13.5	10.8	16.1	10.9	7.1	14.8	10.1	5.9	14.2
Hourly/salary/combination/other	86.5	83.9	89.2	89.1	85.2	92.9	89.9	85.8	94.1
Pesticides- loaded, mixed, or applied									
No	88.6	87.0	90.0	84.0	81.4	86.5	82.6	79.5	85.6
Yes	11.4	9.9	13.0	16.0	13.5	18.6	17.4	14.2	20.5
Employer pays for all equipment									
Yes	88.3	85.7	90.9	88.8	82.8	94.8	91.4	88.7	94.2
No	11.7	9.1	14.3	11.2	5.2	17.2	8.6	5.8	11.3
Worker's compensation coverage									
Yes	52.1	48.5	55.7	65.8	60.9	70.7	55.6	50.8	60.3

Characteristics	Data collection years								
	Period I: 2002–2004 9,992 Interviews			Period II: 2008–2010 5,873 Interviews			Period III: 2014–2015 5,657 Interviews		
	Weighted percent[a]	95% CI[b]		Weighted percent	95% CI		Weighted percent	95% CI	
No	17.8	15.3	20.3	15.3	11.8	18.9	19.2	15.0	23.4
Don't know/missing	30.1	27.4	32.8	18.9	15.2	22.6	25.2	21.4	29.1
Employer provides health insurance									
Yes	71.0	67.9	74.2	74.8	71.1	78.6	72.7	68.6	76.8
No	10.0	7.8	12.2	10.0	7.4	12.6	11.9	8.3	15.4
Don't know/missing	19.0	16.7	21.1	15.2	11.5	18.7	15.5	12.9	18.0
Employer provides clean drinking water and disposable cups every day									
Yes	81.1	77.8	84.4	92.2	90.1	94.2	86.3	83.1	89.4
No	18.9	15.6	22.2	7.8	5.8	9.9	13.7	10.6	16.9
Employer provides a toilet									
Yes	95.4	94.0	96.7	97.8	97.0	98.6	97.2	96.1	98.3
No	4.6	3.3	6.0	2.2	1.4	3.0	2.8	1.7	3.9
Employer provides handwash water									
Yes	94.7	93.3	96.1	98.1	97.3	99.0	97.2	96.2	98.2
No	5.3	3.9	6.7	1.9	1.0	2.7	2.8	1.8	3.8

[a] Weighted percent; National level multi-year weight to account for increases in sampling variance caused by pooling data across multiple years.

[b] CI: confidence interval.

TABLE 2

Bivariate adjusted odds ratios[a] for injury: National Agricultural Workers Survey (NAWS).

Period I (2002–2004), period II (2008–2010), and period III (201–2015)									
	Data collection years								
	Period I: 2002–2004 241 Injury cases			Period II: 2008–2010 141 Injury cases			Period III: 2014–2015 124 Injury cases		
Item	Injury Percent	Adj OR[a]	Wald *p* value[b] Wald 95% CI	Injury Percent	Adj OR[a]	Wald *p* value[b] Wald 95% CI	Injury Percent	Adj OR[a]	Wald *p* value[b] Wald 95% CI
Sex									
Female	14.7	1.0	*p* = 0.0995	15.4	1.0	*p* = 0.1401	20.2	1.0	*p* = 0.3844
Male	85.3	1.5	0.9–2.4	84.6	1.6	0.9–3.0	79.8	1.3	0.7–2.5
Age group (years)									
<25	30.5	1.0	*p* = 0.5101	10.3	1.0	*p* = 0.2619	21.8	–	–
25-34	26.5	0.8	0.4–1.3	26.3	1.8	0.7–4.3	25.4	–	–
35-44	24.0	0.8	0.5–1.3	29.0	2.1	1.0–4.4	16.8	–	–
45+	19.0	0.7	0.4–1.1	34.4	1.9	0.9–4.0	36.0	–	–
Foreign-born									
Yes	65.9	1.0	*p* = 0.0194	67.8	1.0	*p* = 0.2259	69.1	1.0	*p* = 0.1619
No	34.1	1.7	1.1–2.5	32.2	1.5	0.8–2.9	30.9	1.6	0.8–3.1
Hispanic									
Yes	78.8	1.0	*p* = 0.4988	74.7	–	–	81.3	1.0	*p* = 0.6438
No	21.2	1.2	0.8–1.8	25.3	–	–	18.7	1.2	0.6–2.4
English-speaking ability									
Not at all	17.4	1.0	*p* < 0.0001	23.9	1.0	*p* = 0.4542	16.6	1.0	*p* = 0.0179
A little (or) Somewhat	50.8	2.8	1.7–4.6	42.1	1.4	0.7–2.8	43.8	1.7	1.0–2.9
Well	31.8	2.7	1.6–4.4	34.0	1.7	0.7–4.0	39.6	2.6	1.3–5.1
Documentation status									
Undocumented	40.7	1.0	*p* = 0.0869	33.0	1.0	*p* = 0.0545	46.5	1.0	*p* = 0.3728
Documented	21.9	1.0	0.5–1.8	25.7	1.8	0.8–3.9	17.4	0.9	0.5–1.8
Citizen	37.4	1.6	1.0–2.5	41.3	2.1	1.1–3.8	36.1	1.5	0.8–3.0
Marital status									
Not married	41.1	1.0	*p* = 0.7159	35.6	1.0	*p* = 0.9600	32.0	1.0	*p* = 0.4670

Period I (2002–2004), period II (2008–2010), and period III (201–2015)

	Data collection years								
	Period I: 2002–2004 241 Injury cases			Period II: 2008–2010 141 Injury cases			Period III: 2014–2015 124 Injury cases		
Item	**Injury Percent**	**Adj OR[a]**	**Wald *p* value[b] Wald 95% CI**	**Injury Percent**	**Adj OR[a]**	**Wald *p* value[b] Wald 95% CI**	**Injury Percent**	**Adj OR[a]**	**Wald *p* value[b] Wald 95% CI**
Married	58.9	0.9	0.6–1.4	64.4	1.0	0.6–1.8	68.0	1.3	0.7–2.5
Youth <18 years old living in household									
Yes	37.4	1.0	$p = 0.8577$	37.1	1.0	$p = 0.4020$	32.8	1.0	$p = 0.0333$
No	62.6	1.0	0.7–1.6	62.9	1.3	0.7–2.1	67.2	1.8	1.1–3.0
Health condition									
No	75.9	1.0	$p = 0.1481$	75.2	1.0	$p = 0.3192$	45.6	1.0	$p < 0.0001$
Yes	24.1	1.5	0.9–2.4	24.8	1.3	0.7–2.4	54.4	4.4	2.6–7.5
Receive any type of public aid									
Yes	33.6	1.0	$p = 0.1359$	32.0	1.0	$p = 0.5517$	43.2	1.0	$p = 0.2521$
No	66.4	0.7	0.4–1.1	68.0	1.2	0.7–2.1	56.8	1.4	0.8–2.4
Own dwelling in U.S.									
Yes	26.7	1.0	$p = 0.7004$	45.3	1.0	$p = 0.0199$	15.2	1.0	$p = 0.1426$
No	73.3	0.9	0.5–1.5	54.7	0.5	0.3–0.9	84.8	1.7	0.8–3.6
Years of farm work in U.S.									
≤5 years	37.9	1.0	$p = 0.8576$	18.4	–	–	28.5	1.0	$p = 0.2636$
6–20 years	39.0	0.9	0.5–1.4	40.6	–	–	44.7	0.6	0.3–1.2
21+ years	23.1	0.9	0.6–.6	41.0	–	–	26.8	0.6	0.3–1.2
Migrant type									
Migrant	36.8	1.0	$p = 0.0458$	21.7	–	–	13.8	1.0	$p = 0.8954$
Nonmigrant/settled	63.2	0.6	0.4–1.0	78.3	–	–	86.2	1.0	0.5–2.0
Type of hire									
Contract laborer	7.6	1.0	$p = 0.0006$	11.7	–	–	18.9	–	–
Grower direct hire/other	92.4	2.7	1.5–4.6	88.3	–	–	81.1	–	–
Wage type									
Piece rate	7.3	1.0	$p = 0.0544$	11.0	–	–	5.8	–	–
Hourly/salary/combination/other	92.7	2.0	1.0–4.0	89.0	–	–	94.2	–	–
Pesticides- loaded, mixed, or applied									

Period I (2002–2004), period II (2008–2010), and period III (201–2015)									
	Data collection years								
	Period I: 2002–2004 241 Injury cases			Period II: 2008–2010 141 Injury cases			Period III: 2014–2015 124 Injury cases		
Item	Injury Percent	Adj OR[a]	Wald *p* value[b] Wald 95% CI	Injury Percent	Adj OR[a]	Wald *p* value[b] Wald 95% CI	Injury Percent	Adj OR[a]	Wald *p* value[b] Wald 95% CI
No	78.4	1.0	*p* = 0.0791	65.3	1.0	*p* = 0.0168	69.8	1.0	p = 0.1228
Yes	21.6	1.5	1.0–2.3	34.7	2.1	1.1–4.0	30.2	1.7	0.9–3.3
Employer pays for all equipment									
Yes	84.7	1.0	*p* = 0.1693	93.3	1.0	*p* = 0.2787	86.7	1.0	*p* = 0.2223
No	15.3	1.4	0.9–2.3	6.7	0.7	0.3–1.4	13.3	1.5	0.8–2.8
Employer provides clean drinking water and disposable cups every day									
Yes	64.4	1.0	*p* = 0.0002	84.5	1.0	*p* = 0.0071	73.2	1.0	*p* = 0.0072
No	35.6	2.5	1.6–4.0	15.5	2.1	1.2–3.6	26.8	2.5	1.3–4.8
Employer provides a toilet									
Yes	93.7	1.0	*p* = 0.1682	97.5	–	–	91.1	–	–
No	6.3	1.6	0.8–2.9	2.5	–	–	8.9	–	–
Employer provides handwash water									
Yes	94.5	1.0	*p* = 0.4528	99.4	–	–	94.6	1.0	*p* = 0.0820
No	5.5	1.3	0.7–2.3	0.6	–	–	5.4	2.0	0.9–4.2

Note: – Estimates are nonreportable due to a coefficient of variation >36%.

[a]Adjusted odds ratios where injury = 1 divided by weeks of farm work the previous year to incorporate an occupational exposure adjustment.

[b]*p* Value: Wald's chi-square test.

TABLE 3A

Multivariable logistic regression models ($p < 0.05$) for occupational injury to hired crop workers, NAWS[a] U.S. during period I (2002–2004), period II (2008–2010), and period III (2014–2015).

Variable (p Value[b])	Adjusted Odds ratio[c]	Wald 95% CI	
Period I (2002–2004)			
English-speaking ability ($p = 0.0003$)			
Not at all	1.0		
A little, Somewhat	3.0	1.8	5.1
Well	1.6	0.7	3.4
Type of hire ($p = 0.0048$)			
Contract laborer	1.0		
Grower direct hire/other	2.2	1.3	3.8
Employer provides clean drinking water and disposable cups every day ($p = 0.0017$)			
Yes	1.0		
No	2.1	1.3	3.3
Migrant type ($p = 0.0015$)			
Migrant	1.0		
Nonmigrant/settled	0.5	0.3	0.7
Foreign-born ($p = 0.0111$)			
Yes	1.0		
No	2.5	1.2	4.9
Age group (years) ($p = 0.1445$)[d]			
<25	1.0		
25–34	0.8	0.4	1.4
35–44	0.7	0.4	1.2
45+	0.6	0.3	0.9
Period II (2008–2010)			
Employer provides clean drinking water and disposable cups every day ($p = 0.0129$)			
Yes	1.0		
No	2.0	1.2	3.4
Own dwelling in U.S. ($p = 0.0107$)			
Yes	1.0		
No	0.5	0.3	0.9
Sex ($p = 0.1441$)[e]			
Female	1.0		
Male	1.6	0.9	3.0
Foreign-born ($p = 0.4879$)[f]			
Yes	1.0		
No	1.2	0.7	2.2
Period III (2014–2015)			
Health condition ($p < 0.0001$)			

Variable (p Value[b])	Adjusted Odds ratio[c]	Wald 95% CI	
No	1.0		
Yes	4.5	2.7	7.5
Employer provides clean drinking water and disposable cups every day (p = 0.0106)			
Yes	1.0		
No	2.4	1.2	4.7
Own dwelling in U.S. (p = 0.0145)			
Yes	1.0		
No	2.4	1.2	4.9
Foreign-born (p = 0.1300)[g]			
Yes	1.0		
No	1.6	0.9	3.1

[a] NAWS: National Agricultural Workers Survey.

[b] p Value: Wald's chi-square test.

[c] Adjusted odds ratio (OR_{ADJ}) where injury = 1 divided by weeks of farm work to incorporate an occupational exposure adjustment.

[d] Covariate age increased the OR_{ADJ} of foreign-born by 12% and decreased the OR_{ADJ} of English-speaking ability “well” by 5% (period I).

[e] Covariate sex decreased the OR_{ADJ} of “clean drinking water and disposable cups every day” by 5% (period II).

[f] Covariate foreign-born decreased the OR_{ADJ} of “own dwelling in U.S” by 6% (period II).

[g] Covariate foreign-born increased the OR_{ADJ} of “own dwelling in U.S.” by 10% (period III).

TABLE 3B

Multivariable logistic regression models ($p < 0.10$) for occupational injury to hired crop workers, NAWS[a] U.S. during period I (2002–2004), period II (2008–2010), and period III (2014–2015).

Variable (p Value[b])	Adjusted Odds ratio[c]	Wald 95% CI	
Period I (2002–2004)			
English-speaking ability ($p = 0.0004$)			
Not at all	1.0		
A little, Somewhat	2.9	1.7	4.8
Well	1.6	0.8	3.2
Type of hire ($p = 0.0044$)			
Contract laborer	1.0		
Grower direct hire/other	2.2	1.3	3.7
Employer provides clean drinking water and disposable cups every day ($p = 0.0012$)			
Yes	1.0		
No	2.1	1.3	3.2
Migrant type ($p = 0.0008$)			
Migrant	1.0		
Nonmigrant/settled	0.5	0.3	0.7
Foreign-born ($p = 0.0064$)			
Yes	1.0		
No	2.5	1.3	4.7
Receive any type of public aid ($p = 0.0766$)			
Yes	1.0		
No	0.7	0.4	1.0
Age group (years) ($p = 0.1398$)[d]			
<25	1.0		
25–34	0.7	0.4	1.3
35–44	0.7	0.4	1.2
45+	0.6	0.3	0.9
Period II (2008–2010)			
Employer provides clean drinking water and disposable cups every day ($p = 0.0454$)			
Yes	1.0		
No	1.8	1.0	3.1
Own dwelling in U.S. ($p = 0.0558$)			
Yes	1.0		
No	0.5	0.3	1.0
Pesticides- loaded, mixed, or applied ($p = 0.1757$)[e]			
No	1.0		
Yes	1.6	0.8	3.4
Sex ($p = 0.2874$)[f]			
Female	1.0		

Variable (*p* Value[b])	Adjusted Odds ratio[c]	Wald 95% CI	
Male	1.4	0.7	2.8
Period III (2014–2015)			
Health condition ($p < 0.0001$)			
No	1.0		
Yes	4.4	2.7	7.3
Employer provides clean drinking water and disposable cups every day ($p = 0.0092$)			
Yes	1.0		
No	2.4	1.3	4.8
Own dwelling in U.S. ($p = 0.0097$)			
Yes	1.0		
No	2.5	1.3	5.1
English-speaking ability ($p = 0.0708$)			
Not at all	1.0		
A little, Somewhat	1.6	0.9	2.9
Well	3.0	1.1	8.2
Foreign-born ($p = 0.7570$)[g]			
Yes	1.0		
No	0.8	0.3	2.5

[a] NAWS: National Agricultural Workers Survey.

[b] *p*-value: Wald's chi-square test.

[c] Adjusted odds ratio (OR_{ADJ}) where injury = 1 divided by weeks of farm work to incorporate an occupational exposure adjustment.

[d] Covariate age increased the OR_{ADJ} of foreign-born by 11% and decreased the OR_{ADJ} of English-speaking ability "a little or somewhat" by 5% (period I).

[e] "Loaded, mixed, or applied pesticides" *p* value (i.e., 0.1140) was approaching significance until sex was added as a covariate (period II).

[f] Covariate sex decreased the OR_{ADJ} of the "loaded, mixed, or applied pesticides" by 7% (period II).

[g] Covariate foreign-born increased the OR_{ADJ} of speaking English "well" by 15% (period III).