Chapter 6. Goal 4: Hazard Control Systems

Reduce injuries and illnesses in AFF Program-related industries by developing and demonstrating control systems and making them available.

6.1 Tractor Safety

- Reduce injuries that result from tractor overturns
- Stimulate farmers to retrofit their tractors with ROPS or a folding ROPS
- Evaluate safety zones in terms of body size.

6.1a Challenge or Issue

According to data from the BLS CFOI, 2,869 agricultural workers died from tractor-related events between 1992 and 2005; 1,412 of these deaths were due to tractor overturns (Figure 6-1) [BLS 2006]. The use of ROPS has been shown to be effective in preventing tractor overturn-related deaths and injuries [Thelin 1990; Cole et al. 2004]. These findings have been corroborated by fatality data from Nebraska. Between 1967 and 2000, the State of Nebraska investigated all 310 tractor overturn fatalities that occurred within the State. Only one of these deaths involved a tractor with a ROPS. However, data from the AFF Program found that only 38% of tractors used on farms in the United States had a ROPS in 1993; this had increased to 50% in 2001 [Myers 2003; Myers and Snyder 1995]. Since 1992, a modest but not statistically significant decrease has occurred in the fatality rate for farm workers from tractor overturns (Figure 6-2).

Figure 6-1. Agricultural Tractor-related Fatalities by Type of Injury Event, 1992-2005. *Source: BLS CFOI**

Tractor data from the TISF survey provided additional information about the types of tractors without ROPS used on farms. These data indicated that many of these tractors were manufactured before the release of ROPS as an option on farm tractors in the mid- to late-1960s [Myers and Snyder 1995; Arndt 1971]. In addition, these non-ROPS tractors were primarily small to medium size (between 20 and 90 horsepower) and used primarily on farms such as livestock operations (including dairies), field crop operations, and fruit and vegetable operations. Agricultural safety professionals have identified several barriers to farm operators placing ROPS on tractors. Common reasons include the cost of placing ROPS on older farm tractors, the inconvenience of having the ROPS placed on the tractor, and the possibility of ROPS interfering with the use of tractors in low-clearance areas, such as animal facilities and orchards.

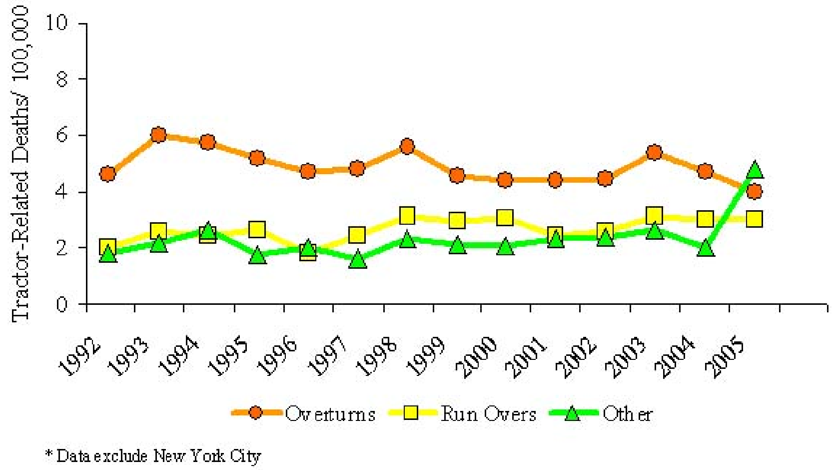


Figure 6-2. Agricultural Tractor-related Fatality Rates by Cause and Year, 1992-2005. *Source: BLS CFOI.**

6.1b Activities

On the basis of the tractor demographic data and the barriers to ROPS use identified by others, the AFF Program has undertaken an intramural and extramural program to increase the use of ROPS on farms in the United States. The intramural program involves surveillance of ROPS use on farms, evaluating the cost-benefit of placing ROPS on tractors, and an engineering research program to develop ROPS designs to address these issues. The engineering program is focused on developing an auto-deploying ROPS for use in low-clearance areas and low-cost retrofit ROPS designs. While conducting this work, AFF Program researchers began to have concerns about the anthropometric data used to define the ROPS protective zone for national consensus ROPS standards. This resulted in a separate research project to collect anthropometric data on a large sample of farm workers. Extramural activities are exploring different methods of promoting the use of ROPS.

<u>Surveillance</u>

Fatalities are the primary issue associated with farm tractors in the agricultural production industry. Farm tractors account for nearly 37% of all work-related farming deaths between 1992 and 2000 [Myers 2003]. The rate of these tractor-related deaths differs by region of the United States (Figure 6-3) with the highest rates occurring in the Northeastern States and the lowest in the West. The majority of these deaths involve farmers and farm workers over age 55 (Figure 6-4); this same age group also has the highest fatality rates due to tractors (Figure 6-5). (Appendices 3.2-01, 3.2-02, 3.2-04)

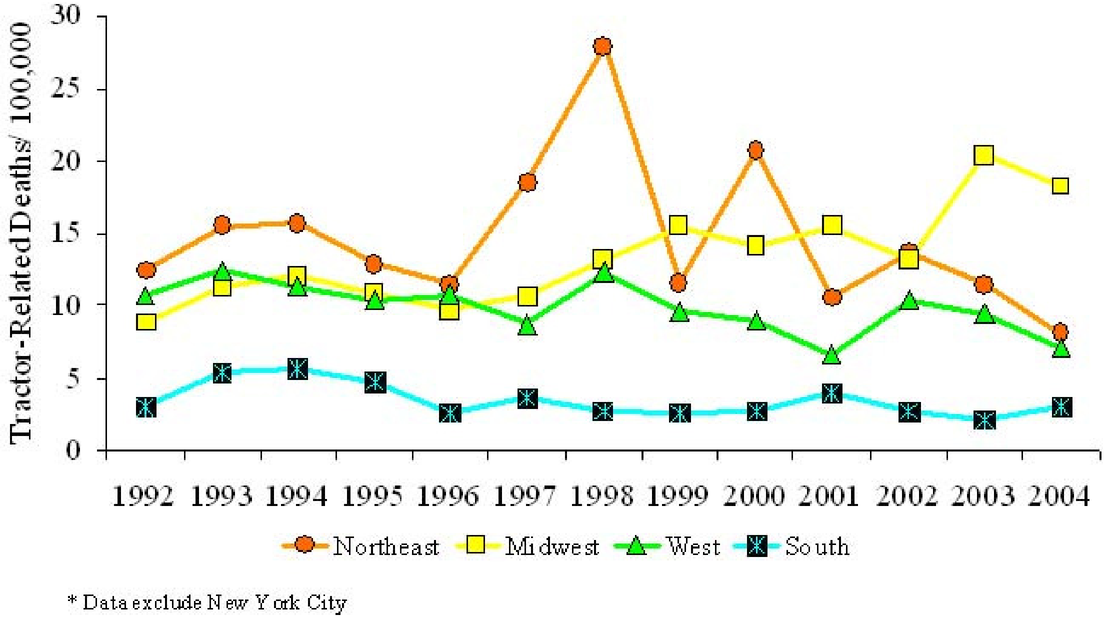


Figure 6-3. Agricultural Tractor-related Fatality Rates by Region and Year, 1992-2004.
*Source: BLS CFOI**

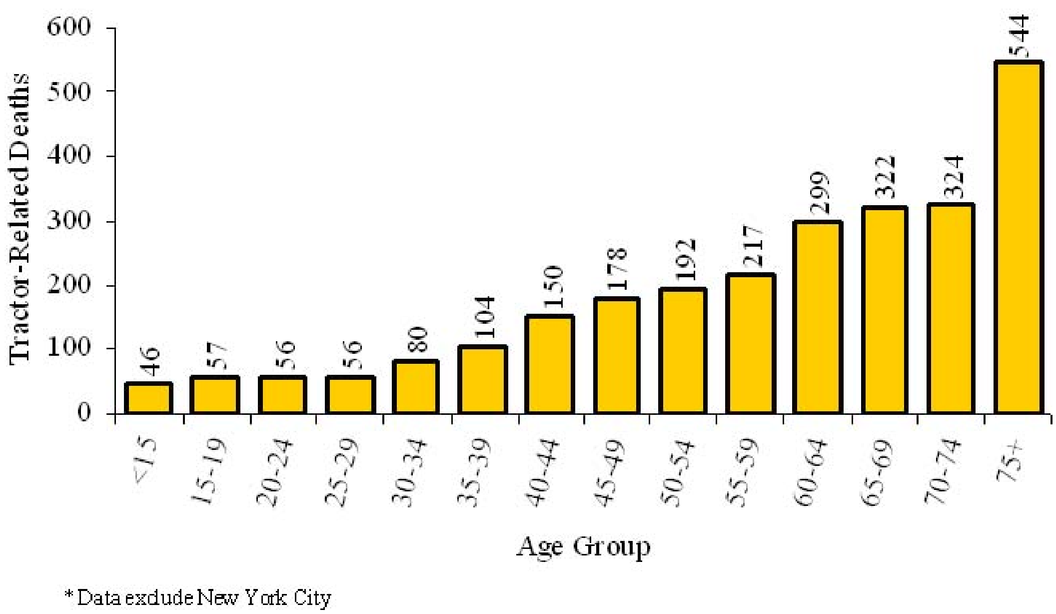


Figure 6-4. Agricultural Tractor-related Fatalities by Age Group, 1992-2004.
*Source: BLS CFOI**

Figure 6-5. Agricultural Tractor-related Fatality Rates by Age Group, 1992-2004
*Source: BLS CFOI**

In 1994, the AFF Program established the TISF system as a means of collecting occupational injury data for farmers and farm workers across the United States. In addition to injury information, the TISF collected data on tractors used on U.S. farms and whether these tractors had ROPS. These data were considered important because tractor overturns were the leading cause of death among farm workers. ROPS were considered the best method of preventing overturn-related deaths and their efficacy was well documented by the early 1990s [Thelin 1990]. However, no data were available to identify the farm tractors in common use and whether they had ROPS in place or could be retrofitted with ROPS. TISF collected the tractor manufacturer, model, and age of each tractor on a farm, ROPS status, and the hours of use for each tractor. Farms averaged more than two tractors; each tractor was on the average more than 20 years old. More than 60% of U.S. farm tractors were without ROPS (Table 6-1). Unfortunately, the 1993 tractor survey did not have any information on the age of the farm operator.

Table 6-1. Summary of farm tractors used on farms in the U.S. in 1993.

	Estimate
Tractors in use	4,800,000
Average Tractor age	22.8 years
Tractors per farm	2.3
Tractors with ROPS	1,824,000
ROPS Roll bar	*528,000*
ROPS Cab	*1,296,000*
Tractors without ROPS	2,980,000
ROPS tractors per farm	0.90
Source: TISF	

In addition to providing baseline tractor information for the AFF Program and others in the agricultural safety and health community, the

TISF tractor data also provided estimates of the most common tractors used on farms that were without ROPS (Table 6-2). The AFF Program used these data to identify common older tractor models to target engineering research designing new ROPS and assessing the structural integrity of older tractors to support ROPS structures during overturns.

Table 6-2. The five most common farm tractors without ROPS in use on U.S. farms, 1993	
Manufacturer and Model	**Non-ROPS units in use**
John Deere 4020	100,000
Ford 8N/9N	84,000
International Farmall M	77,000
International Farmall H	66,000
John Deere 3020	56,000
Source: TISF	

Because of budgetary constraints, TISF was discontinued in 1997.

In 2001, the AFF Program re-established surveillance of occupational injuries occurring to farmers and farm workers through the OISPA project. As with the TISF before it, OISPA collected demographic and ROPS use information about tractors used on farms in the United States These data indicated that the use of ROPS increased in the United States between 1993 and 2001, with nearly 50% of all tractors in use on farms having either a ROPS roll bar or ROPS cab (Table 6-3) in 2001. Roll bar style ROPS showed the largest increase in use (75%). Historically, tractors have had a long useful lifetime, and the average age increased somewhat over the 8 years between surveys. The distribution of the most common tractors without ROPS changed little between the surveys with the oldest tractors, the Farmalls, being slowly taken out of service.

Table 6-3. Summary of farm tractors used on farms in the United States, 2001.	
	Estimate
Tractors in use	4,700,000
Average Tractor age	25.7 years
Tractors per farm	2.5
Tractors with ROPS	2,326,000
ROPS Roll bar	*926,000*
ROPS Cab	*1,400,000*
Tractors without ROPS	2,374,000
ROPS tractors per farm	1.2
Source: OISPA	

Economic Assessments of ROPS Use

On the basis of the tractor information collected through the TISF, the AFF Program conducted a cost-effectiveness assessment of retrofitting tractors with ROPS [Myers and Snyder 1995]. The study concentrated exclusively on fatalities due to tractor overturns. The key findings from the study were that the immediate ROPS retrofitting of the most common farm tractor in 1993 would save nearly 1,500 lives over 20 years at an estimated cost of $825,000 per life saved. The paper also found that the 1985 ASAE voluntary standard to place ROPS on all farm tractors manufactured after 1985 was having an impact on the use of ROPS. But the paper concluded that it would take 20 to 25 years for the increased use of ROPS on farms to cause a major reduction in tractor overturn deaths. (Appendix 3.2-01)

This analysis was followed by more complex economic analyses that incorporated the cost of nonfatal injuries with the cost of fatal injuries associated with tractor overturns [Pana-Cryan and Myers 2000, 2002]. This analysis found that retrofitting tractors with ROPS would save approximately $490,000 per averted injury, and that the United States could save approximately $1.5 billion by retrofitting tractor with ROPS within its borders.

The NIOSH-funded Agriculture Safety and Health Center at the University of Kentucky is using OISPA tractor prevalence data from 2001 and 2004 for an economic analysis project of ROPS use on farms. The project includes analysis of tractor and ROPS use by hours worked, farming operation, and the need and feasibility of retrofitting ROPS to existing tractors. This project is part of a larger national AFF Program—the Agricultural Research Centers tractor initiative.

AutoROPS prototype test, September 1999.

Engineering Controls—AutoROPS

The three types of farming where clearance is a major issue are livestock operations, dairy operations, and fruit and nut tree operations. This is because tractors are driven into animal facilities or through rows of trees. According to the 1993 tractor survey, these farms accounted for about 2.7 million tractors, of which 67% did not have ROPS [Myers and Snyder 1995]. Although it is not possible to say that all of these tractors do not have ROPS because of clearance issues, it does show that these farms had lower than average ROPS usage. We are not aware of any data on whether these types of farmers deferred buying new tractors because of ROPS being on new tractors. Although fold-down ROPS are available for low clearance use on new tractors, they still require the operator to manually put the folded ROPS into the upright position once he leaves the low clearance area. (Appendices 6.1-01, 6.1-02, 6.1-03)

In 1993, the AFF Program began development of AutoROPS, and in 1995, it began development of an AutoROPS overturn sensor. The first project developed a ROPS that could be lowered and latched for day to day use, but that could deploy during an overturn. The second project developed an overturn sensor that monitored tractor operating conditions and provided a signal that would deployed the AutoROPS when needed.

Third generation AutoROPS in a retracted position

By 1999, these projects had developed workable devices. The AutoROPS was tested at West Virginia University, and the sensor was tested in an intramural AFF Program laboratory. However, to verify that the components would work together, we conducted field tests.

In 2000, a new NORA project continued the AutoROPS work and included research for CROPS and composite ROPS (described separately). The project included funding for the development of a remote control test tractor and a field overturn test site at the NIOSH Pittsburgh Research Laboratory (PRL).

In the spring of 2000, the first AutoROPS overturn test was conducted at PRL. It showed that the AutoROPS worked. Subsequent testing refined the AutoROPS structure and sensor designs. The structure design was refined to make the AutoROPS smaller and lighter. The latching mechanisms were redesigned for easier operation and better manufacturing. The sensor was redesigned to replace obsolete parts and to incorporate other functions to reduce false deployments. One of the issues we encountered when trying to interest manufacturers in these designs was their reluctance to adopt new technologies because of liability issues. Tractor manufacturers encouraged us to further refine the technology before serious consideration could be given to full collaboration in transferring the AutoROPS design for application on new tractors.

In June, 2003, we solicited equipment manufacturers for a partnership with an announcement in the Federal Business Opportunities publication, a common method of identifying private companies interested in contracting work with Federal agencies. Through this advertisement, we entered into a partnership with SCAG Power Equipment. They were interested to see if we could develop an AutoROPS for their line of zero turn lawn mowers.

Retracted Deployed

An AutoROPS adapted for a zero turn lawn mower.

With the NORA project coming to a close, we applied for a grant through the California State University San Bernardino Office of Technology Transfer and Commercialization (OTTC) to continue work with SCAG. OTTC's mission is to promote the transition of new technologies to the marketplace [OTTC 2006].Our grant was awarded at the end of 2004, and the new AutoROPS was developed with SCAG for its Turf Tiger zero-turn mower.

During our work with OTTC to transfer the new ROPS technology, it came to our attention that another major barrier to adoption by manufacturers was the lack of an appropriate standard for testing the AutoROPS design. With assistance from Emerging Growth, LLC, we petitioned ASABE to begin work on a performance standard for the AutoROPS. Once a standard is issued, manufacturers such as SCAG can begin producing the AutoROPS.

Engineering Controls - CROPS

In 2000, a new NORA project continued the AutoROPS work. It included research for CROPS and composite ROPS. The CROPS research investigated the use of readily available commercial parts to construct a ROPS for different model tractors. The AFF Program team looked at data estimating the most common tractors in use without ROPS. On the basis of the data, the team chose 10 tractor models for CROPS designs. Initially, the researchers investigated different CROPS designs for a Ford 4600 model tractor (because we already owned one). In 2002, the team successfully designed, built, and tested a CROPS design that passed the ASAE–J2194 industry ROPS standard. (Appendix 6.1-04)

Having successfully demonstrated that commercially available components could be used to build a valid ROPS, the team began work on five more CROPS designs. Through Federal Business Opportunities, we solicited help from a ROPS manufacturer. A partnership with FEMCO resulted. FEMCO was responsible for manufacturing two of the five CROPS designs. Because of FEMCO's production schedule, they have not yet produced any CROPS.

CROPS design for a Ford 4600 tractor.

The AFF Program team completed the designs for all five tractor models. However, there were more models identified that required a CROPS design. We plan to complete five additional CROPS designs and are seeking a new partnership with a ROPS manufacturer for production and sale of CROPS.

Anthropometry of Agricultural Populations

Inappropriate fit of people to workplace vehicles and equipment can directly or indirectly result in injury to workers. People in the United States are becoming taller and heavier with time. In addition, much of the anthropometric data available regarding the fit or design of machines in the workplace are two dimensional. In addition, anthropometric data on working women and minorities is typically not available. (Appendix 6.1-05)

To address this gap in reliable anthropometry data, the AFF Program invested in the lastest whole-body scanning technology, and began collection 3-D body measurements of specific worker populations, including farmers and farm workers. The use of 3-D body form models allows designers and manufacturers to deliver more accurate and better fitting products through a substantial reduction in measurement error and a reduced reliance on body form assumptions.

3-dimensional scanned image of an agricultural worker.

A total of 100 agricultural workers were scanned using the 3-D system [Hsiao et al. 2005]. The results showed that the vertical clearance for the current Society of Automotive Engineers ROPS standard is approximately 12% too short. We are sharing these data with the Society of Automotive Engineers J2194 standard committee so that the tractor cab dimension standard might be updated. Other uses of these data are also being explored.

Tractor Hazard Control Policy

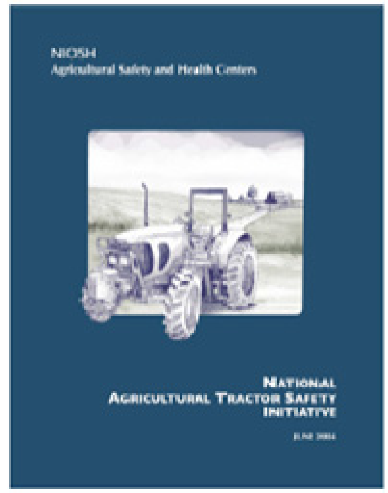
In 1997, extramural AFF Program staff at the University of Iowa sponsored the TRAC Policy Conference. The purpose of the event was to develop a consensus approach to implementing a tractor-related injury and fatality prevention program. This program was based in part on the TRAC-Safe program developed by the University of Iowa [NIOSH 1996]. Representatives from the farming community, research community, Federal agencies, and Iowa State legislature staff participated in the conference.

TRAC-SAFE

The conference ended with a list of recommendations:

- Increase the use of ROPS on tractors
- Reduce injuries and deaths due to collisions between tractors and motor vehicles on public roadways
- Reduce injuries and deaths from being run over by tractors
- Reduce the incidence of tractor-related injuries and death to youth on farms [Donham et al. 1998].

However, no clear consensus was reached on all aspects of this topic, which has prevented the recommendations from being implemented in Iowa and elsewhere.



The NIOSH Centers for Agricultural Safety and Health convened a Tractor-Related Injury and Death Meeting in Pittsburgh in 2003. AFF Program researchers met with partners to address tractor-related injuries and fatalities. The Centers published goals and recommendations to reduce the number of tractor-related injuries and fatalities in the United States. The AFF Program is currently funding five grants to address these goals and recommendations.

6.1c Selected Outputs

Hsiao H, Whitestone J, Bradtmiller B, Zwiener J, Whistler R, Kau T, Gross M, Lafferty C. [2005]. Anthropometry criteria for the design of tractor cabs and protection frames. Ergonomics 48(4):323-353. (Current research that applied newly collected anthropometric data to identify areas where the existing Roll-Over Protective Structure standard can be improved. These changes in the ROPS standard are currently being developed by the Society of Automotive Engineers. Paper has been cited at least 3 times based on a literature citation search. The results of this work were presented at the 2005 National Institute for Farm Safety Annual Conference, June 28, 2005, Wintergreen, VA.)

Pana-Cryan, Myers ML. [2000]. Prevention effectiveness of Roll-Over Protective Structures-Part III: economic analysis. Journal of Agricultural Safety and Health 6(1):57-70. (Paper provides the most comprehensive economic analysis by NIOSH of the cost benefit of using ROPS on farm tractors. The paper included the benefits of preventing nonfatal injuries along with the benefits of preventing fatal injuries from tractor overturns in the US. Paper has been cited at least 5 times based on a literature citation search.)

Myers JR, Snyder KA. [1995]. Roll-over protective structure use and the cost of retrofitting tractors in the United States, 1993. Journal of Agricultural Safety and Health 1(3):185-197. (Paper presented ROPS use information for the first time at the national level, defined what specific tractors needed retrofitted with ROPS, and provided an estimate of the cost to do the retrofitting of ROPS on these tractors. Results lead to NIOSH and other extramural partners work on developing inexpensive ROPS designs for older farm tractors. Paper has been cited at least 29 times based on a literature citation search. Results of this work were presented at the Tractor Risk Abatement and Control Policy Conference, September 10-12, 1997, University of Iowa, Iowa City, IA.)

A complete list of outputs can be found in section 6.3 at the end of this chapter.

6.1d Intermediate Outcomes

ROPS Development

In 1985, ASAE adopted the voluntary standard S318.10, which recommended that all new farm tractors sold in the United States be fitted with a ROPS. We estimate that more than 95% of all tractors used on farms manufactured after the adoption of this voluntary standard have ROPS. The use of these newer ROPS–equipped tractors accounts for most of the 12% increase in ROPS use on farms.

A new standard for AutoROPS, Standardized Deployment Performance of an Automatic Telescoping ROPS for Agricultural Equipment (ASABE–X599), is in draft form and has undergone its first review by ASABE. This standard, once issued, will give the manufacturers criteria to build, test, and sell AutoROPS to consumers.

Anthropometry

Anthropometry data from the AFF Program are being used by the ASAE J2194 standard committee to examine updating the tractor cab dimension standard, which will have a potential impact on the design of the next generation tractor cabs, affording better protection to the estimated six million tractor/farm machine operators in the United States.

Surveillance

Tractor data collected through the TISF survey were used by Colorado State University. Engineering research was conducted to evaluate the ability of pre-ROPS tractors to withstand the forces of a tractor overturn if ROPS were designed and mounted on them. TISF tractor prevalence data were used to identify common tractors by manufacturer and model for ROPS retrofit evaluations (e.g., Ford 8–N). The TISF data were the only information source for prioritizing these research evaluations.

6.1e External Factors

An external factor affecting our efforts on tractor safety is the workforce's lack of perceived need for ROPS or urgency to obtain ROPS [May et al. 2006; Hallman 2005; Kelsey et al. 1996].

Another external factor was manufacturers' attitudes and behaviors. We learned that some manufacturers are reluctant to help prove the concept or adopt new safety technology relevant to their products because of concerns about liability. If new safety technology has been proven but has not been adopted or integrated into a manufacturer's product, the manufacturer may be liable for injuries that the technology could have prevented. Thus, manufacturers, particularly those with a large share of the market, proceed slowly to finalize and prove new safety technology. Manufacturers are also reluctant to implement new technology without a specific consensus standard addressing building and testing criteria. In addition, we learned that the patent process is very time consuming and can significantly delay product adoption.

We learned that small companies are often more willing than large name-brand companies to partner with researchers and take risks to gain stature in the market, so we worked with smaller manufacturers. Another strategy was to engage with manufacturing partners (and relevant trade associations) early in the development process to seek their input and ensure their buy-in of the end product. In the final stages of prototyping and testing, partnership agreements that share and formalize roles and responsibilities of both the government and the manufacturers help to avoid manufacturer efforts to forestall progress towards a proven safety technology. The importance of facilitating the development of product standards simultaneously with new technology was also an important lesson. The cost-benefit of patenting AFF Program-developed technology, in terms of both time and cost, is an ongoing lesson we are learning.

Voluntary standards from organizations like ASABE or ASAE are critical to getting manufacturers to adopt new technology. Regulatory mandates for the use of ROPS have not occurred, despite mandates in other nations, such as Sweden.

6.1f Future Directions

The AFF Program plans to continue tracking the use of ROPS on farms through the OISPA project. We plan to continue efforts in the development of the X599 AutoROPS Performance Standard within ASABE. The goal is to have the standard published within the next two years. The CROPS project will not be complete until the end of 2007. By this time, we hope to have a ROPS manufacturer offering CROPS as an alternative for consumers.

6.1g List of NIOSH projects that are included in this section

- DSR-VLB827-Occupational Traumatic Injury Surveillance of Farmers (Appendix 3.2-01)
- DSR-9277135-Occupational Injury Surveillance of Production Agriculture (Appendix 3.2-02)
- DSR-9278951-Analysis of Surveillance Data for Agricultural Injuries (Appendix 3.3-04)
- DSR-9277178-New Technology to Increase ROPS Use on Tractors (Appendix 6.1-01)
- DSR-9278818-Development of Automatic ROPS (Appendix 6.1-02)
- DSR-9278885-Development of Automatic ROPS Overturn Sensor (Appendix 6.1-03)
- DSR-927006T-Commercialization of a Cost-effective ROPS (CROPS) Design (Appendix 6.1-04)
- DSR-9278933-Anthropometry of Agriculture Populations (Appendix 6.1-05)

6.2 Ergonomic Interventions

Reduce musculoskeletal morbidity resulting from work in AFF Program industries by introducing ergonomics to reduce harmful exposures while potentially increasing productivity as an incentive.

6.2a Challenges and Issues

At the 1991 Surgeons General's conference on Agricultural Safety and Health, MSDs were recognized as the second leading work-related disease or injury in agriculture [DHHS 1992]. Farm work is typically hard physical labor. Researchers have found that backaches and pain in the shoulders, arms, and hands are the most common ailments farm workers report [Mobed K et al]. One third of farm worker sprain/strain injures and one quarter of their back injuries result in missed work [BLS 1996]. In other industries that are prone to MSDs, reengineering work procedures or redesigning tools has commonly been used to reduce injuries [NIOSH 1997]. However, very little has changed in the way most farm work is performed. Field work is still performed in a stooped position; workers often carry heavy weights in awkward positions, kneel frequently, work with their arms above shoulder level, or perform repetitive movements with their hands and wrists. These jobs can be made safer.

In 1998, the AFF Program convened a conference of researchers who were working in the area of agriculture and musculoskeletal disorders. The partners determined that until recently, ergonomic research for farm workers in this area had been minimal and not widely known. It was speculated that only five or six researchers in the United States were working in this area.

6.2b Activities

AFF Program work on ergonomic issues in the agriculture industry has been done by university researchers through extramural NIOSH funding mechanisms. (Appendix 3.1-04)

AFF Program researchers at the University of California Davis have conducted ergonomic research among tree nursery workers and wine grape and tree fruit harvesters from 1990 to the present. Over the years, the research with these different groups had a cumulative effect, with newer research building on the results of earlier studies. Between 1990 and 1994, we worked with nursery workers and employers to identify the most strenuous tasks and then find ways to make them easier. Together we developed a nursery pot carrier system for reducing bending and stooping movements.

The AFF Program researchers began working with the wine grape harvesters in 1996. We worked on reducing the size of the grape bins used by the workers, thus reducing lifting demands. Adjustments were also made in the material used for the bin handles to reduce workers' gripping effort requirements. Musculoskeletal pain was significantly without reducing production significantly by the use of lighter, slightly smaller bins for harvesting. More recently, AFF Program researchers worked to develop a "bolt-on" tractor apparatus that helps workers move the smaller bins with less bending and lifting.

Use of small bins with better grips reduces musculoskeletal pain without reducing production

Organizational partners in the California research include four major wine grape producers with their own vineyards; the California Farm Bureau, the California State Compensation Insurance Fund (the State's largest workers' compensation insurer), USDA extension advisors for wine grape growing in Napa and Sonoma counties; two large farm labor contractors; equipment manufacturers; commodity-focused agricultural organizations (e.g., the California Pear Advisory Board, Avocado Commission and Citrus Research Board); and other California universities.

Use of bin mover reduces lifting and carrying in grape harvesting

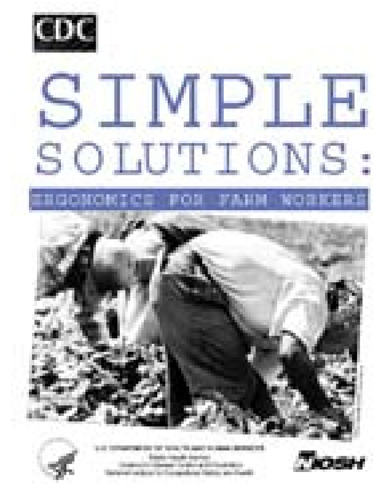
Since 2004, the California AFF Program researchers have worked with tree fruit harvesting workers and employers on multiple interventions to reduce ergonomic hazards. One is a specially designed platform machine previously used by apple growers in Washington State. The machine eliminates the need for a ladder and picking bags. Tests of the platform harvester showed no significant bruising of fruit, a critical factor.

AFF Program researchers at the University of Wisconsin developed social marketing hypotheses to research the adoption of ergonomic and other safety innovations in the dairy, berry, and nursery industries. Information materials were prepared for workers and employers about these innovations, but other information was prepared for targeted trade publications too. In addition, some farmers were recruited to talk with their peers about the innovations at trade shows. Extensive evaluation of these diffusion efforts was undertaken, measuring farmers' likelihood of adopting ergonomic changes after information campaigns, and comparison of measured rates with those of a control group. Those methods were presented by the principal investigator at the NORA symposium in April, 2006 in an invited presentation. Known as the Healthy Farmers/Healthy Profits project, it began in 1996 and is ongoing (http://bse.wisc.edu/hfhp).

In 1993, the AFF Program received a Health Hazard Evaluation request from the Maine Department of Human Services to investigate cases of "rakers tendonitis," which was reported among seasonal harvesters who raked wild blueberries in Maine. The AFF Program staff recommended a redesign of the rake to give it a long handle or to provide two handles. A report of this study was published in the New England Journal of Medicine (1994) and the American Industrial Hygiene Association Journal (1996).A fact sheet on the new rake was also published in *Simple Solutions: Ergonomics for Farmworkers* (2001). The Maine Agricultural Safety and Health Program developed a pamphlet about the rake that they distributed in schools and then evaluated the incidence of musculoskeletal disorders. Their report was published in the American Journal of Public Health (1996). The Maine Department of Human Services, the Maine Agricultural Safety and Health Program, and the C&D Corporation were partners on the rake project.

6.2c Selected Outputs

In 2001, intra- and extramural AFF Program researchers developed a booklet, *Simple Solutions: Ergonomics for Farm Workers* in collaboration with several stakeholders. Since many farmers are small employers with limited resources, the booklet focuses on low-cost solutions and includes diagrams for building them on the farm. AFF Program researchers developed 12 of the 16 interventions presented in the booklet. The booklet helps readers to develop their own solutions through guidelines, resources, and a "how to build ergonomic teams" section.



NIOSH Document: Simple Solutions: Ergonomics for Farm Workers

Simple Solutions takes research and puts it into the hands of those who can use it. Letitia Davis, Director of the Massachusetts Occupational Health Surveillance Program, wrote, "Congratulations! *Simple Solutions* is absolutely wonderful....we need them for all sectors."

Nitsa Allen-Barash, Ph.D., of the University of Washington wrote, "I have just reviewed [it]. I like it a lot—both content and format—and am planning to share it with people in eastern Washington. The examples seem comprehensive and very well presented, attractive, and nicely laid out. I also like the cost effectiveness information [Allen-Barash 2001]."

More than 80,000 copies of *Simple Solutions* have been disseminated (20,000 in Spanish). Because of continuing demand, the AFF Program will print additional copies in Fall 2006. It is available on the NIOSH Web site. Agriculture safety and health stakeholders such as the National Center for Farmworker Health have linked to this document from their Web sites.

Because of the good reception of this document, NIOSH has plans to develop similar documents for construction, mining, and maritime workers.

AFF Program researchers published information about ergonomics related to children in the document *Children and Agriculture: Opportunities for Safety and Health: A National Action Plan (NAP)* (Appendix A2-4).

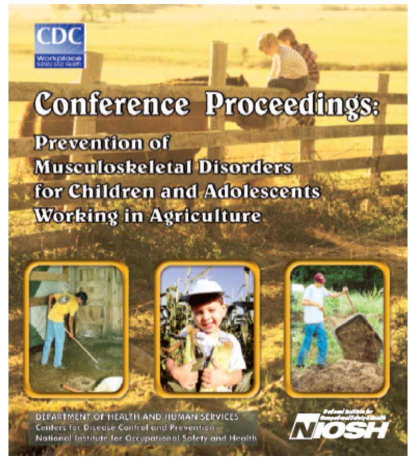
Strap-on stool improves ergonomics in tasks normally requiring bending and stooping

A publication related to the wine grape production tub project received the National Institute for Farm Safety's 2003 Research Award for its contribution toward preventing agricultural injury and illness [Meyers et al. 2001]. Further information and a research report on this project and other AFF Program-funded ergonomic work at the University of California, Davis can be found at http://ag-ergo.ucdavis.edu

The Healthy Farmers/Healthy Profits project created 24 tip sheets related to dairy direct-market farmers, berry growers, and nursery operations. The tip sheets are disseminated through a Web site (http://bse.wisc.edu/hfhp) and at trade shows. Recruited volunteer peer farmers staff exhibits at trade shows to share these tips. They do it in exchange for registration fees.

In 2006, the principal investigator on this project presented the results of the Healthy Farmers/Healthy Profits project at a plenary session of the NORA Symposium as a model for evaluating interventions. In addition, materials were included in other publications such as *Small-Scale Post-Harvest Handling Practices*, *a Manual for Horticultural Crops,* which was published in several languages [Newenhouse, 2002].

An AFF Program Health Hazard Evaluation report was prepared on blueberry harvesting. The document reported the first documentation of the musculoskeletal risk factors of harvesting blueberries. The report proposed new designs for the rake that is used to harvest blueberries. A New England Journal of Medicine report and another peer-reviewed journal article were prepared by AFF Program staff. This investigation was highlighted as a fact sheet in *Simple Solutions: Ergonomics for Farmworkers*.



In 2002, the AFF Program convened *Prevention of Musculoskeletal Disorders for Children and Adolescents Working in Agriculture.* This conference of multidisciplinary experts discussed the issues of preventing musculoskeletal disorders among children working in agriculture. The published proceedings helped describe the hazards faced by children and adolescents who work in agriculture (typically on family farms) and gave specific suggestions for how to assess high risk jobs, conduct surveillance, and implement interventions [Waters and Wilkins 2004]. In 2004, the AFF Program contributed to *Stooped and Squatting Postures in the Workplace,* a conference for assessing ergonomic problems and potential interventions of ergonomic problems in agriculture as well as in construction and other sectors. The proceedings were published [Fathallah et al. 2005].

A complete list of outputs can be found in section 6.3 at the end of this chapter.

6.2d Intermediate Outcomes

AFF extramural researchers in California redesigned nursery pot carriers to reduce ergonomic hazards for workers moving nursery pots. The nursery pot handles are now being sold through Gemplers, an agriculture products mail order catalog.

AFF Program researchers promoted six different safer, more profitable dairy farming practices among all dairy farmers in Wisconsin (~20,000) from 1997 to 2005. Questionnaires were used to measure the degree of adopting the new practices. Results showed that the likelihood of adopting barn lights, silo bags, and calf care feeding sites all increased significantly among northeast Wisconsin dairy farmers [Chapman et al. 2005]. Over this same period, there were also increases in the awareness of barn lights and the calf feed sites

The response to the *Simple Solutions* document has been positive.

- Matthew Keifer, MD of the Harborview Medical Center, Seattle reported on the Migrant Health Research Listserv, "For those of you who have not seen that pub yet, I encourage you to get a copy. It's a practical and very clearly written collection of recommendations. I found it very useful and thought provoking. It's a great handout for farmers, farm workers and farm managers." [Keifer 2001]
- East Carolina University systems engineering classes use it in their introductory class to applied technology as a guide for student projects and evaluation of those projects [Personal communication 2005].

- The North Carolina Labor Department praised the Spanish version of the document and indicated that they would use it for orientation of Mexican immigrant workers [North Carolina Dept. of Labor 2003].
- The USDA Coordinator of Agricultural Labor Affairs in the Office of the Chief Economist, USDA sent a three-paragraph article about the booklet to all their [?] Agricultural Health Centers, recommending that they get copies [Personal communication 2001].
- Gregorio Billikopf, of the University of California wrote the following to the Agricultural Health Listserv, "The manual is full of photographs and practical ideas. There is an excellent section on lifting, and a second example on lifting translated into Spanish as a sample [Billikopf 2003]."
- ErgoWeb and *CTD news* both wrote stories to make sure their readers knew about the booklet and directed their readership to download it from the Web site [Personal communication 2001]

As a result of the AFF Program research on ergonomic interventions for harvesting tree fruit, one major producer of pears has ordered two of the harvesters. In addition, in the 2006 harvest season, women were employed to do the pear harvesting from the platforms, a task reserved for men before. Women are probably being used because of a labor shortage and the fact that the platform system does not require carrying heavy bags up and down ladders.

6.2e End Outcomes

Management and workers in wine grape production adopted the smaller, lighter picking tubs (>3000 tubs in 2002 and 3400 in 2003) developed by AFF Program researchers. The only incentive for adoption was improved working conditions. Since the study, these smaller tubs have become the most common type used in the Napa and Sonoma counties' hand harvest. We presume that exposures have been reduced.

6.2f External Factors

Like other occupational safety and health issues, ergonomic research is affected by social, economic, and regulatory conditions that may help or hinder progress.

Social conditions include attitudes of workers and employers toward innovation in the workplace. They know the demands of their work, are creative about improving well-known processes, and have skills to adapt equipment and procedures. These factors help transfer ergonomic solutions to the workplace. However, workers and employers may lack knowledge of body systems that are affected by ergonomic risks—knowledge that would help them collaborate with researchers. Further, workers and employers may resist workplace changes when they have been doing things a certain way for a long time. Some workers are concerned that ergonomic changes will de-skill their work, reducing their potential income.

Good ergonomic interventions are often cost-effective and can enhance production. Workers and employers will often adopt interventions they perceive to be cost-effective, even in the absence of regulatory requirements. However, ergonomic changes can be expensive to adopt, with economic benefits uncertain for some time after adoption.

The ergonomic regulatory environment has been relatively inactive in the last decade. That has both stimulated and retarded ergonomic research and prevention efforts in the workplace.

Finally, evidence of outcomes from this research is limited by at least two factors. First, surveillance systems do not yet capture agricultural injuries in general and ergonomic-related musculoskeletal injuries in particular. Second, much of the population at risk is still unaware of their risk of experiencing work-related musculoskeletal problems.

6.2g Future Directions

Limited interventions are currently available to prevent the need to stoop and bend in many agricultural tasks, e.g. in the harvesting of berries. Research in this area is planned.

Plans are underway to further disseminate effective solutions to ergonomic hazards.

6.2h List of NIOSH projects that are included in this section

- DSHEFS-9278501-Community Partners for Healthy Farming (Appendix 3.1-04)

6.3 Outputs

6.3a Tractor Safety

Sponsored Workshops

Tractor Risk Abatement and Control Policy Conference, September 10–12, 1997, University of Iowa, Iowa City, IA.

Tractor-Related Injury and Death Meeting, February 13–14, 2003, Pittsburgh, PA.

Peer Reviewed Articles

Etherton JR, Cutlip RG, Harris JR, Ronaghi M, Means KH, Gillispie A [2002]. Static load test performance of a telescoping structure for an automatically deployable ROPS. J Ag Safety Health 8(1):119–126. (IS I Web of Science: Cited 1 time as of 11/20/06)

Etherton JR, Cutlip RG, Harris JR, Ronaghi M, Means KH, Howard S [2002]. Dynamic performance of the mechanism of an automatically deployable ROPS. J Ag Safety Health 8(1):113–118. (IS I Web of Science: Cited 1 time as of 11/20/06)

Etherton JR, McKenzie Jr EA, Lutz TJ, Cantis DM, Kau TY [2004]. An initial farmer evaluation of a NIOSH AutoROPS Prototype. Int J Ind Ergonomics 34:155–165

Harris JR, Ronaghi M, Snyder KA [1998]. Analyzing tractor rollovers using finite element modeling. Analysis Solutions *2*(4):24–25.

Hsiao H, Long D, Snyder K [2002]. Anthropometric differences among occupational groups. Ergonomics *45*(2):136–152. (IS I Web of Science: Cited 3 times as of 11/20/06)

Hsiao H, Whitestone J, Bradtmiller B, Zwiener J, Whistler R, Kau T, Gross M, Lafferty C. [2005]. Anthropometry criteria for the design of tractor cabs and protection frames. Ergonomics *48*(4):323–353.

Myers ML [1998]. NIOSH perspective on tractor-related hazards. J Ag Safety Health *4*(4):205–230.

Myers ML [2000]. Prevention effectiveness of roll-over protective structures. Part I: strategy evolution. J Ag Safety Health *6*(1):29–40. (IS I Web of Science: Cited 3 times as of 11/20/06)

Myers ML, Pana-Cryan R [2000]. Prevention effectiveness of roll-over protective structures. Part II: decision analysis. J Ag Safety Health *6*(1):41–55. (IS I Web of Science: Cited 1 time as of 11/20/06)

Myers JR, Snyder KA [1995]. Roll-over protective structure use and the cost of retrofitting tractors in the United States, 1993. J Ag Safety Health *1*(3):185–197. (IS I Web of Science: Cited 8 times as of 11/20/06)

Myers JR, Snyder KA, Hard DL, Casini VJ, Cianfrocco R, Fields J, Morton L [1998]. Statistical and epidemiology of tractor fatalities-a historical perspective. J Ag Safety Health *4*(2):95–108. (IS I Web of Science: Cited 5 times as of 11/20/06)

Pana-Cryan R, Myers ML [2002]. Cost effectiveness of roll-over protective structures. Am J Ind Med 42(S2):68–71.

Pana-Cryan R, Myers ML [2000]. Prevention effectiveness of Roll-Over Protective Structures-Part III: economic analysis. Journal of Agricultural Safety and Health 6(1):57-70.

Powers JR, Harris JR, Etherton JR, Snyder KA, Ronaghi M, Newbraugh BH [2001]. Performance of an automatically deploying ROPS on ASAE Tests. J Ag Safety Health 7(1):51–61. (IS I Web of Science: Cited 2 times as of 11/20/06)

Powers JR, Harris JR, Etherton JR, Ronaghi M, Snyder KA, Lutz TJ, Newbraugh BH [2001]. Preventing tractor rollover fatalities: performance of the NIOSH AutoROPS. Inj Prev 7(Suppl I):54–58. IS I Web of Science: Cited 1 time as of 11/20/06)

Conference Papers

Etherton JR, McKenzie EA Jr., Powers JR [2004]. Commercializing an automatically deployable rollover protective structure (AutoROPS) for a zero-turn riding mower: initial product safety assessment criteria. In: Proceedings of the ASME International Mechanical Engineering Congress and Exposition, Anaheim, CA, November 13–19.

Harris JR, Cantis DM, McKenzie EA Jr., Etherton JR, Ronaghi M [2005]. Commercialization of cost-effective rollover protective structures (CROPS): research-in-progress. In: Proceedings of the National Institute for Farm Safety (NIFS) Annual Conference, Wintergreen, VA, June 26–30.

Harris JR, Etherton JR, Cantis DM, McKenzie EA Jr., Ronaghi M [2004]. Tractor overturns and ROPS performance—is the SAE standard tough enough? National Symposium on Agricultural Safety and Health, Keystone Resort, CO, June 20–24.

Harris JR, McKenzie EA Jr., Cantis DM, Etherton JR, Ronaghi M [2004]. Technology transfer— putting cost-effective rollover protective structures in the field. National Symposium on Agricultural Safety and Health, Keystone Resort, CO, June 20–24.

Harris JR, McKenzie EA Jr., Etherton JR, Cantis DM [2002]. Designing cost-effective rollover protective structures (CROPS) at NIOSH. In: Proceedings of the National Institute for Farm Safety (NIFS) Annual Conference, Ponte Vedra, FL, June 23–27.

Guan J, Hsiao H, Current RS, Powers JR, Ammons DE [2003]. Traumatic injury potential to seat belted operator during a rearward overturn of a ROPS equipped farm tractor. NORA Meeting, Arlington, VA, June 23–24, p. 51.

Guan J, Hsiao H, Zwiener J, Current RS, Newbraugh BH, Powers JR, Spahr J [2005]. Injury potential to a seat-belted operator during a rear and side overturn of a ROPS equipped farm tractor. In: Proceedings of the National Institute for Farm Safety Conference, Wintergreen, VA, June 28, p. 81. (ISI Web of Science: Cited 2 times as of 11/20/06)

Harris JR, Mucino V, Etherton JR, Snyder KA, Means KH [1997]. Computer simulation of ROPS testing in ASAE S519. National Occupational Injury Research Symposium (NOIRS), Morgantown, WV, October 15–17, p. 46.

Lutz TJ, McKenzie EA Jr. [2005]. Remote control on a zero-turn commercial lawn mower to conduct SAE J2194 rollover test. In: Proceedings of the 2005 American Society of Agricultural Engineers Annual International Meeting, Tampa, FL, July 17–20.

McKenzie EA Jr., Etherton JR, Harris JR, Cantis DM, Lutz TJ [2005]. NIOSH AutoROPS research to practice: zero turn commercial mowers. In: Proceedings of the 2005 American Society of Mechanical Engineers Congress and Exposition, Orlando, FL, November 8–11.

McKenzie EA Jr., Etherton JR, Harris JR, Cantis DM, Lutz TJ [2003]. NIOSH AutoROPS 3rd generation static testing and human interaction element. In: Proceedings of the 2003 American Society of Mechanical Engineers Congress and Exposition, Washington, DC, November 15–21.

Myers JR [2003]. Tractor occupational safety and health update. In: Record of tractor- related injury and death meeting. Pittsburgh, PA, February 13–14. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, pp. 5–23.

McKenzie EA Jr., Etherton JR [2002]. NIOSH AutoROPS latch and release mechanism: second generation. In: Proceedings of the 2002 American Society of Mechanical Engineers Congress and Exposition, New Orleans, LA November 17–22.

McKenzie EA Jr., Etherton JR [2002]. Novel latch and release mechanism for an automatically deployable ROPS. Agricultural Equipment Technology Conference, Kansas City, MO, February 20–23.

McKenzie EA Jr., Powers JR, Harris JR, Ronaghi M, Etherton JR, Current RS, Cantis DM, Newbraugh BH, Lutz TJ [2001]. Continuing developments at NIOSH on ROPS for agricultural tractors. In: Proceedings of the National Institute for Farm Safety Annual Conference, Pittsburgh, PA, June 24–27.

Powers JR, Harris JR, Etherton JR, Snyder KA, Ronaghi M, Newbraugh BH [2000]. Performance of a new ROPS on ASAE tests. In: Proceedings of the 93rd Annual International Meeting of ASAE, Paper No. 007005, Milwaukee, WI, July 9–12.

Powers JR, Harris JR, Snyder KA, Ronaghi M, Etherton JR, Newbraugh BH [2000]. Performance of the NIOSH AutoROPS. National Occupational Injury Research Symposium (NOIRS), Pittsburgh, PA, October 17–19, p.12.

Ronaghi M, Abukhadra SM, McKenzie EA Jr., Etherton JR, Means KH [2005]. Finite element modeling of a fiber reinforced plastics composite materials in automatically deployable rollover protective structure. In: Proceedings of the 2005 American

Society of Mechanical Engineers Congress and Exposition, Orlando, FL November 8–11.

Ronaghi M, Harris JR, Powers JR, Snyder KA [2000]. Dynamic nonlinear analysis of tractor rollovers. In: Proceedings of the 9th International ANSYS Conference and Exhibition, Pittsburgh, PA, August 28–30.

6.3b Ergonomic Interventions

Peer-reviewed articles

Allread WG, Wilkins JR III, Waters TR, Marras WS [2004]. Physical demands and low-back injury risk among children and adolescents working on farms. J Ag Safety Health *10*(4):255–272.

Bartels S, Niederman B, Waters TR [2000]. Job hazards for musculoskeletal disorders for youth working on farms. J Ag Safety Health 6(3):191–201. (IS I Web of Science: Cited 4 times as of 11/20/06)

Chapman LJ, Newenhouse AC, Meyer RH, Karsh B, Taveira AD, Miquelon M [2003]. Musculoskeletal discomfort, injuries and tasks accomplished by children and adolescents in fresh market vegetable work. J Ag Safety Health 9(2):91–105. (IS I Web of Science: Cited 1 time as of 11/20/06)

Chapman LJ, Meyers J [2001]. White paper: ergonomics and musculoskeletal injuries in agriculture: recognizing and preventing the industry's most widespread health and safety problem (paper and oral presentation). NN: 20022184.

Chapman LJ Meyers J [2001]. Proceedings of the Agricultural Safety and Health Conference: Using Past and Present to Map Future Actions. Baltimore, MD, March 2–3, 2001. Available at http://www.uic.edu/sph/glakes/agsafety2001/
Chapman L, Newenhouse A, Meyer R, Taveira A, Karsh B, Ehlers J, Palermo T [2004]. Evaluation of an intervention to reduce musculoskeletal hazards among fresh market vegetable growers. Applied Ergonomics *35*(1):57–66. NN: 20025596.

Chapman LJ, Newenhouse AC, Pereira KM, Karsh BT, Meyer RM, Brunette C, Ehlers JJ [in press]. Evaluation of a four year intervention to reduce musculoskeletal hazards among berry growers. Appl Ergonomics.

Ehlers J, Palermo T [2005]. Community partners for healthy farming intervention research. J Ag Safety Health *2*(11):193–203. NN: 20028889

Ehlers J, Palmero T [1999]. Community partners for health farming: involving communities in intervention planning, implementation, and evaluation. Am J Ind Med (Suppl1):107–109. NN: 20000843 (IS I Web of Science: Cited 2 times as of 11/20/06)

Estill CF, Tanaka S [1998]. Ergonomic considerations of manually harvesting Maine wild blueberries. J Ag Safety Health *4*(1):43–57.
NN:20025139 (ISI Web of Science: Cited 1 time as of 11/20/06)
[http://asae.frymulti.com/tocjournals.asp?volume=4&issue=1&conf=j&orgconf=j1998].

Estill C, Tanaka S, Wild D [1996]. Ergonomic considerations of manually harvesting Maine wild blueberries. Am Ind Hyg Assoc J *57*(10):946–948. NN: 00233944

Estill CF, Tanaka S, Wild DK [1996]. Ergonomic considerations of manually harvesting Maine wild blueberries (AIHCE extended abstract) Am Ind Hyg Assoc J *57*(10):946–948. NN: 00233944

Faucett J, Meyers J, Tejeda D, Janowitz I, Miles J, Kabashima J [2001]. An instrument to measure musculoskeletal symptoms among immigrant Hispanic farm workers: validation in the nursery industry. J Ag Safety Health *V7*(3):185–198 (IS I Web of Science: Cited 1 time as of 11/20/06)

Meyers J, Miles J, Faucett J, Janowitz I, Tejeda D, Weber E, Smith R, Garcia L [2001]. Priority risk factors for back injury in agricultural field work. J Agromed *8*(1):37–52. (Received the National Institute for Farm Safety's 2003 Research Award for its contribution toward prevention of agricultural injury and illness)

Millard PS, Shannon SC, Carvette B, Tanaka S, Halperin WE [1996]. Maine students' musculoskeletal injuries attributed to harvesting blueberries. Am J Public Health *86*(12): 1821–1822. (IS I Web of Science: Cited 1 time as of 11/20/06)

Newenhouse A, Meyer RH, Chapman LJ [2002]. Work efficiency tips for small scale growers. In: Kitinoja L, Kader A, eds. Small-Scale Post-Harvest Handling Practices, a Manual for Horticultural Crops. 4th ed. Davis, CA: University of California-Davis, Postharvest Technology Research and Information Center. (Translated into Spanish, Arabic, Bhasa Indonesia, Portuguese and several other languages).

Spielholz P, Silverstein B, Stuart M [1999]. Reproducibility a self-report questionnaire for upper extremity musculoskeletal disorder risk factors. Appl Ergonomics (30):429–433. (IS I Web of Science: Cited 5 times as of 11/20/06)

Spielholz P, Howard N [2000]. A critical evaluation the participatory ergonomics approach in industry. In: Advances in Occupational Ergonomics and Safety III: Proceedings of the Annual ISOES Conference, International Society for Occupational Ergonomics and Safety.

Book

Newenhouse, A. Meyer RH, Chapman LJ. Work efficiency tips for small-scale growers [2002]. In L. Kitinoja and A. Kader, Eds. Small-Scale Post-Harvest Handling Practices: A Manual for Horticultural Crops. 4th ed. Postharvest

Technology Research and Information Center: University of California-Davis, p 38-40. Translated into multiple languages.

Booklets

Baron S, Estill C, Steege A [2001]. Simple solutions: ergonomics for farm workers. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication Nos. 2001–111 (English) and 2001–111(*Sp2002*) (Spanish). Available at: http://www.cdc.gov/niosh/01-111pd.html (English) and http://www.cdc.gov/spanish/niosh/docs/01-111pd-sp.html (Spanish).

Booklets by Delahaut and Newenhouse below available through the University of Wisconsin publication at: http://cecommerce.uwex.edu/showcat.asp?id=18

Delahaut K, Newenhouse A [1997] Growing broccoli, cauliflower, cabbage, and other cole crops in Wisconsin: a guide for fresh-market growers. University of Wisconsin Extension Publication A3684. (Includes ergonomics information).

Delahaut K, Newenhouse A [1997]. Growing beans and peas in Wisconsin: a guide for fresh-market growers. University of Wisconsin Extension Publication A3685. (Includes ergonomics information).

Delahaut K, Newenhouse A [1997]. Growing tomatoes, peppers, and eggplants in Wisconsin: a guide for fresh-market growers. University of Wisconsin Extension Publication A3687. (Includes ergonomics information).

Delahaut K, Newenhouse A [1998] Growing carrots, beets, radishes, and other root crops in Wisconsin: a guide for fresh-market growers. University of Wisconsin Extension Publication A3686. (Includes ergonomics information).

Delahaut K, Newenhouse A [1998]. Growing pumpkins and other vine crops in Wisconsin: a guide for fresh-market growers. University of Wisconsin Extension Publication A3688. (Includes ergonomics information).

Delahaut K, Newenhouse A [2003]. Growing salad greens in Wisconsin: a guide for fresh-market growers. University of Wisconsin Extension Publication A3788. (Includes ergonomics information).

Delahaut K, Newenhouse A [2003]. Growing onions, garlic, leeks, and other alliums in Wisconsin: A Guide for Fresh-Market Growers. University of Wisconsin Extension Publication A3785. Includes ergonomic content.

Fact Sheets

Healthy Farmers/Healthy Profits Tip Sheets
University of Wisconsin at http://bse.wisc.edu/hfhp/
16 tip sheets related to Vegetable Production available at:
http://bse.wisc.edu/hfhp/TipVeggie.htm

10 tip sheets related to Berry Production available at:
http://bse.wisc.edu/hfhp/TipBerry.htm

11 tip sheets related to Nursery Production available at:
http://bse.wisc.edu/hfhp/TipNursery.htm

9 tip sheets related to Dairy Production available at:
http://bse.wisc.edu/hfhp/TipDairy.htm

Proceedings

Chapman LJ, Meyers J [2001]. Agricultural safety and health conference: using past and present to map future actions. Conference Proceedings. Baltimore, MD, March 2–3. Available at: http://www.uic.edu/sph/glakes/agsafety2001/

Fathallah FA, Meyers JM, Janowitz I [2005]. Stooped and squatting postures in the workplace. Conference Proceedings. Oakland, CA: University of California, Center for Occupational and Environmental Health; University of California, Berkeley. Davis, and Oakland, July 29–30. Available at: http://ag-ergo.ucdavis.edu/ .

Waters TR, Wilkins JR III [2004]. Prevention of musculoskeletal disorders for children and adolescents working in agriculture. Conference Proceedings. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2004–119.

Report (unpublished)

Kidd P, Draime J [1998]. Non-traumatic, work-related, musculoskeletal disorders in farm youth. Unpublished final report, NIOSH Contract No. 79278284.

Waters TR [2003]. Two-dimensional biomechanical modeling for estimating strength of youth and adolescents for manual material handling tasks. Poster presented at 2003 Challenges in Agricultural Health and Safety Conference, San Francisco, CA, September 7–9.

Thesis or Dissertation: Example

Spielholz P [1999]. A comparison of upper extremity physical risk factor measurement methods [dissertation]. Seattle, WA.: University of Washington.

Web Pages

Healthy Farmers/Healthy Profits Healthy Farmers-Healthy Profits. Tip sheets related to specific tools and work practices that reduce risks for musculoskeletal injury and are cost effective (Sources of tools provided). Available at: http://bse.wisc.edu/hfhp

NIOSH [2004]. Community Partners for Healthy Farming http://www.cdc.gov/niosh/pgms/commpart/default.html. Linked from the NIOSH Agricultural home page. Contains description of extramural projects funded 2000–2004 and links to extramural projects.

UC Davis. Agricultural ergonomics. Davis, CA. Available at: http://ag-ergo.ucdavis.edu. Contains link to research article summarizing wine grape projects and other ergonomic work funded by NIOSH.

Presentations at National and International Conferences (Selected)

Aherin R, Hard D, Murphy D [1996]. Should ASAE be involved in safety practice standards? Invited panel participant in a panel presentation of the pros and cons of ASAE involvement in developing safety practice standards. Sponsored by T–15 Ergonomics, Safety and Health committee at the Annual International meeting of the American Society of Agricultural Engineers. Phoenix, AZ.

Chapman L, Meyers J [2001]. Ergonomics and musculoskeletal injuries in agriculture: recognizing and preventing the industry's most widespread health and safety problem. Invited white paper. Agricultural Safety and Health Conference: Using Past and Present to Map Future Actions (a major conference reviewing the prior 10 years of work nationally).

Chapman L, Pereira KM, Newenhouse, AC [2006]. A theory-driven, evidence-based intervention: seven years, 4,000 businesses, 3 safer ways to work. Invited plenary. NORA Symposium 2006: Research Makes a Difference, Washington, DC April 18–20.

Duraj V, Miles J, Meyers J [1999]. Development of a conveyor-based loading system for manual harvest of winegrapes. Presented at the ASAE conference, Toronto, Canada July 18–21.

Ehlers J, Palermo T [1998]. Community partners for healthy farming: involving communities in intervention planning, implementation, and evaluation. NIOSH-FIOH-NIWL Symposium, Pennsylvania. Symposium of selected NIOSH researchers and their counterparts from Finland and Sweden.

Ehlers J Palermo T [2006]. Community partners for healthy farming intervention research. NORA Symposium 2006: Research Makes a Difference, Washington, D.C. April 18–20. (poster and rapid oral presentation).

Faucett J, Miles J, Meyers J, Janowitz I [1998]. Cultural issues in the assessment of work-related pain. International Occupational Health and Environmental Health Nurses Conference, Eastbourne, UK: Royal College of Nursing and American Association of Occupational Health Nurses.

Faucett J, Miles J, Meyers J, Janowitz I [1998]. UE musculoskeletal symptoms in agricultural jobs. International Conference on Occupational Disorders of the Upper Extremities, San Francisco, CA. Sponsored by University of California at San Francisco, University of Michigan.

Meyers J, Miles J, Faucett J, Janowitz J, Tejeda D, Weber E, Smith R, Garcia L [1998]. Ergonomics risk factors for musculoskeletal disorder in wine grape vineyard work. Presented at National Institute for Farm Safety, Winnipeg, Canada.

Meyers J [1998]. The problem of musculoskeletal disorders in agricultural field work. Presented at the Research, Education and Extension Service Symposium, United States Department of Agriculture, Washington, DC.

Meyers J, Faucett J, Miles J, Janowitz I, Tejeda D, Duraj V, Smith R, Weber E [1999]. Effect of reduced load weights on musculoskeletal disorder symptoms in wine grape harvest work. Presented at the American Public Health Association: Celebrating a Century of Progress in Public Health, November 7–11, Chicago, IL.

Miles JA, Meyers JM, Faucett J, Janowitz I, Tejeda DG, Weber E, Smith R, Garcia L [1998]. Ergonomics risk factors in labor intensive agricultural work. Presented at the 4th International Symposium, Centre for Agricultural Medicine, University of Saskatchewan, Saskatoon, Canada.

Miles J [1999]. Research priorities for NORA from agricultural ergonomics. Presented at NIOSH/NORA Research Meeting, Houston, TX.

Waters T [1998]. Children in agriculture: ergonomic issues. Paper presented at the North American Guidelines for Children in Agriculture Symposium, New Orleans, LA., March 15–18.

6.4 References Cited

Allen-Barash N [2001]. Personal communication from Nitsa Allen-Barash, University of Washington, to the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, U.S. Department of Health and Human Services.

Arndt JF [1971]. Rollover protective structures for farm and construction tractors—a 50 year review. In: Society of Automotive Engineers Earthmoving Industry Conference, April 5–7, Peoria, IL.

Billikopf G [2003]. Comment from Gregorio Billikopf, Labor Management Farm Advisor, University of California to the Agricultural Health Listserv.

Bureau of Labor Statistics [1996]. Number of nonfatal occupational illnesses by industry division and illness category. Accessed at http://www.bls.gov/iif/

Bureau of Labor Statistics [2006]. Census of Fatal Occupational Injuries. Accessed at http://www.bls.gov/iff/oshfat1.htm.

Chapman, LJ, Newenhouse, AC, Pereira, KM, Karsh,BT, Meyer, RM, Brunette, C, and Ehlers, JJ [2005 accepted pending revisions]. Evaluation of a Four Year Intervention to Reduce Musculoskeletal Hazards Among Berry Growers. *Applied Ergonomics*.

Cole HP, Myers ML, Westneat S [2004]. Cost-effectiveness of promoting roll-over protective structures (ROPS) and seat belts on family farm tractors. Technical report to CDC/NIOSH. Lexington, KY: University of Kentucky, Southeast Center for Agricultural Health and Safety.

DHHS [1992]. Papers and Proceedings of the Surgeon General's Conference on Agricultural Safety and Health, PL 101–517. NIOSH, US Department of Health and Human Services, Centers for Disease Control, September, 1992. GPO number 017–033–00463–3 or NTIS number PB 93–114890

Donham K, Osterburg D, Myers M, Lehtola C [1998]. Tractor risk abatement and control: The policy conference, September 10-12. Final report. Iowa City: University of Iowa.

Fathallah FA, Meyers JM, Janowitz I [2005]. Conference proceedings: stooped and squatting postures in the workplace. July 29–30. Oakland, CA: University of California, Center for Occupational and Environmental Health; University of California, Berkeley. Davis, and Oakland. Available at: http://ag-ergo.ucdavis.edu/ .

Hsiao H, Whitestone J, Bradtmiller B, Zwiener J, Whistler R, Kau T, Gross M, Lafferty C. [2005]. Anthropometry criteria for the design of tractor cabs and protection frames. Ergonomics 48(4):323-353

Hullman EM [2005]. ROPS retrofitting: measuring effectiveness of incentives and uncovering inherent barriers to success. JASH 11(1):75-84.

Keifer M [2001]. Personal communication from Matthew Keifer, MD, of the Harborview Medical Center, Seattle, WA, to the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, U.S. Department of Health and Human Services.

Kelsey TW, Jenkins PL, May JJ. [1996]. Factors influencing tractor owners' potential demands for Rollover Protective Structures on farm tractors. JASH 2(2):35-42. TH

May JJ, Sorensen JA, Burdick PA, Earle-Richardosn GB, Jenkins PL [2006]. Rollover protection on New York tractors and farmers' readiness for change. JASH 12(3):199-213.

Mobed K, Gold EB, Schenker MB. Occupational health problems among migrant and seasonal farm workers. In Cross Cultural Medicine: A decade Later (Special Edition). West J Med 157:367-373, 192.

Myers JR, Snyder KA [1995]. Roll-over protective structure use and the cost of retrofitting tractors in the United States, 1993. J Ag Safety Health *1*(3):185–197.

Myers J, Miles J, Faucett J, Janowitz I, Tejeda D, Weber E, Smith R, Garcia L [2001]. Priority risk factors for back injury in agricultural field work. J Agromed *8*(1):37–52.

Myers JR [2003]. Tractor occupational safety and health update. In: Record of Tractor- Related Injury and Death Meeting. Pittsburgh, PA, February 13–14, 2003, pp. 5–23. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

Newenhouse A, Meyer RH, Chapman LJ [2002]. Work efficiency tips for small scale growers. In Small-Scale Post-Harvest Handling Practices, a manual for horticultural crops (38,40). 4th ed. L. Kitinoja and A. Kader, ed. Postharvest Technology Research and Information Center: University of California-Davis. Davis, CA. Translated into Spanish, Arabic, Bhasa Indonesia, Portuguese and several minor languages.

NIOSH [1996]. TRAC-Safe: a community-based program for reducing injuries and deaths due to tractor overturns. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication 96–108.

NIOSH [1997]. Elements of Ergonomics Programs: A Primer Based on Workplace Evaluations of Musculoskeletal Disorders. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and

Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication 97-117.

North Carolina Labor Department (personal communication 2003).

OTTC [2006]. Office of Technology Transfer and Commercialization. http: //ottc.csusb.edu/what_we_do.htm

Pana-Cryan R, Myers ML [2000]. Prevention effectiveness of roll-over protective structures. Part III: economic analysis. J Ag Safety Health *6*(1):57–70.

Pana-Cryan R, Myers ML [2002]. Cost effectiveness of roll-over protective structures. Am J Ind Med 42(S2):68–71.

Thelin A [1990]. Epilogue: agricultural occupational and environmental health policy strategies for the future. Am J Ind Med *18*:53.

Waters TR, Wilkins JR III [2004]. Conference proceedings: prevention of musculoskeletal disorders for children and adolescents working in agriculture. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2004–119.