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Occupational Injury Among California Migrant Hispanic Farm Workers: Fighting the Invisible Epidemic

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INTRODUCTION

Agriculture is one of humanity's oldest and worthiest endeavors. For millennia, humans have wrested a livelihood from the soil. In addition to providing a dependable food supply, agriculture is thought to have sown the seeds for modern civilization by promoting a shift from hunter-gatherer cultures to settled communities. A critical mass of people was thereby freed to look beyond the next meal and to ponder larger questions, leading to the development of intellectual potential and the flowering of art and science. All that we are as a civilization we owe to several inches of moist topsoil and to those who labor to grow our food.

Civilization's advances have not been won without cost, however. Agriculture is a dangerous industry, and the people who provide the day-to-day labor bear the greatest risk. Hired workers perform approximately 90% of the agricultural labor in California, and nearly two-thirds of that work is done by migrant and seasonal farm workers.[1] Migrant farm workers are predominantly Hispanic, although many other ethnic groups are also represented.[2]

Certain unique characteristics of this population contribute to our ignorance of their occupational health status and potentially increase their risk for work-related health problems and disability. Although farm workers are often "invisible" with respect to research, policy, and public perception, they are critical to the success of one of our largest industries and the state as a whole.

An important body of research exists documenting health problems among migrant farm workers,[3] yet relatively little attention has been paid specifically to occupational injury—an unfortunate shortcoming in view of the heavy burden (both economic and noneconomic) associated with it. The purpose of this paper is to describe what is known about occupational injury among California's migrant Hispanic farm workers and to consider a framework for reducing its toll among farm workers, the agricultural community, and California's society at large.

OVERVIEW

Injury is defined as physical damage occurring to an individual due to exposure to energy at levels outside the normal tolerance bands for human tissue.[4] This includes trauma (for which the agent is kinetic or mechanical energy), thermal burns (for which the excessive energy is in the form of heat), and disruption of normal metabolic energy pathways (for example, by anoxia or acute chemical exposures). Occupational health specialists typically limit consideration to injuries of sufficient severity to require medical care or that result in lost work time.

Historically an important risk in American industry, occupational injury has been decreasing over the past half-century. For example, occupational injury mortality for all industries combined decreased from 37 per 100,000 workers in 1933 to 8 per 100,000 workers in 1993.[5] Much of this decrease may be attributed to advances in the design of industrial machinery and workplaces. An increased emphasis on regulation heralded by the passage of the Occupational Safety and Health Act in 1970 has also played an important role.

These improvements notwithstanding, injury remains one of the most important occupational health problems among agricultural populations.[3,6] The National Safety Council estimated approximately 1,100 occupational fatalities in agriculture for 1993, or 35 per 100,000 workers, the highest occupational-injury mortality rate of all industry groups.[5] The Council also estimated approximately 130,000 nonfatal occupational injuries in agriculture for 1993.

Statistics from other sources confirm this high toll. The National Census of Fatal Occupational Injuries for 1996 reported 660 occupational injury deaths for agriculture (exclusive of forestry and fishing), yielding a rate of 19.3 per 100,000 persons per year versus 4.8 per 100,000 persons per year in the private sector.[7] The U.S. Department of Commerce, in its Census of Agriculture for 1992, noted 673 farm-related deaths and 64,813 nonfatal injuries.[8] (These figures do not include workers employed through farm-labor contractors.) Although rates and absolute numbers of occupational deaths and injuries vary by source, higher morbidity and mortality in agriculture compared with general private industry is a consistent finding.

California occupational health statistics paint a similar picture. The Workers' Compensation Insurance Rating Bureau documented 34,214 cases (including

47 deaths) among agricultural-industry class codes in 1994, leading to a combined medical and indemnity loss of more than $176 million (unpublished data). California Workers' Compensation system data for 1991 showed more than 35,000 occupational injuries reported in agriculture, yielding an incidence rate of 11.6 reported injuries per 100 full-time-equivalent employees per year.[9] More than half of these injuries were associated with lost or restricted work time, totaling over 391,000 days. High as they are, these figures may underestimate the true injury rate because they exclude agricultural operations with fewer than 11 employees. Small operations may be the most dangerous because of their limited resources for safety and occupational health measures.

Epidemiologic Framework for Examining Occupational Injury Among Migrant Hispanic Farm Workers

Although the figures cited above show convincingly that agriculture is a hazardous industry, they represent information combined from numerous distinct populations, including farmers and farm workers, men and women, and all ethnic and demographic groups. Thus, these data do not allow us to identify groups at especially high risk, limiting our understanding and development of prevention strategies. To gain further insight, we must turn to the science of epidemiology.

Epidemiology (from the Greek—*epi:* upon, *demos:* the people) entails examining patterns of disease in populations. In particular, epidemiology identifies exposures or potential risk factors and investigates whether these are associated with increased health risk. The most timely example of our age involves lung cancer and smoking. Basic health statistics show the number of lung cancer deaths, yet little can be drawn from this alone. Epidemiology provides the fundamental insight to the pattern of these deaths in our population: they are nearly uniquely concentrated among people who smoke.

Epidemiology has formidable strengths. First, it is reality-based. Although one can speculate why a given exposure or risk factor should (or should not) be associated with increased health risk, epidemiology provides a real-world answer. The most carefully forged chain of argument will be sundered if real data do not cooperate with our assumptions. Second, we do not need to understand underlying mechanisms before we act on epidemiologic findings. For example, the observation that smoking is strongly associated with lung cancer drives our prevention efforts. We do not need to name the guilty chemical in tobacco smoke or show the pathological chain of events leading to cancer before we advise people not to smoke.

Along with these strengths, epidemiology has its limitations. First, epidemiologic conclusions depend fundamentally on the accuracy of underlying data. Misinformation obscures true underlying patterns, and we may fail to see important associations. Second, epidemiology allows us to identify patterns of disease in

a population, but determining whether these patterns represent cause and effect can be difficult. For example, women have lower injury rates than men. This does not necessarily mean, however, that women have a fundamental, inborn advantage that lowers injury risk. Numerous other factors could contribute to this pattern, such as fewer work hours, safer jobs, or a lower likelihood of reporting injuries. Overlooking such important factors can lead to invalid conclusions.

The basic model of injury epidemiology was pioneered by Gibson[10] and refined by Haddon and others.[11] This model defines a basic mechanism for injury: injury results when the *agent* (energy), carried by a *vector* (e.g., machinery), interacts with a *host* in an *environment.* The model provides a matrix (the Haddon Matrix) of potential interventions and guides development of preventive approaches (Table 1).

TABLE 1

Injury Risk and Prevention Among Migrant Hispanic Farm Workers*

Agent (Energy: kinetic, mechanical, thermal, electrical, chemical) and Vector	Host Population (Migrant Hispanic farm workers)	Environment (Physical and sociopolitical)
	Factors Contributing to Injury Risk	
Machinery and equipment Wide variety Potentially unsafe design Variable age and condition	Linguistic barriers Mistrust of officialdom and medical system	Dispersed and variable physical environment Wide variety of tasks and hazards
Farm animals Heights Chemicals Electricity	Economic barriers to care Lack of health insurance Inability to lose work time Transportation difficulties Fear of jeopardizing employment and earnings	Brief job tenure Variable safety training Time pressure Difficulty in regulating 77,000 widely dispersed California farms Responsibility for health and safety devolved to farm-labor contractors
	General Preventive Approaches	
Avoid or reduce use of high energy Improve ergonomic design Develop engineering controls to prevent contact of human beings with energy	Educate and train workers	Prevent contact between host and energy source (e.g., improved engineering, protective guards, protective clothing) Improve and enforce regulatory requirements

*Based on Haddon model.[11]

Agent and vector. The causal agent for injury is energy, which is carried by a vector. Energy is an important input for productivity in agriculture. Energy and its vectors are used in a wide variety of forms, making control challenging. For example, farm machinery is a common vector for energy in agriculture. Agricultural machinery may be poorly designed, poorly maintained, or improperly operated, bringing human beings into contact with high energy levels and leading to injury. Amputation injuries from contact with unshielded power take-offs are a classic example. Preventive approaches focus on reducing energy requirements and protecting human beings from contact with the energy carried by the vector. Shielding a power take-off to preclude human contact is effective prevention—although the measure may be defeated if the shield is removed because it hampers maintenance.

Host population. Underlying the remarkable success of California's $22 billion agricultural industry is the essential contribution of farm laborers. Yet for all their importance, California's migrant and seasonal farm worker population is relatively invisible. Even the most basic demographic information is difficult to find and subject to wide variation among sources.

California hosts between 600,000 and 1.1 million migrant and seasonal farm workers and their dependents;[2] approximately 90% of this group are Hispanic.[12] The U.S. Department of Labor's National Agricultural Workers Survey (NAWS) is a helpful source of demographic data for farm workers who have been employed in the preceding year (Table 2).[13] The population is made up predominantly of young males and is overwhelmingly Hispanic and foreign-born. Mexico is the most common place of birth. Educational level is sixth grade or below for half the population. Spanish is the primary language; slightly more than one in 10 persons has verbal fluency in English.

Occupational and socioeconomic indicators show an economically stressed population. California farm laborers work an average of 35 weeks per year, yielding a median total family income of $10,000 to $12,499. Nearly half exist below the poverty line as defined by the U.S. Bureau of the Census. In spite of these extreme circumstances, farm workers infrequently utilize social services: approximately 13% of California's seasonal agricultural workers reported using social support programs (primarily food stamps).[13] More recent NAWS data from 1994–95 indicate that the national farm-worker population has become increasingly male, more likely to be engaged in their first year of agricultural work, more likely to be unauthorized for work in the United States, and more likely to live in poverty.[14]

Because of the seasonal nature of their jobs, migrant farm workers have brief tenure of employment. Whereas employees of most other industries are hired, trained, and retained in longer-term positions, migrant agricultural laborers work seasonally and for several employers. This makes employee training difficult and

produces a workforce that may be unfamiliar with the local work environment, its hazards, and available occupational health resources.

Their brief window of employment also makes migrant farm workers reluctant to jeopardize their income by taking time off due to injury. Occupational injuries that in other populations would lead to time off work or medical care (making them "visible" to occupational health specialists) may not come to official attention. The burden of injury is carried by the individual farm worker and is not reflected in the occupational health statistics that serve as the basis for industry and government policy. Underreporting for occupational deaths in agriculture is significant, with true rates estimated at 20% to 100% above reported rates.[15,16] Underreporting is probably even greater for nonfatal injuries.

Environment. California agriculture is characterized by tremendous diversity and productivity. The state's 77,000 farms grow more than 250 crops and lead

TABLE 2

Demographic and Socioeconomic Characteristics of California Farm Workers (1990–91)

Demographics	
Age	Median 32 years
Sex	74% male (81% of unauthorized workers are male)
Place of birth	92% foreign-born (82% from Mexico)
Education	Median sixth-grade education
Accompanied by family	60%
Spanish as primary language	88%
English-language fluency	11% speak, 14% read
Employment characteristics	
Weeks of work per year	Average 33 in agriculture, 2 in nonfarm work
Hired through farm-labor contractor	31%
Payment scheme	69% hourly, 22% piece-rate, 9% mixed
Average wage	$5.41/hr. ($4.45/hr. when employed by farm-labor contractor)
Work authorization	9% unauthorized
Economic status	
Median family income	$10,000 to $12,499
Poverty rate (based on U.S. Census definition)	48% (poverty increases with family size)
Social services utilization	13% (primarily food stamps)

Source: Based on data from U.S. Department of Labor, National Agricultural Workers Survey.[13]

the United States in aggregate market value of agricultural products sold.[17] Eight of the 10 top-producing agricultural counties nationally are in California.[17] The state's lead is especially strong for commodities requiring large inputs of manual labor, such as vegetables, tomatoes, grapes, tree fruit, ornamental crops, and strawberries.[17]

California's farm environment poses special problems for injury control because it is nearly unique in its broad and changing array of occupational hazards. Unlike other industries with defined production lines and processes that can be engineered to minimize risk, farms have production tasks spread across a wide geographic area under changing or dangerous weather, light, and other environmental conditions. Risk is increased if machinery is poorly designed, inadequately maintained, or improperly operated.

These problems are compounded by the fact that U.S. agriculture has a history of regulatory exemption, often enjoying a de facto exception to Federal regulation under the Occupational Safety and Health Act. Riders attached to funding bills for the Federal Occupational Safety and Health Administration (OSHA) have specifically prohibited the expenditure of funds to enforce workplace regulations on farms with fewer than 11 employees (the "small-farm exemption").[18] However, state OSHA agencies are not required to grant such exemptions and may, as in California, regulate agriculture as they do other industries. Yet coverage for such a large and dispersed industry is challenging: of CalOSHA's approximately 300 compliance officers, none are dedicated to agriculture.[19]

The increasing use of farm-labor contractors as labor-market intermediaries represents an additional regulatory challenge for health and safety among migrant farm workers. Nearly one-third of California's seasonal farm workers in 1990–91 were hired through farm-labor contractors.[13] Responsibility for health and safety, including Workers' Compensation insurance, typically devolves to the contractor in these cases (however, recent regulatory developments make the employer jointly responsible).[20] Farm workers' high degree of dependence on the contractor for employment, transportation, housing, and other amenities may hinder willingness to report work-related conditions.

The Invisible Epidemic

The model described above provides a useful framework for injury epidemiology. Although a significant body of work has examined occupational injury among agricultural workers, most studies have focused on farmers or agricultural workers in general, primarily in midwestern or eastern states. Few health studies have addressed migrant Hispanic farm workers or occupational injury in this group. Nevertheless, injury studies in other agricultural populations provide a useful starting point. To the extent that patterns of injury in other agricultural groups are causally

based, they may apply as well to migrant Hispanic farm workers. Table 3 summarizes risk factors for injury in agriculture relevant to hired seasonal farm workers.

Risk factors. Nonmodifiable risk factors such as age and sex identify high-risk groups that may benefit from focused prevention efforts. Modifiable risk factors such as work activities or prescription drug use identify areas where a change in the risk factor (e.g., altered work activities, different medication) may reduce injury risk. Although modifiable risk factors represent opportunities for injury reduction, they do not guarantee it. Practical considerations may not allow changes in some risk factors that are, in theory, modifiable. For example, alternate job assignments may not be available, or a worker may require a medication that increases injury risk. In addition, modifying a risk factor may not reduce injury if the risk factor is merely a marker of risk and not causally connected with injury. For example, if smoking is found to be associated with elevated injury risk, smoking cessation, while desirable on many grounds, may not lead to fewer injuries. Lower injury risk among nonsmokers may be due to other personal characteristics (e.g., concern for one's health) that are more common among nonsmokers and that also reduce injury risk.

Existing studies demonstrate the importance of machinery, falls, and animals in agricultural injury.[21-30] Machinery is the most prevalent, accounting for up to 54% of injuries.[21] Falls and animal-related injuries each account for approximately 10% to 30%. According to California Workers' Compensation data for 1995, strains and sprains accounted for the largest fraction of lost-work-time injuries (Table 4).[31] The most frequently affected body parts were the trunk, back, and upper extremities.

California occupational mortality data showed a statistically significant increase in mortality among farm workers for machinery-related causes of death (a nearly 13-fold increased risk over other occupational groups) and animal-related causes of death (35-fold increased risk).[32] A study of Workers' Compensation claims in Washington State found that farm workers were at up to 2.5-fold increased risk for fatal injury, sprains and strains, fractures, dislocations, concussions, and amputations.[33]

Risks among children. While agricultural injury has long been recognized as an important occupational and public health problem among adults, its importance among children is gaining increased attention. Approximately 1.1 million persons younger than 14 years of age live on U.S. farms,[34] a figure that excludes persons working but not living on farms, such as migrant farm workers. The Centers for Disease Control and Prevention estimates up to 300 fatal and 27,000 nonfatal injuries annually to persons under 19 years of age on U.S. farms.[34,35] Approximately 14% to 24% of fatal farm injuries are sustained by children younger than 16 years.[36] In a study of farm injuries in 31 states, Hoskin et al. observed that children aged 5 to 14 were at increased risk.[23] Injury fatalities were also higher among children younger than 15.

TABLE 3

Risk Factors for Occupational Injury Among Agricultural Workers

Risk Factor	Population	Results	Selected References
Nonmodifiable risk factors			
Age	Farmers; all agricultural workers	Mixed; increased risk for younger and older workers in large studies of all agricultural workers.	23,64
Sex	Farmers; all agricultural workers	Higher risk for males (4.4% to 8.7% per year) than females (1.3% to 2.7% per year); difference in risk decreased after adjusting for hours worked.	23,64,65
History of previous injury	Farmers; all agricultural workers	Previous injury associated with three- to four-fold increased risk.	21,29
Modifiable risk factors: work environment			
Crop or work activities	Farmers; all agricultural workers	Increased risk on beef, dairy, and fruit farms.	23,65
Farm size	All agricultural workers	Nearly 25% increased risk for persons working on farms $\leq$ 49 acres.	23
Part-time vs. full-time farm employment	Farmers; all agricultural workers	Risk per hour worked higher among part-time workers; overall risk (not adjusting for hours worked) higher for full-time workers.	29,30,65-67
Participation in safety courses	All agricultural workers	No apparent effect in small Dane County, WI, study; limited data on efficacy of educational interventions.	18,21
Modifiable risk factors: personal			
Prescription drug use	Ontario beef and dairy farmers	Increased risk (2.8-fold) for persons regularly using stomach remedies or laxatives; increased risk (4.2-fold) in men 45 years of age or older using heart or circulatory medications.	68
Alcohol consumption	Rural Alabama farmers	Alcohol consumption of over 200 ml/day more than doubled risk.	29

TABLE 4

Characteristics of Nonfatal Occupational Lost-Work-Time Cases in California, 1995

	Agriculture *N* (%)	All Private Industry *N* (%)
Total cases	11,830 (100)	219,085 (100)
Nature of injury		
Sprains, strains	5,151 (43.5)	87,938 (40.1)
Bruises, contusions	909 (7.7)	15,556 (7.1)
Cuts and lacerations	730 (6.2)	17,064 (7.8)
Multiple injuries	545 (4.6)	7,917 (3.6)
Fractures	467 (3.9)	10,194 (4.7)
Body part affected		
Trunk (including back)	4,797 (40.6)	77,707 (35.5)
Back	3,592 (30.4)	55,063 (25.1)
Upper extremities	2,226 (18.8)	53,138 (24.3)
Eye	789 (6.7)	7,024 (3.2)
Source of injury or illness		
Worker motion or position	3,344 (28.3)	51,959 (23.7)
Containers	1,742 (14.7)	27,400 (12.5)
Floor, walkway, ground surfaces	1,453 (12.3)	29,966 (13.7)
Vehicles	1,082 (9.1)	16,311 (7.4)
Chemicals	144 (1.2)	3,915 (1.8)
Event or exposure		
Contact with objects or equipment	3,128 (26.4)	55,904 (25.5)
Overexertion	2,168 (18.3)	45,589 (20.8)
Falls	1,546 (13.1)	29,854 (13.6)
Transportation accidents	711 (6.0)	9,563 (4.0)

Source: Based on data from California Department of Industrial Relations, *Occupational Injuries and Illnesses Survey, California, 1995.*[31]

Several factors contribute to agricultural injury among children of migrant Hispanic farm workers. Economic need may force children to engage in labor,[35,37] especially when piece-rate pay schemes are used. Lack of adequate childcare facilities may lead parents to bring children to worksites, where supervision in a dangerous environment is inadequate.[35,37] Finally, the writ and enforcement of child labor law have historically been weaker in agriculture than in other industries.[35,38] It is legal for children as young as 12 to work full-time in agriculture during school breaks, while 14 is the minimum age in other industries. Dangerous machinery may not be operated by persons younger than 18 in general industry, but in agriculture the minimum age is 16.[35]

Epidemiologic data suggest that sex is an important factor in childhood agricultural injury risk. Rivara calculated national mortality rates among rural children of 21.5/100,000 per year for boys, compared with 3.8/100,000 for girls.[34] A similar pattern was observed in a study of death certificates in Wisconsin and Illinois.[39] A preponderance of injury to boys has also been reported in case series from Wisconsin[40,41] and Minnesota.[42] Age may be an important modifying factor: a study of 246 pediatric agricultural trauma patients in Wisconsin found approximately equal risks for boys and girls below the age of 6.[41] Above this age, boys were at three- to four-fold increased risk. Studies from Wisconsin have noted a bimodal age distribution, with peaks around the ages of 4 and 14 to 16.[40,41] Seasonal and temporal factors are also important in agricultural injuries among children, with injuries more likely during summer[40,41] and on weekends.[41]

Studies from Kentucky,[22] Wisconsin,[40,41] and Minnesota[42] indicate that the most important causes of childhood agricultural injury are machinery, animals, and falls. The relative importance of each varies with age and sex. The pediatric trauma study by Stueland et al. noted that boys between the ages of 6 and 18 were most likely to suffer machinery-related injuries, whereas girls were more likely to be injured by animals.[41] This probably reflects the different pattern of farm chores for boys and girls.

Agricultural injury studies of children, like those of adults, primarily reflect the experience on midwestern family farms rather than the conditions of migrant farm workers or ethnic minorities. Anecdotal evidence documents the involvement of migrant Hispanic farm-worker children in California agriculture,[43] yet epidemiologic studies characterizing its extent are few. A survey of 125 Southern California farm workers conducted by the California State University at Fresno Center for Agricultural Business indicated that approximately 20% of respondents had children working in agriculture.[44] Data that I and colleagues at UC Davis have collected from an ongoing injury study among migrant Hispanic farm workers living in state-supported migrant family housing centers indicate rare involvement of children under 16 in agricultural labor (data unpublished). However, this study

population comprises families with relatively stable employment characteristics. Child labor may be more common among other migrant groups.

Schenker and coworkers at the UC Agricultural Health and Safety Center at Davis studied death certificates of childhood fatalities occurring on California farms.[45] The study reviewed 40 unintentional traumatic deaths of children younger than 15 occurring on farms between 1980 and 1989. Deaths occurring in a farm residence or resulting from traffic accidents were excluded. Although the study did not focus on farm workers, it categorized subjects as Hispanic and non-Hispanic. Boys were at several-fold higher mortality risk than girls (1.2 versus 0.4 per 100,000 rural population), an effect observed in all age groups and for both Hispanics and non-Hispanics. The rate for Hispanic boys was 70% higher than for non-Hispanic boys (1.7 versus 1.0 per 100,000). Machinery accounted for 30% of deaths; the largest portion of these (67%) involved tractors.

Fighting the Invisible Epidemic

We have seen the socioeconomic and employment characteristics likely to contribute to injury risk and hinder epidemiologic study and prevention among migrant Hispanic farm workers. Although existing epidemiologic data are helpful in a broad sense—providing estimates of the overall annual risk for injury among agricultural workers, pointing to possible risk factors, and characterizing the spectrum of injuries—they are limited in several respects. First, they are not drawn from migrant Hispanic farm workers, and their applicability to this group is unclear. Second, the data lack precision and information on causality. For example, California Workers' Compensation data indicate that the most frequent event leading to injury is contact with objects or equipment (Table 4). Although important, this information lacks detail and may therefore be of limited utility in designing more focused studies and preventive measures.

I believe the future demands two basic approaches. The first is to draw back the veil of invisibility by focusing epidemiologic research specifically on migrant Hispanic farm workers. The second is to move forward with preventive measures in the context of current and developing knowledge. We have seen progress in both of these areas. As recognition of occupational health problems, including injury, among migrant Hispanic farm workers has grown, researchers are focusing increased attention on this group. Below are examples of recent or ongoing research.

The Targeted Industry Partnership Program. Epidemiology has traditionally focused on individual subjects as the fundamental unit within a group. This makes intrinsic sense because it is the individual who suffers injury and displays characteristic risk factors, such as age, sex, or smoking. Results of epidemiologic studies often lead to recommendations for changes in modifiable risk factors at the individual level—e.g., reduction in smoking or adoption of safety training.

Regulatory and policy groups within industry and government, however, frequently work at the organizational rather than the individual level. In such situations, it may be helpful to consider risk factors and patterns of "disease" (in this case, high injury rates) at the level of the agricultural employer rather than the individual worker. The underlying assumption is that organizational changes can reduce individual injury risk.

Dr. Don Villarejo, of the California Institute for Rural Studies, and I used this approach in a review of agricultural health-and-safety and labor-law violations from data collected by the state Labor Commission's Targeted Industry Partnership Program (TIPP).[46] This program was instituted in 1992 to partner state and Federal agencies with regulatory responsibility in agriculture, a targeted industry because of high rates of labor and occupational health violations. Many agricultural employers supported TIPP because it focused on producers who gain an unfair competitive advantage by failing to meet occupational health and labor requirements.

We examined 601 TIPP reports comprising more than 1,500 violations for 1993 and 1994. Using a large database of California farms maintained by the California Institute for Rural Studies, we identified farms with TIPP reports and compared them to farms without such reports, producing a profile of high-risk farms. Based on this comparison, farms with violations had more acreage and were more likely to be part of a firm operating farms in several counties. TIPP citations were more likely for fruit and nut operations and operations with less than $100,000 in annual receipts. Farm-labor contractors were at greater risk than farmers for TIPP citations.

These characteristics identified establishments with a higher likelihood of violations. However, the most important limitation of these data is that they were not collected by formal representative sampling and therefore may not truly represent the underlying pattern of violations. For example, the higher risk noted among fruit and nut operations may be due, in part, to greater regulatory attention paid to them. Nevertheless, TIPP remains a novel and creative way to improve efficiency of regulatory efforts. Representative sampling of agricultural employers would provide a more valid picture of occupational health and safety conditions within the industry, facilitating the most rational use of regulatory resources.

UC Davis Farm Worker Injury Study. Our group is now conducting an epidemiologic study of injury risk among California migrant Hispanic farm workers living in local migrant family housing centers. The study is supported by the National Institute for Occupational Safety and Health and is the first of its kind to follow a group of farm workers through a harvest season to document their injury experience and to examine patterns of injury risk in relation to exposures and risk factors such as age, sex, and work tasks. The advantage of this longitudinal approach is that injuries are reported when they are fresh in the subject's mind. They

can then be examined in detail in association with the subject's work and other potential risk factors.

The study focuses on several possible factors relating to injury risk. These include the following:

1. Demographic characteristics (e.g., age, sex, educational level). This information will allow us to develop hypotheses about injury mechanisms and help identify groups at high risk.
2. Piece-rate pay versus hourly pay. Approximately 30% of California farm workers are paid on a piece-rate basis.[13] Piece-rate payment may increase injury risk by focusing inordinate attention on production, potentially at the cost of safety.
3. The possible association between organophosphate pesticide exposure and injury. Organophosphate agents are heavily used in agriculture, and in California more than 9 million pounds are used annually.[47] These agents inhibit cholinesterase in the peripheral and central nervous system, leading to neuronal overactivity.[48,49] We and others have shown depressed cholinesterase levels and urinary metabolites of organophosphate agents in workers using organophosphate pesticides.[50-53] Investigators have demonstrated cognitive and motor abnormalities among pesticide-exposed persons, which could increase risk for injury.[54-57] Determining whether organophosphate exposures for harvest workers increase injury risk may have important policy and occupational-hygiene implications for the industry.
4. Language-appropriate safety training. Safety training can reduce injury rates and costs when part of a comprehensive program,[18] yet efficacy studies are few, and training has not always been associated with reduced injury risk.[21] Although safety training is available in Spanish, we know of no studies describing the availability or efficacy of English- or Spanish-language safety training among farm workers. The UC Davis Farm Worker Injury Study will address safety training in relation to the language in which it was provided, the subject's primary language, and self-assessed English-language ability. These data will be used to examine whether English-language skills and provision of training in one's primary language protect against injury.

Our ultimate goal is to characterize the injury experience of migrant farm workers and to identify risk factors that may point to preventive strategies. We have surveyed approximately 1,100 adults and 1,000 children and will have completed data collection by the time this paper is published in November 1997. Preliminary analysis indicates an annual injury risk of approximately 11% among adults; the overwhelming majority of these injuries are occupational (unpublished

data). After identifying subgroups at high risk and with the greatest health impact from injuries, we can consider potential preventive interventions. The Haddon Matrix serves as a guide for developing such preventive strategies, as shown in Table 5.

TABLE 5

Haddon Matrix Applied to Hypotheses of the UC Davis Farm Worker Injury Study

	Potential Preventive Strategies		
Hypothesis	**Agent and Vector**	**Host**	**Environment**
Organophosphate exposure increases injury risk.	Substitute less toxic agents.	Provide protective clothing and equipment.	Alternate spraying regimens.
		Train in safe work practices.	Lengthen time period after spraying before field re-entry.
		Test for exposure.	
Piece-work pay is a risk factor for injury.	Engineer tasks to protect workers.	Train in safe work practices.	Alter payment scheme.
Safety training and English skills are protective against injury.	Engineer tasks to protect workers.	Train in safe work practices.	Provide safety materials in primary language of workers.
		Improve English skills.	
Having multiple employers is associated with increased injury risk.	Engineer tasks to protect workers.	Train in safe work practices.	Encourage policies to promote full employment with single employer.

Camp Health Aide Program. The National Institute for Occupational Safety and Health is currently funding a study of occupational health, including injury, among migrant farm workers in Florida and Illinois. Collaborators from UC Davis and the California Institute for Rural Studies are involved. The program uses community members as camp health aides to document occupational health problems, assist workers in obtaining care, and follow the course of any medical care they receive. Approximately 225 workers were interviewed in Florida during March and April 1997; an additional 200 persons were surveyed in July and August 1997 in Kankakee, Illinois.[58] Results of this study will be available in 1998.

Agricultural Ergonomic Interventions. Dr. John Miles of the Department of Biological and Agricultural Engineering at UC Davis is the principal investigator for this project, funded by the National Institute for Occupational Safety and Health, to develop tools and work practices to reduce ergonomic hazards in agriculture.

With collaborator Julia Faucett, R.N., Ph.D. (UC San Francisco Occupational Health Nursing Program), and others, Dr. Miles is focusing on nursery workers. One of the main ergonomic hazards for these workers is frequent moving of heavy plant containers. Dr. Miles has developed a handheld device that markedly improves the ergonomic characteristics of this task. Data collection is ongoing, and preliminary review shows reductions in ergonomic hazards (data unpublished).[59] Subsequent analyses will examine whether injury experience has been reduced.

Nurses Using Rural Sentinel Events (NURSE) Project. The NURSE Project, sponsored by the National Institute for Occupational Safety and Health, is a surveillance program for occupational injuries in agriculture in the counties of Fresno and Monterey. Investigators from the Occupational Health Branch of the California Department of Health Services use a variety of sources—including the Workers' Compensation system, hospitals and clinics, and the media—to identify agricultural injuries. Fatal, serious, or unusual cases are investigated in detail. More than 5,000 cases have been identified since 1994, and in-depth reports have been completed on 35 of these.[60] More than 80% of the injured workers are Hispanic; the most common lesions are lacerations of the finger and back strains. These data are an important resource for characterizing the scope of occupational injuries among farm workers in these heavily agricultural counties. The program also has an outreach component with bilingual field staff who deliver health and safety education to farm workers, ensuring that the program's findings are brought quickly to the workplace. This research group is also conducting the Farm Family Health and Hazard Survey, an ambitious project to investigate health hazards among agricultural workers in the counties of Fresno and Monterey.

A Framework for Preventive Measures

The Haddon Matrix is useful in spurring our thinking about preventive measures. In general, such measures are designed to prevent exposure to excessive levels of energy. The matrix allows us to categorize different interventions in terms of whether they address the agent and vector, the host population, or the environment.

Interventions for the agent and vector. Interventions at this level typically involve engineering controls to reduce energy and prevent its contact with workers. A major advantage of engineering controls is that they are passive and do not require special efforts or ongoing attention by the operator. The success of this approach has been shown by the reduction of deaths from tractor rollovers as a result of rollover protection structures (ROPS).[61] Dr. Miles's work addressing ergonomic hazards holds promise in reducing musculoskeletal injury among some groups of farm workers.

There are several important limitations for engineering controls, however. First, migrant Hispanic farm workers are primarily involved in manual labor such

as harvesting, hoeing, and other activities that may not readily lend themselves to engineering interventions. Second, there may be economic disincentives to changing engineering or work practices. Employers and farm workers may be reluctant to adopt such changes if they increase costs or reduce productivity.[62]

Interventions for the host population. Educational measures have enjoyed popularity as a means of injury reduction. Migrant Hispanic farm workers present special problems for developing training programs, chiefly owing to brief tenure of employment and linguistic barriers. Although training and education have obvious value, there are few data documenting a resultant reduction of risk. The UC Davis Farm Worker Injury Study will examine whether safety training is indeed associated with reduced injury risk. In any case, education should emphasize general safety habits, including those related to transportation (e.g., seat-belt use, safe driving habits), in addition to safety in the workplace.

Interventions for the environment (physical and sociopolitical). Regulatory efforts are important in agriculture as in other industries; however, the regulatory climate reflects society's priorities. Agriculture is highly dispersed and, unlike mining, does not claim large numbers of victims at one time to intrude on the public conscience and fuel demand for regulation. The low priority of occupational health in agriculture is also evident in the lack of Federal support. Federal expenditures for occupational health in agriculture in 1985 were approximately $0.30 per agricultural worker, compared with $181.00 per miner and $4.34 for all industry.[63] Regulatory infrastructure is critical to ensure that farm workers benefit from existing occupational health protections. Creative programs such as the Targeted Industry Partnership Program present an opportunity for efficient use of existing resources.

Conclusions

Migrant Hispanic farm workers are essential to the remarkable success of California's agriculture and the state as a whole. They work in circumstances that are likely to increase their risk of injury and hinder occupational health efforts. These circumstances include social and linguistic marginalization, economic hardship, mistrust of officialdom, and tenuous employment. As a result, few epidemiologic data addressing occupational injury are available for this population. Preliminary data from the UC Davis Farm Worker Injury Study suggest that farm workers have an injury risk of approximately 11% per year. However, rates may be significantly higher among certain subpopulations, to be identified in upcoming analyses.

Engineering interventions to reduce the potential for contact between humans and excessive energy and to improve ergonomic conditions are most likely to be effective in injury reduction. Safety training should also play a role in preventive efforts, although further work is necessary to characterize and optimize its efficacy. Regulatory infrastructure, including the enforcement of existing occupational health

and labor regulations, is a critical component of prevention. Finally, continued research is essential to identify high-risk groups, examine risk factors, and develop and evaluate prevention strategies. Recent increases in support from governmental and private agencies for occupational health in agriculture are a welcome development. These efforts should ultimately lead to reductions in the occupational health burden of injuries among migrant Hispanic farm workers—benefiting the individual worker, his or her family, and all Californians.

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