



The Current State of Agricultural Health Research and Practice: Critical Review

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EXECUTIVE SUMMARY

The Current State of Agricultural Health Research and Practice: Critical Review

Agriculture work is centered in rural areas and includes traditional crop farming but also consists of ranching (raising animals), fishing, and forestry activities. The fishing sub-sector consists of establishments involved in harvesting marine and aquatic organisms, and the forestry sub-sector encompasses workplaces that harvest timber and other forest resources. Although the agricultural industry employs slightly less than one percent of all workers, this industry has some of the highest fatal and non-fatal injury rates of all industries.^{1,2} In 2011, the fatal injury rate for the U.S. agriculture industry was 24.4/100,000 full time equivalent workers (FTE) and the non-fatal work-related injury or illness rate for the U.S. agriculture industry was 5.5/100 FTE.^{1,2}

Agricultural workers are exposed to a variety of hazards including environmental conditions; chemicals from pesticides, fertilizers, and cleaners; ergonomic hazards such as repetitive movements, heavy lifting, and awkward postures; animals; and mechanical equipment. The health and safety concerns in the agricultural industry vary by industry sub-sector and by occupation within each sub-sector. The purpose of this report is to provide an overview and summary of the present state of agricultural health research for rural health care policy makers and providers. New health and safety concerns have emerged within specific occupations and worker populations as a result of changes within the agricultural industry and are outlined in this report. For example, the number of traditional family farms is decreasing while the size and animal density of larger agriculture operations is increasing. The report is intended to serve as a resource for health care providers and policy makers to identify priority areas for future research and for improved health care delivery among agriculture populations to improve agricultural worker health.

Occupational injury and prevention initiatives aim to reduce injury and adverse health outcomes in the workplace. Injury prevention controls range in type, and include administrative controls implemented in the work setting to substitute a hazardous substance or process with a safer one (i.e. mixing chemicals in an enclosed structure to reduce dermal or respiratory exposure). Prevention strategies also address work practices by changing job design and work organization (i.e. job rotation during a workday to reduce redundant and repetitive tasks) or reduce or eliminate workplace hazards with engineering controls (i.e. retrofitting a Rollover Protective System onto an older tractor). In the clinical setting, practitioners are involved in the treatment and rehabilitation stages of agricultural injuries and they also identify risk factors for work-related injuries. However, there are many barriers health care providers face when providing occupational injury treatment and preventative services to agricultural industry workers. Additional prevention initiatives of various degrees of effectiveness stem from community organizations, government agencies, and service and advocacy groups.

For this study, emerging health issues in agricultural populations as described by the National Institute for Occupational Safety and Health (NIOSH) and the National Occupational Research Agenda (NORA) Agricultural, Forestry, and Fishing Sector Council were examined to outline and summarize the present state of agricultural health research. Current and emerging issues related to agricultural safety and health are discussed by agricultural industry sub-sector. Prevention and treatment strategies initiated at the community, workplace, and clinical levels to serve agricultural workers are also outlined.

Priority areas for future research include:

- Integrating technology in agricultural processes to decrease hazardous exposures;
- Preventing zoonotic and emerging diseases among animal agricultural workers;
- Addressing health care cost, quality, and access concerns for priority worker populations, including foreign-born and migrant workers;

- Preventing acute and chronic illnesses including musculoskeletal disorders, respiratory diseases, and mental health issues;
- Evaluating injury prevention training and educational initiatives; and
- Developing multifaceted approaches to injury prevention that combine interventional approaches such as education and training, provision of personal protective equipment, engineering controls, and regulatory interventions.

Priority areas for improved health care delivery among rural agricultural populations include:

- Decreasing cultural, social, and economic barriers to health service access;
- Stretching resources of health care delivery systems by collaborating with other organizations, providing easily accessible resources, and identifying effective strategies to deliver services and prevention initiatives;
- Providing screenings for early detection and treatment of health problems among workers; and
- Developing a provider's knowledge and skills regarding priority agricultural issues in their patients and trends in worker health.

INTRODUCTION: THE AGRICULTURAL INDUSTRY

Agriculture refers to the activities of farming (growing crops), ranching (raising animals), fishing (harvesting fish), and forestry (harvesting timber).^{3,4} The scope of agricultural industry activities and agricultural support activities extends across a variety of workplaces including ranches, dairies, green houses, crop lands, nurseries, orchards, hatcheries, boats, and natural habitats.⁴ A range of agricultural sub-sectors results in a diversity of farm types, farm sizes, work environments, and production outputs within the industry. In addition, farm production methods are changing as the number of crop, cattle, dairy, and hog farms in the country is decreasing while the total acreage of individual farms and the livestock density of individual farms is increasing.⁵

Agriculture is a hazardous industry. Agricultural workers risk fatal and nonfatal injuries caused by an event or exposure occurring in the work environment. In 2011, the U.S. agriculture industry employed approximately 975,000 workers in the agriculture, forestry, fishing and hunting industry (excluding workers on farms with less than 11 employees).² Preliminary 2011 fatality data reports the agriculture industry has the highest fatal work injury rate at 24.4/100,000 full-time equivalent workers (FTE) while the all-worker fatal injury rate in 2011 was 3.5/100,000 FTE.¹ The agricultural industry had one of the highest non-fatal work-related injury or illness rates in 2011 at 5.5/100 FTE compared to 3.5/100 FTE for the overall work-related non-fatal injury rate.² Within the agricultural industry, certain occupations and work environments have a disproportional rate of injuries. In 2011, fishers and related fishing workers had the highest fatal occupational injury rate (121.2/100,000 FTE) followed by logging workers (102.4/100,000 FTE).¹ Non-fatal injury rates in 2011 were highest among animal production occupations (6.7/100 FTE), followed by crop production (5.5/100 FTE) and forestry and logging occupations (5.0/100 FTE).² An increased amount of time spent working on a farm and the farm size and type is also associated with injury rate.⁵

Injuries are categorized by the events or exposures leading to the injury: contact with objects, falls, transportation, exposure to harmful substances, bodily reaction and overexertion, and fires and explosions. Transportation incidents result in approximately half of all agricultural injury incidents, while contact with objects and equipment lead to approximately 27percent of agricultural fatal injuries.⁶ Among the most common work-related adverse health outcomes are noise-induced hearing loss, lung-disease, skin disease, cancer, and soft-tissue disorders of non-traumatic origin known as musculoskeletal disorders (MSDs).⁷

One of the earliest set of recommendations for the agricultural safety and health field, "Agriculture at Risk", was published in 1989 and addressed injuries, respiratory hazards, pesticide-related illness, agricultural-related concerns, and migrant health issues.⁸ Current and emerging agricultural health issues generally fall into the same broad categories as those first presented in the 1989 report.⁹ However, agricultural safety and health research is advancing and the field has broadened to include more specific occupations and health topics related to contaminated air, water, or soil exposure, chemical and antibiotic exposures, aquaculture, heat-related injuries, zoonotic diseases, mental health issues, bioterrorism, and biotechnologies.

The purpose of this report is to provide an overview and summary of the present state of agricultural health research for health care policy makers and providers. Emerging health issues in agricultural populations as described by the National Institute for Occupational Safety and Health (NIOSH) and the National Occupational Research Agenda (NORA) Agricultural, Forestry, and Fishing Sector Council were examined to outline and summarize the present state of agricultural health research by agriculture industry subsector. The report is intended to serve as a resource for health care providers and policy makers to identify priority areas for future research and for improved health care delivery among agriculture populations. Prevention and treatment strategies initiated at the community, workplace, and clinical levels to serve agricultural workers are also outlined.

METHODOLOGY

Agriculture health recommendations and emerging research issues identified by NIOSH and the NORA Agricultural, Forestry, and Fishing Sector Council were compiled in order to review the emerging issues in agricultural populations. They were combined with supplemental literature to summarize the current state of agricultural health research by industry subsector. This report was written in a consolidated format that serves to provide a brief overview of priority issues and areas for rural health care policy makers and providers.

NIOSH's publicly available list of emerging scientific and health issues in the Agriculture, Forestry and Fishing sector and NORA's Agriculture, Forestry, and Fishing Agenda goals served as the outline for the topics discussed in this review. While other organizations and entities contribute to agricultural research, NIOSH and NORA were highlighted in this project due to their primary involvement in and organization of agriculture research throughout the U.S.. NIOSH has ten Centers for Agricultural Disease and Injury Research, Education, and Prevention throughout the country that conduct research on and provide education and prevention activities for agricultural health and safety topics. The Agricultural Centers focus on research needs pertinent to the health and safety of agricultural workers in a specific geographic area, including health and safety of large-herd dairy workers, respiratory exposures in swine workers, confined-space manure storages, and agricultural work and injury among children.¹⁰

The NORA partnership program involves occupational researchers, public health practitioners, educators, supporting industry representatives, and other stakeholders collaborating to identify critical occupational health and safety issues for research (<http://www.cdc.gov/niosh/nora/default.html>).¹¹ NORA developed an updated, formal occupational safety and health research agenda for the agriculture, forestry, and fishing industry based on scientific research, public testimonies, and personal expertise, which was used to organize this report.^{11,12}

CURRENT RESEARCH AND FUTURE RESEARCH PRIORITIES

Priority Populations for Agricultural Health Research

Specific populations of agricultural workers are at a higher risk for occupational exposures, injuries, illnesses, and diseases. These priority populations include people with disabilities, aging workers, children, and foreign-born and migrant workers.^{9,12} Social, economic, biological, psychological, language, and immigration factors distinguish these high-risk workers, and injury prevention efforts are often tailored to these groups.

People with disabilities: Workers with physical or cognitive disabilities have an elevated risk of occupational injury due to a decreased ability to respond to workplace situations, including emergency situations, and perform job tasks. Approximately 20 percent of farm or ranch workers have a disability that restricts work performance, such as MSDs, hearing impairment, cardiovascular diseases, or respiratory illnesses.¹³ Persons with disabilities in the agricultural setting may also include workers with amputations, functional disability, or those participating in work rehabilitation after MSDs or other types of injuries.⁹

Aging workers: A trend toward increasing age of principal farm operators is prominent among farm workers. The 2007 Census of Agriculture reported a rise in the average age of U.S. farm operators from 55.3 in 2002 to 57.1 in 2007, and the number of farm operators age 75 and older increased by 20 percent.¹³ Farmers continue to work later into life due to economic implications and may concurrently rely on off-farm occupational income as their primary source of income.³ In 2007, approximately 45 percent of 2.2 million total farm operators reported farming as their primary occupation while the remaining operators reported a primary occupation other than farming.¹³ Farm operators may rely on income from other occupations because 60 percent of all farms in 2007 made less than \$10,000 in sales from agricultural products.¹³

Aging workers across agricultural sub-sectors are at increased risk of occupational injury and illness due to vision changes, hearing loss, loss of balance, symptoms and secondary effects from existing health conditions, and medication side-effects.¹⁴ In 2001 and 2004, agriculture production workers age 55 and older had similar non-fatal injury rates compared to workers ages 20-54, but the injuries were more severe in older workers including fractures, sprains/strains, and increased restricted work days.¹⁵ From 1992-2004, the fatality rate for farm workers ages 55 and older (45.8/100,000 workers) was 1.8 times that of the overall agriculture fatality rate (25.4/100,000 workers).¹⁵ In 2003, farmers over age 75 had a high fatality rate of 57/100,000 FTE and were two times as likely to die while farming compared to younger farmers.¹⁴

Children: Children living on or near family farms become involved in agricultural employment at a young age.³ In 2009, an estimated 1.03 million youth under the age of 20 resided on farms and approximately 519,000 of these youth residents worked on the family farm. In addition, 230,000 workers under age 20 were hired to work on farms in 2009.¹⁶ Agriculture-related injuries among those less than 20 years of age have declined from 13.5 per 1,000 farms in 2001 to 7.2 per 1,000 farms in 2009.¹⁷ Youth ages 16 and above may be employed in any occupation on a farm, but there are restrictions on the type of work those under age 16 may perform. However, no laws or standards apply to youth working on a family owned or operated farms and youth on small fishing vessels that do not require contract protections.¹⁸

Young agricultural workers are vulnerable to injuries due to their lack of work experience and job training. They are likely to be physically and mentally unprepared for hazardous work compared to their adult counterparts and may not recognize hazards on the job. Young workers may perform tasks inappropriate for their skill level and physical and mental development due to economic needs of the family.¹⁸ Fatal injuries to youth on farms from 1995-2000 most frequently involved machinery (25 percent), motor vehicles (17 percent), and drowning (16 percent).¹⁹ The most common source of non-fatal injuries among youth in 2009 was

transportation events.¹⁹ Children typically experience muscle strains in the upper extremities, shoulders, back, and neck from agricultural work.⁹ While some states have school-directed programs or safety camps to teach youth about injury prevention, injuries among children on farms are common. These educational lessons are successful in achieving short term improvements in knowledge and behavior change.²⁰

Foreign-Born & Migrant Workers: The National Agriculture Workers Survey (NAWS) reported 72 percent of all farm workers were foreign-born in 2007-2009, and the majority of the foreign-born workers were from Mexico.²¹ Foreign-born workers in the agriculture industry are employed in occupations such as dairy, livestock, and crop production as well as in forestry jobs.²² Migrant workers are farm workers who relocate to accommodate employment opportunities that fluctuate by season. There is a decreasing trend of migrant workers employed in the agriculture industry from approximately 53 percent (1998-2000) to 25 percent (2007-2009).²³ The most commonly reported injuries among foreign-born and migrant agricultural workers are MSDs, hearing loss, eye injuries, skin disease, mental health issues, heat-related injuries, pesticide exposure, and green tobacco sickness. Injuries and illness in the migrant worker population also result from alcohol use, poor oral health, and infectious disease due to lifestyle factors.²²

Foreign-born and migrant workers are employed in hazardous farm work involving long work hours, heavy physical labor, and high pressure to perform on the job.^{9,24} Latino migrant workers in North Carolina perceived their work safety climate as poor, and a poor work safety climate was associated with health outcomes including musculoskeletal discomfort and working while injured or sick.²⁴ Some workers may not complain about low compensation and job risks due to fear of losing their job, economic necessity of the job, and improper work authorization.²²⁻²⁴ Approximately 48 percent of farm workers in the U.S. from 2007-2009 data did not have legal authorization to work in the United States while 18 percent had a green card and 1 percent had work authorization through the H2 Temporary Guest Worker program.²³

Migrant workers are at an increased risk of poor health status attributed to increased poverty rates, mobility of work, and hazardous living conditions including substandard housing.²⁵ Migrant workers sometimes lack sufficient access to health services due in part to their transient work. The Affordable Care Act does not cover illegal immigrants and includes provisions for reduced payments to hospitals that treat a large share of uninsured patients including illegal immigrants.²⁶ The highly mobile nature of the work makes it difficult to develop a social network and connect with primary health care services.²⁵ 85 percent of adult migrant and seasonal farm workers were uninsured in 2000, which is substantially greater than the 37 percent of national low-income adults who were uninsured.²⁵ In 2000, approximately 90 percent of children in migrant farm worker families were uninsured compared to 22 percent of U.S. low-income children.²⁵ Receiving Medicaid coverage is difficult because coverage is dependent on immigration status, number of dependent children, asset tests, and state residency requirements that are often unmet by transient migrant workers.²⁵ The cost implications to the health care system of providing services to uninsured migrant populations are unknown and are an important area of future research. However, foreign-born and migrant workers also face language, cultural, and psychosocial barriers to accessing health care services from the U.S. medical system that need to be addressed.^{22,27}

Health and Safety Research Priorities by Types of Agricultural Activity

Farming:

Farmers acknowledge hazards as an inherent component of farming and have a high tolerance for risk while on the job.²² Farmers may believe safety measures from outside agencies are unnecessary and accept work-related risks in order to increase production.²² Injuries occur at a higher rate among males than females and are most often transportation and

machinery-related or animal-related.^{5,9} Developments in farm machinery increase crop output but may contribute additional hazards to operators. For example, tractor overturns were a leading cause of death among farmers and farm workers in 2010.¹⁶ Despite the development of rollover protective structures (ROPS) to protect tractor operators during an overturn, many farmers lack the resources to buy a new tractor with ROPS or retrofit an older tractor with ROPS. NIOSH estimated that the U.S. fatality rate from tractor overturns could be reduced by 71 percent if all tractors had ROPS.²⁸ Still, Occupational Safety and Health Administration (OSHA) requirements to equip employer-operated tractors made after 1976 with ROPS and a seatbelt do not apply to family farms and farms with less than 11 employees.²⁹ Other developments in farm machinery and equipment technology include sensor systems and power take-off for tractors and attached implements that are designed to prevent accidental contact with a machine.

MSDs are caused by or exacerbated by interaction with the work environment and excessive work-related physical or psychosocial demands leading to soft-tissue disorders.⁷ MSDs to the neck, arms, and low back are common in both crop and animal agricultural work practices.⁷ Risk factors for MSDs include, but are not limited to, awkward postures involving reaching, twisting, and lifting; forceful exertions and carrying loads; contact stress from contact or rubbing between tools and body tissue; repetitive motion; vibration from tools that restrict blood flow to the extremities; and whole body vibration from riding farm equipment.⁷ Manual handling techniques are part of many agricultural tasks and require repetitive movements, unusual postures, or excessive force by a worker.⁷

Agricultural chemicals, including pesticides, solvents, cleaners, and nitrogen based fertilizers improve crop production but may result in illness or death among exposed workers. Exposure to pesticides is associated with farmer reports of acute symptoms including skin irritation, headache, eye irritation, and flu-like symptoms.⁹ Chronic conditions associated with long-term pesticide exposures include cancers, reproductive effects such as infertility, miscarriages, and preterm delivery among women working in agricultural industries, and congenital birth defects among children of pesticide applicators.⁹

The Agriculture Health Survey reported farmers have a decreased risk for some cancers including lung, bladder, and colon cancers compared to the general population.³⁰ However, farmers have a higher incidence of cancers of the lip, skin, brain, lymphatic and hematopoietic systems, soft-tissue sarcoma, prostate, and ovary.³⁰ Pesticide applicators have excess cancer rates for breast, colon, leukemia, lung, non-Hodgkin's lymphoma, ovarian, and prostate cancers.^{30,31} Specifically, breast cancer is associated with exposure to the pesticide dichloro-diphenyl-trichloroethane (DDT) prior to puberty; leukemia with exposure to 1,3-butadiene; non-Hodgkin's lymphoma with exposure to pesticides and solvents; and prostate cancer with exposure to pesticides or polyaromatic hydrocarbons (PAHs).^{30,31}

Farmers are exposed to air contaminants from activities such as tilling, soil preparation, planting machinery emissions, pesticide spray drift, and agricultural burning. Respiratory irritants and agent vary by season, location, and type of work and may lead to a variety of respiratory illnesses including one of the most common, bronchitis.⁵ Other acute and chronic respiratory diseases, including farmers hypersensitivity pneumonitis, organic dust toxic syndrome, occupational asthma, mucus membrane inflammation syndrome, and sinusitis, were associated with organic dust, ammonia, and bacteria exposures related to agricultural work.³² Increased dust exposure was associated with work shift reductions in lung function among grain elevator and corn farm workers. Lung function reductions occur as a result of dust inhalation, and exposure to pesticides and herbicides among crop workers exacerbates reduced lung function.³³ Further analysis suggested an exposure-response relationship particularly among workers who smoked, workers applying pesticides or herbicides, and workers with asthma, allergies, or genetic polymorphisms.³³

Burning in agricultural fields is a method to remove crop stubble, weeds, and pests. Smoke emitted as a result of this agricultural burning contains chemicals, gases, and fine particulate matter (PM). For example, the PM composition around a Bermuda grass stubble burning site consisted primarily of carbon and semi-volatile polycyclic aromatic hydrocarbons (PAHs) which include naphthalene, a respiratory carcinogen. Since most of the particles created by agricultural burning are small, they can travel large distances and are present in PM samples downwind of burning sites.³⁴

Ranching:

Many animal production facilities and livestock operations have transformed from smaller operations to high-density animal production facilities, commonly known as concentrated animal feeding operations (CAFOs). These CAFOs comprise approximately 5 percent of all farms in the U.S., but contain about 54 percent of the country's livestock.⁵ Animal production systems are regionalized with the swine industry located in the upper Midwest and North Carolina, the poultry industry generally concentrated in southeastern U.S., and the dairy industry located mainly in the upper Midwest, California, Oklahoma, eastern New Mexico, and the Texas Panhandle regions.³⁵

The shift to a large-herd, mass production farming model in many animal and ranching facilities resulted in increased hazardous work scenarios. Automation of work practices, repetitious work tasks, performing tasks in awkward postures, and high muscle loads lead to MSDs and cumulative trauma injuries among animal facility workers.⁵ Farm animals are a major source of injuries among animal and livestock workers. Livestock handlers perform tasks such as feeding animals, moving and transporting animals, administering medications to animals, and providing basic animal care placing them at increased risk for animal-related injuries. Livestock-handling injuries are more costly and require more time off work than other agricultural injuries.³⁴ Other injuries and illnesses from working with livestock include skin conditions, respiratory diseases, arthritis, noise-induced hearing loss from loud machinery, amputations, and electrocutions.⁹

The shift from smaller farms to CAFOs has heightened concerns regarding adverse human health outcomes related to water and air contamination. Disposal of nearly three million tons of animal waste each year results in nitrates leaching into ground water and contaminated water supplies.⁵ In addition, the large number of animals in a confined space emits high concentrations of known respiratory irritants including organic dusts, allergens, bacteria, mold, greenhouse gases, microorganisms, and endotoxins.^{5,9} PM, gas, agrochemical, and pesticide exposures from livestock operations are associated with mucous membrane irritation, bronchitis, asthma, asthma like syndrome, and Chronic Obstructive Pulmonary Disease (COPD). Specifically, employment in CAFOs was linked to respiratory and systemic effects, reduced lung function, increased decline in lung function, and asthma.⁵ Decreased lung function in dairy industry workers exposed to organic dusts during daily activities of feeding, milking, and moving animals resulted in COPD and asthma-like diseases.³³ To reduce respiratory disease risk in dairy parlor workers, research suggested improving ventilation in buildings and frequent washings of the dairy parlors to help reduce endotoxin (components of bacterial cell walls that are included in agricultural dusts) and respirable dust exposure among workers.³⁶

Poultry dust, a mixture of bird feed, wood shaving or bedding material, bird droppings, feathers, dander, dust mites, and micro-organisms, is a major occupational health risk for poultry CAFO workers. Working in a poultry environment may result in itchy eyes, sneezing, throat discomfort, flu-like symptoms, and breathing problems such as coughing, bringing up phlegm, shortness of breath, wheezing, and chest tightness. Worker interaction with animals and animal waste materials in ranching occupations results in zoonotic disease threats as infections may transfer from an animal to a human. Contact with animals through work tasks and exposure to animal dusts, dander, and waste materials may increase the risk of bacteria,

parasite, or virus transfer. Brucellosis, leptospirosis, tuberculosis, avian or swine influenza, or cryptosporidiosis are hazardous zoonotic diseases that are prevented with vaccines, worker isolation from animal bodily fluid, use of gloves and masks, and proper hand washing.³⁵ A critical area for future research is preventing zoonotic and emerging diseases among animal workers.

Fishing Workers:

The fishing industry sub-sector includes workers harvesting various types of marine and aquatic organisms. *Aquaculture* involves harvesting fish and aquatic life from controlled conditions while *commercial fishing* includes harvesting fish from uncontrolled or wild environments. Commercial fishermen had a higher annual fatality rate from 2000-2010 at 124 deaths/100,000 workers compared to the annual average for all U.S. workers at 4/100,000 workers.³⁷ Fishing vessel sinking, as a result of flooding, vessel instability, waves, or severe weather conditions, resulted in almost half of all fishing fatalities from 2000-2010, and man overboard incidents contributed to one-third of all fatalities.³⁷ Other fatalities in the fishing industry were attributed to onboard injury, injury while diving, or onshore injury. The East Coast region has the greatest percent of fishing fatalities (33 percent) in the U.S. as a result of hazards from the Northeast multispecies groundfish fisheries and Atlantic scallop fisheries. Alaska also has a high percent of fatalities (26 percent) as a result of the hazardous West Coast Dungeness crab fisheries on the Alaskan Coast.³⁷

Working conditions for fishermen lead to physical, chemical, environmental, and biological hazardous exposures. Fishermen perform strenuous tasks and repetitive movements, use heavy machines, and work for long periods of time.³⁷ They commonly experience fatigue, musculoskeletal sprains and strains, and exposure to excessive noise, toxic chemicals, and UV radiation. Exposure to the fertilizers, pesticides, and flocculants used in fish ponds may cause skin irritations and respiratory problems among aquaculture workers.³⁸ Fishermen work in a variety of geographic regions exposing them to extreme environmental conditions resulting in a disproportionate level of occupational illnesses and safety hazards. Zoonotic diseases are also a health concern among aquaculture workers. For example, stings from fish spines may result in tetanus infection and parasites or pathogens in fish ponds may infect workers.³⁸

Over half of fishermen and fishing-related workers are self-employed and spend a considerable amount of time off-shore, away from health care facilities.³⁹ A variety of injury prevention engineering solutions have been adopted by the fishing industry to prevent occupational injuries through substitution of a hazardous process with a less hazardous one or with equipment modification. Technological advancements have updated some fishing vessels with hydraulics for hauling catches and gear, emergency stops on winches, flood prevention monitoring systems, and vessel stability improvements to increase safety. Synthetic nets and lines that are less likely to break improve productivity and safety onboard, and personal floatation device requirements have been established by some fishing associations.³⁹

Forestry:

Forestry occupations include workers involved in harvesting forest resources and products (i.e. loggers and log truck drivers) and workers providing services to the forest (i.e. planting trees, preparing sites, building forest roads, and fighting wild land fires). Within the forestry sub-sector, logging receives considerable attention due to the high injury rate among logging workers. Logging workers are at risk for being struck by trees or tree limbs and face injury risks from exposure to extreme conditions, slips and falls, and machinery incidents (i.e. chainsaws, cable lines).⁴⁰ Many forestry workers perform physically demanding tasks resulting in muscle strain, cumulative trauma, and musculoskeletal diseases. One exception includes machine operators who perform less physically demanding tasks but are exposed to sedentary

and repetitive work postures. Forestry workers are also exposed to toxic materials from pesticides, insect repellents, herbicides, dust, smoke, and engine emissions.³⁵ The use of machines versus manual work by forestry workers also presents different types of occupational exposures and injuries.

Organizational and work patterns of the forestry industry vary by region and worksite resulting in different types of injury based on geographic location similar to other agriculture subsectors. Manual tree felling and tree planting occurs in various regions of the U.S., including the East Coast. Cable logging is more prominent on steep slopes in the western part of the country, while mechanized operations occur in southern states. Loggers at high altitudes are at an increased risk for hazardous climate exposures such as high UV exposure and elevated wind speeds. Extreme weather conditions and temperatures result in heat-related injuries including health stress or frostbite.³⁵

Prevention technologies and heightened OSHA regulations have been developed to reduce injuries among forestry workers. Technologies that decrease manual work and ergonomic strain include radio-controlled chokers and other machines that substitute manual work processes for mechanical processes. Chokers, wire ropes used to secure felled trees during transfer to the landing collection point, can be radio-controlled to mechanically release felled trees on the landing instead of manually unhooking the choker.⁴¹ Replacing wire ropes with lighter, stronger synthetic lines reduces the number of line breaks and mechanical issues caused by worn or broken wire ropes. Another recent development in the injury prevention field is hardening glass windows on machine cabs to prevent tree harvester blades from breaking into the cabs of operating equipment and injuring a machine operator.³⁴ Improvements in OSHA requirements for personal protective equipment, machinery operations, and safe practices have helped reduce hazards to workers. Increased employee training is also recommended since forestry workers are typically at job sites in small groups of four to eight workers. OSHA logging regulations require employers to "provide training for each employee, including supervisors, at no cost to the employee," but about 30 percent of forestry workers are self-employed in logging and forestry work and may not receive these trainings.⁴⁰

Despite the differences between agriculture industry sub-sectors, there is an overlap in priority areas for future agriculture occupational injury research. Continued developments that integrate new technologies in agricultural processes to decrease hazardous exposures are a priority area for future prevention research. Research to prevent acute and chronic illnesses including MSDs, respiratory diseases, and mental health issues would benefit agriculture workers in all sectors. Evaluating injury prevention training and educational initiatives and developing multifaceted approaches to injury prevention are needed for all agricultural workers.

Agricultural Sub-sector	Summary of Major Health Issues
Farming	<ul style="list-style-type: none"> -Transportation and machinery-related injuries -MSDs from repetitive movements, unusual postures, or overexertion-Exposure to agricultural chemicals (pesticides, solvents, cleaners, and nitrogen based fertilizers) -Respiratory effects including bronchitis, farmers hypersensitivity pneumonitis, organic dust toxic syndrome, occupational asthma, mucus membrane inflammation syndrome, and sinusitis -Mental health issues
Ranching	<ul style="list-style-type: none"> -MSDs from automation of work practices, repetitious work tasks, performing tasks in awkward postures, and high muscle loads -Animal-related injuries -Contamination of water and air from animal waste producing respiratory irritants -Particulate matter, gas, agrochemical, and pesticide exposures associated with mucous membrane irritation, bronchitis, asthma, asthma like syndrome, and COPD -Zoonotic Diseases: Brucellosis, leptospirosis, tuberculosis, avian or swine influenza, or cryptosporidiosis -Mental health issues
Fishing Workers	<ul style="list-style-type: none"> -Exposure to physical, chemical, environmental, and biological hazards -Injuries from fishing vessel loss and man overboard -Machinery-related injuries -Falls on deck -MSDs from performing repetitive movements, operating machines, and working for long periods of time -Fatigue, sprains and strains, and exposure to excessive noise, toxic chemicals, and UV radiation. -Zoonotic diseases -Mental health issues
Forestry	<ul style="list-style-type: none"> -Muscle strain, cumulative trauma, and MSDs -Sedentary and repetitive work postures among machine operators -Exposure to toxic materials from pesticides, insect repellent, herbicides, dust, smoke, and engine emissions -Hazardous climate exposures such as high UV exposure, elevated wind speeds, and extreme weather conditions and temperatures -Mental health issues-Machinery-related injuries including struck-by injuries

PRIORITY AREAS FOR IMPROVED HEALTH CARE DELIVERY

Agriculture injury literature highlights prevention initiatives that aim to decrease injury and health problems among workers.^{3,9,20,42} This research suggests a variety of effective engineering, organizational, ergonomic, educational, and personal protective equipment prevention controls to reduce injury. However, implementation and enforcement of many prevention initiatives and practices must be endorsed by management or approved into legislation, not only supported by researchers, practitioners, or workers themselves. In the clinical setting, practitioners are most often involved in the rehabilitation and treatment stages of agricultural work injuries, but many injured workers are unlikely to seek medical care.²⁷

The Clinical Health Care Setting

Agriculture work is centered in rural areas. There are a variety of primary care practices serving agricultural workers in rural areas including private physician practices, Rural Health Clinics (RHC), and Health Resources and Services Administration (HRSA)-funded Health Centers. RHCs are public, private, or non-profit clinics that provide services to patients in rural shortage/underserved areas and receive enhanced Medicare and Medicaid reimbursements.⁴³ The rural health care infrastructure differs from urban and suburban areas in regard to the limited number of services provided and shortage of health care workers.⁴³ Rural residents are less likely to receive specialized care and post-hospital home care compared to non-rural residents.⁴³ Emergency medical service response and transport times are greater in rural areas compared to urban areas.⁴³ According to 2013 data, there were 8,541 Health Professional Shortage Areas in rural areas, compared to 5,746 in urban areas, across primary care, dentists, and mental health providers.⁴⁴ Health care coverage is also lacking in rural areas as fewer residents have employer-provided health care and Medicaid benefits.⁴⁵

HRSA-funded Health Centers provide primary health care services to medically underserved populations and some receive funding for special populations including migrant farm workers. In 2012, there were 159 federally funded Migrant Health Centers, which operated around 700 satellite service sites.⁴⁶ In 2011, it was estimated that HRSA-funded Health Centers served 25 percent of migrant workers in the U.S., or 862,808 migrant and seasonal farm workers and their family members.⁴⁷ Non-HRSA funded clinics that serve migrant populations may be reimbursed by Medicare and Medicaid for migrant and seasonal farm workers depending on the clinic's reimbursement status. Many clinics serving agricultural workers rely on other funding sources and offsets including tax revenues, donations, grants, Medicaid, Medicare, and other government revenue for added support, but clinic resources and funds may be limited.²⁵

The Practitioner

Conducting Health Screenings:

In addition to treating patients, practitioners identify risk factors and early signs of work-related injuries and illnesses. Clinicians have an opportunity to ask and record a patient's industry and occupational history and to perform screening and prevention assessments to detect occupational-related health outcomes in early stages. Preventative screenings include asking workers about dust exposure in their workplace, conducting lung function tests to monitor respiratory health, and performing hearing assessments on workers exposed to excessive and loud noises.²⁰ Regular skin checks among pesticide applicators and workers with dermal exposures increase early detection of skin cancer. Other recommended cancer screenings among agriculture workers include regular prostate screenings, bowel health assessments, and blood monitoring for detection of lymphatic cancers among agriculture workers.³² Health care providers may identify risk factors for transportation-related injuries and other injuries, especially in older workers, by checking patient medication use, neurology, and mobility.¹⁴

Agricultural workers and rural residents have a high prevalence of mental health symptoms and are at an increased risk for suicide.^{20,45} Mental health issues are increased in agricultural workers as a result of work-related stress including the physical environment and economic uncertainties and difficulties.^{20,45} Mental health and depression screenings help identify mental health symptoms, including exhaustion, fatigue, and decreased concentration, which increase injury risks among those in agriculture work environments. Stress-related to the workplace and lifestyle factors (financial problems, social isolation, and drug and alcohol abuse) are additional risk factors for mental health issues.^{3,14,20} However, it may be difficult for residents of rural areas to seek help for mental health issues because rural areas lack mental health services compared to urban areas.⁴⁵

Implementing Effective Prevention Strategies:

Nationally mandated agriculture health and safety programs in the U.S. are lacking. Pesticide training is the only nationally required agricultural training by the U.S. Environmental Protection Agency (EPA) through the EPA's Work Protection Standards. However, implementation is limited and training materials have been evaluated and found to be insufficiently educationally and culturally relevant.²² Government agencies, service and advocacy groups, and universities developed many publically available training materials and programs. Many such programs provide voluntary worker training in community settings, rather than worksite settings. Only a few culturally appropriate and literacy-appropriate industry-developed programs were identified by Arcury et al. including a safe operating program by Caterpillar and an internal safety program for customers of Cargill, a private company which produces and markets food, agricultural, financial and industrial products and services.²² Materials developed by private companies are not readily available for review like the materials developed by government agencies, service and advocacy groups, and universities.²²

Rural agricultural health models and recommendations highlight partnerships between clinicians and community organizations as an effective method to develop and implement injury prevention activities. Community organizations and health care providers working together to incorporate interventions and prevention strategies into daily job activities improves worker safety and health.¹² However, before committing time and resources to prevention programs, a review of evaluated prevention efforts must be conducted to select effective prevention initiatives. A Cochrane review of educational strategies to prevent injuries among agricultural workers found little evidence supporting solely educational interventions for injury reduction.⁴² Pooled results showed educational interventions aimed at reducing injury among adult and child agricultural workers were not effective, although moderate evidence of effectiveness was shown for improved farm safety knowledge and behaviors.²⁰ Educational interventions for children, such as school lessons and farm safety camps, have improved short term safety knowledge and beliefs.¹⁹ Among adults, short term improvements in knowledge, attitudes, and behaviors from environment audits or reviews were evident in evaluations of adult educational interventions.²⁰ Educational interventions as a component of a multifaceted intervention have a better place than educational programs alone, especially when an intervention aims to increase the use of protective equipment among workers.^{20,42} For example, there was a significant increase in safety eye glass use among Latino farm workers who were given safety eye glasses, and an even greater increase among workers given safety eye glasses and brief training by a community health worker.²⁰

An example of a multifaceted injury prevention model program serving agricultural producers is the AgriSafe Network. This non-profit national membership organization represents professionals who are concerned about the health and safety of farm families. Many agricultural injuries, diseases, and fatalities can be prevented through the delivery of agricultural occupational health services.

Effective prevention strategies must be developed by for the appropriate education level of

workers. The majority of farm workers have less education. From 2007-2009, the average grade level of education completed by farm workers with 8th grade, and approximately 26 percent of farm workers completed a grade level above grade 10.²¹ Language barriers also increase risk of injury in the workplace as 35 percent of farm workers in 2007-2009 reported not speaking English “at all”.²¹ Training and prevention programs must be developed for populations with lower literacy levels and in the primary language of workers the programs are targeted to.²²

Engineering controls are often associated with a high implementation cost. However, cost is not the only barrier to implementing effective engineering controls because financial incentives applying engineering controls may only have short-term effects. Financial incentives to retrofit ROPS on older tractors had a short-term decrease on injury level, but no long-term effect.⁴² Financial incentives such as insurance premium discounts for participants in interventions decreased injury claims directly after the intervention but were not effective over time.²⁰ Additional research is needed to examine whether financial incentives may lead to a long-term reduction in injury.

Increasing Foreign-born and Migrant Worker Health Care Utilization:

Foreign-born and migrant worker health care utilization patterns are an area of needed improvement. Foreign-born and migrant workers may not access health care services for agricultural injury prevention because they experience significant language, literacy, and cultural barriers that decrease access to and quality of health care.^{27,49} A statewide survey of primarily foreign-born California agricultural workers in 1999 reported approximately one-third of male agricultural workers never visited a clinic or doctor’s office. However, the 1999 survey also found about 75 percent of female agriculture workers reported a medical visit within the past two years suggesting that maternal and child health programs may engage female agricultural workers.⁵⁰ In 2000, about 20 percent of national migrant and seasonal agriculture workers reported using any health care services in the past two years.²⁵ When time permits, practitioners should also address worker and overall health status issues during maternal and child patient visits since visits to medical facilities are infrequent for foreign-born and migrant workers.

Practitioners must acknowledge that cultural beliefs of immigrant workers and prior experiences affect their receptiveness to health and safety initiatives. A study of Latino farm workers in California concluded they generally believe health, illness, and accident control are beyond the power of the individual.²² When it comes to treatment of illnesses or diseases, foreign-born agricultural workers may defer medical care for illnesses and prevent or self-treat conditions with traditional or home remedies.²² Sometimes workers may acquire culturally-based, lay definitions of biomedically recognized illnesses. For example, a study of migrant and seasonal workers in North Carolina reported the workers believed green tobacco sickness was the result of exposure to pesticides or heat rather than the result of nicotine absorption.⁵¹

Practitioners must be aware of the language and literacy preference of a patient. The use of printed materials for training and providing safety information may be useless for a quarter of Mexican workers who speak pre-Columbian indigenous languages and lack Spanish or English literacy skills.²² Dissemination of health and safety information to Spanish or other non-English speaking populations must be done through an effective and appropriate method.³⁴

Treatment Strategies:

Some agriculture workers seek treatment in a clinical setting after a work-related injury or illness has occurred. The specific treatment goal varies by patient and may include surgery, rehabilitation, minimizing harm, or avoiding complications from an injury. However, well-informed practitioners can anticipate the types of agricultural injuries and illnesses they will encounter in a clinical setting because trends in workforce demographics, farm type, and

occupation are unique to a geographic location. Knowledge of such trends helps designate the most appropriate prevention and treatment activities for workers in that location. Upon return to work after injury, workers may be advised to request accommodations in their workplace such as temporary job changes, ergonomic tool designs, or limited work hours to gradually adapt to muscle demands.⁷

Training for providers to identify and treat health problems associated with agricultural work should be made available because a survey of primary care physicians reported underestimating the risks of agriculture work.⁵² Nursing students and faculty report an interest in agricultural health topics in the classroom, but providing additional training to those serving agricultural populations is difficult due to limited clinic and staff resources.⁵² Health clinic employees already perform many duties for which they are not trained. For example, Migrant Health Clinic workers report spending time requesting medicine samples from pharmaceutical companies and applying for discounted government services.²² Ideally, time would be allotted for continuing education opportunities on agricultural health topics.²⁷ Migrant clinics provide health care, but they too lack the resources for delivering health prevention initiatives and occupational health training.²¹ Even in instances where preventative services were offered, clinicians often reported that migrant workers did not utilize the services due in part to demanding work schedules or language barriers.²⁷ Areas for improvement regarding training and collaboration activities were also identified by agricultural health and primary care informants such as provision of continuing education in agricultural health related topics for health care workers as well as time and funding those opportunities and improved coordination of activities between health care professionals and public agencies in occupational and agricultural domains.

CONCLUSIONS

Priority areas for future research have been discussed within agricultural industry occupations and sectors. Advancements in technology infiltrate the agriculture field to improve production, but these advancements may introduce corresponding hazards to workers. Continued research is needed to develop new technologies that eliminate work-place hazards. The foreign-born and migrant worker populations, and other vulnerable worker populations, face many cultural, social, and economic barriers to health care and research is needed to reduce these disparities. Further evaluation of injury prevention strategies will inform practitioners and health care workers about the most effective methods to educate patients at the local level. Research on risk factors and treatment strategies to identify and monitor acute and chronic illnesses as well as zoonotic and emerging diseases is also a priority area. The Bureau of Labor Statistic's Census of Fatal Occupational Injuries (CFOI) data reports a decline in the number of fatal injuries from 779 in 1992 to 557 in 2011, but the rate of fatal injuries has increased from 23.1/100,000 FTE in 1992 to 24.4/100,000 FTE in 2011.¹ The rate of non-fatal injuries has declined from 10/100 FTE in 1994 to 7.6/100 FTE in 2001 to 5.5/100 FTE in 2011.^{2,9}

Priority areas for improved health care delivery to agricultural populations must continue to address the insurance, cost, and access barriers to health care. Health care models that involve collaboration of agencies and resources need to be disseminated to help clinics increase the value of their resources. Evaluation and feasibility studies of health care preventive screenings must be continued as injury and illness prevention will improve overall health status of workers. Practitioners and health care workers must stay informed about the work trends and agricultural-related issues in their area to improve patient treatment.

Agricultural workers are employed in hazardous work. As the nature of the agricultural industry changes, workers face a range of shifting hazards and occupational health outcomes. It is evident that occupational health and safety research in the agricultural industry highlights prevention initiatives in the work environment to decrease injury, but the application of such initiatives is often lacking. Without the support and resources of employers to implement

effective prevention programs in the workplaces, much of the burden falls to the clinical setting for treatment of occupational injuries, if treatment is sought at all.

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