Injury Risk Factors Associated with Agricultural Workplace Fatalities

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Abstract

Agriculture has consistently ranked among the top four industries in both frequency and rate of death from workplace injuries. Analysis of a case series of 119 field investigations of occupational agricultural fatalities, conducted through the NIOSH State Fatality Assessment and Control Evaluation (FACE) program, indicated the presence of multiple injury risk factors for 90% of the incidents. The most common risk factors were unrecognized or unaddressed injury hazards, safety equipment not being available at the worksite, and the use of equipment or work methods that contributed to the worker's exposure to injury risk. The risks identified here are amenable to a variety of prevention strategies, including educational programs and engineering controls.

Keywords. Occupational fatalities, Fatality investigation, Injury risk factors.

Agriculture has consistently been ranked in the top four (both rate and frequency of death) most hazardous industries in the United States for the past 50 years (Burke, 1987; Murphy, 1992). Farmers perform a variety of tasks using a variety of equipment. They work under adverse and varied environmental conditions, with weather, crop prices, and market demand creating substantial economic and time pressures (Gammon and Anibal, 1997; Geller, 1996; Runyan, 1993; Murphy, 1992). In addition, the majority of farmers work alone (Aherin et al., 1992; Hair, 1991; Knapp, 1966). All of these factors are major influences on the injury risks to which farmers are routinely exposed.

Heinrich's theory of the "accident sequence" proposed that injury events could be attributed to a series of antecedent occurrences (Heinrich, 1959). Despite the recognition that multiple factors, immediate and underlying, are usually associated with a single injury event (DeReamer, 1958), there remains an emphasis on determining the primary or most obvious factor influencing the event (Krause and Russell, 1994; Tritch, 1992). Heinrich's premise that most injuries are caused by unsafe acts of individuals has since been called into question (Anton, 1989; Hammer, 1989). However, his original contention that eliminating any event in the sequence will prevent the injury continues to influence the development of intervention strategies today. Current injury prevention theory and practice

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categorizes factors which cause injury as either unsafe acts or unsafe conditions (behavioral or environmental) (Anton, 1989). For most injury events, both behavioral and environmental factors are present.

Murphy identifies seven occupational safety and health principles for production agriculture. The first two of these are particularly appropriate for consideration here: Principle 1: Injuries have identifiable causes and are either preventable or controllable; and Principle 2: An injury incident normally derives from multiple causes rather than a single cause. This results in multiple approaches to hazard and injury prevention and control being more effective than any single approach (Murphy, 1992).

The purpose of this study was to identify injury risk factors associated with traumatic occupational fatalities in the agricultural production sector, with the goal of determining the most effective approaches leading to the reduction or elimination of these factors in the agricultural workplace.

Methods

Data consisted of a case series of 119 site investigations of work-related fatalities in the agricultural production sector (Standard Industrial Classification [SIC] Major Groups 01 and 02) (Office of Management and Budget, 1987). Classified to this sector are establishments engaged primarily in the production of crops, livestock, and livestock products. The investigations were conducted through the State Fatality Assessment and Control Evaluation (FACE) program between 1990 and 1996 in ten states: California, Colorado, Indiana, Iowa, Kentucky, Minnesota, Missouri, New Jersey, Wisconsin, and Wyoming. Alaska, Massachusetts, Maryland, and Nebraska participated in the FACE program during this period, but did not conduct any agricultural production fatality investigations.

With funding and technical assistance from NIOSH, state agencies carry out surveillance of all occupational fatalities, conduct site investigations of selected occupational fatalities, develop recommendations for prevention of occupational fatalities, and disseminate findings to appropriate audiences. A detailed narrative report describing the incident and offering prevention recommendations is the product of each fatality investigation. The FACE investigative program emphasized electrocutions and confined space fatalities between 1990 and 1994, and falls and machinery-related incidents beginning in October 1994. However, states were encouraged to conduct investigations of other kinds of incidents germane to state injury control priorities. Only homicides and suicides were specifically excluded from the FACE investigative program.

Data from the initial report of fatality submitted through the surveillance component of the State FACE program were merged with results abstracted from the FACE investigative report for this analysis. The initial fatality report included data on the date of incident, cause of death, age, gender, industry, occupation, and a brief narrative description of the incident. Detailed industry codes were assigned using the 1987 Standard Industrial Classification system, and occupation codes using the 1980 Bureau of the Census classification system (Bureau of the Census, 1982). Each case was also assigned an external cause of death code (E-code) from the International Classification of Diseases, Ninth Revision (ICD-9) (World Health Organization, 1977). Items abstracted from the FACE investigative report were the victim's work task, the sequence of events leading to the fatality, and up to three injury risk factors associated with the fatality. Determination of injury risk factors was based on a critical review of each FACE investigative report, including an evaluation of recommendations offered by the FACE investigator. An injury risk

factor may be any characteristic of the work environment or worker which contributes to the potential for injury. Identification of a given injury risk factor implies only that it was present at the worksite when the fatality occurred. It does not address worker responsibility or intent.

Results

Five State FACE programs, Colorado, Iowa, Kentucky, Minnesota, and Wisconsin, conducted 112 of the 119 (94%) of the fatality investigations in the agricultural production sector (table 1). Victims were predominantly male (97%) and white non-Hispanic (92%). They ranged in age from 10 to 87 years, with a median age of 52; over 25% were age 65 or older (table 2).

More than two-thirds (69%) were engaged primarily in general crop farming, followed by dairy farming (13%), cattle ranching (6%), field crops, except cash grains (3%), cash grains (3%), and other types of farming (7%). Most were classified as either farmers (80%) or farm workers (15%).

Machinery-related incidents were the most common cause of death, accounting for 57% of the fatalities. Falls comprised 8% of the fatalities, and incidents in which the victim was struck by an object or caught in or between objects made up another 7% (table 3).

Agricultural work tasks being performed by the victim at the time of the incident were grouped into six categories. Twenty-five of the victims (21%) were moving materials or equipment: hauling grain, logs, or bales of hay, or moving a grain auger.

Table 1. State Fatality Assessment and Control Evaluation (FACE) investigations in the agricultural production industry by state, 1990-1996

State	Number	Percent
California	1	0.8
Colorado	11	9.2
Iowa	10	8.4
Indiana	1	0.8
Kentucky	25	21.0
Minnesota	49	41.2
Missouri	2	1.7
New Jersey	1	0.8
Wisconsin	17	14.3
Wyoming	2	1.7
Total	119	100.0

Table 2. State FACE investigations in the agricultural production industry by age of victim, 1990-1996

Age	Number	Percent
< 16	4	3.4
16-19	4	3.4
20-24	4	3.4
25-34	11	9.2
35-44	19	16.0
45-54	21	17.6
55-64	25	21.0
65-74	19	16.0
75+	11	9.2
Unknown	1	0.8
Total	119	100.0

Table 3. State FACE investigations in the agricultural production industry by cause of death, 1990-1996

Cause of Death	Number	Percent
Machinery-related incident	68	57.1
Fall	10	8.4
Struck by object/caught in or between objects	8	6.7
Asphyxiation	7	5.9
Electrocution	7	5.9
Motor vehicle (traffic)	7	5.9
Struck by falling object	4	3.4
Poisoning	3	2.5
Animal	2	1.7
Fire	2	1.7
Nature/environment	1	0.8
Total	119	100.0

Twenty-two (19%) were repairing, cleaning, adjusting, or maintaining machinery. These activities included removing hay that was impeding a baler mechanism, performing electrical maintenance on a conveyor, and repairing a tractor, farm truck, or planter. Twenty victims (17%) were driving or riding on farm machinery (nearly all were tractors) for the purpose of traveling from one work area to another or returning the machine to a storage area. Thirteen of these 20 incidents occurred on farm property, the remainder on public highways. An additional 17 incidents (14%) involved operation of farm machinery to perform farm work: mowing, cutting hay, plowing, or moving earth. Fifteen of these 17 incidents involved tractors; 12 of the 15 tractors had implements attached. In 19 incidents (16%), the worker was loading or transferring grain or feed (from a grain bin to a truck or wagon, or from a wagon to a feeding trough or hopper). The remaining 16 incidents (13%) involved a variety of work tasks such as clearing snow from the roof of a barn, refueling a gas-powered generator, and rounding up livestock.

Overall, the most common types of incidents were machine rollovers (26%), entanglement in machinery (15%), and machine runovers (14%) (table 4). All but three of the rollovers and all but four of the runovers involved tractors. Other machinery associated with rollovers and runovers were windrowers, farm trucks, skid-steer loaders, forklifts, and combines. Incidents in which workers were entangled or caught in machinery involved a variety of machines and implements: grain augers, skid-steer loaders, hay balers, power take-offs (PTOs), corn pickers, and feed grinders. Three different scenarios were present in the fatalities involving engulfment or suffocation in grain: entering a silo or grain bin to clear a clogged

Table 4. State FACE investigations in the agricultural production industry by type of incident, 1990-1996

Type of Incident	Number	Percent
Machine rollover	31	26.1
Machine entanglement	18	15.1
Machine runover	17	14.3
Struck or crushed by object or equipment not under power	15	12.6
Fall	13	10.9
Grain engulfment	8	6.7
Electrocution	7	5.9
Other	10	8.4
Total	119	100.0

Table 5. Injury risk factors identified by state FACE investigations in the agricultural production industry, 1990-1996

Risk Factor	Number	Percent
Unrecognized or unaddressed hazard	82	68.9
Safety equipment or personal protective equipment (PPE) not available at worksite	51	42.9
Equipment or method contributed to injury risk	39	32.8
Hazardous energy not controlled	32	26.9
Worker action (intentional or inadvertent)	17	14.3
Safety equipment available at worksite but not used	16	13.4
Inadequate maintenance	15	12.6
Worker needed additional training or knowledge to perform task safely	12	10.1
Ability to perform task safely potentially affected by illness or disability	9	7.6
Working alone in circumstances under which a standby person is recommended	7	5.9
Equipment design contributed to injury risk	6	5.0
Equipment safety features removed or modified	6	5.0

auger intake; stepping onto crusted grain that subsequently broke free; or falling into the bin. Five of the seven electrocutions occurred when irrigation pipes or grain augers that were being moved contacted overhead power lines. Incidents in which the victim was struck by an object or by a piece of equipment not under power occurred under a variety of circumstances. Most common were a load falling from a loader bucket, a machine or implement falling on a worker during servicing, and a worker being struck by an unattached wagon or implement. The fatal falls were most often from silo ladders, wagons, and tractors.

Two or more risk factors were identified for 107 cases (90%). Seventy cases had three injury risk factors, and 37 cases had two. The cases with a single risk factor included four tractor rollovers, three machine entanglements, and two runovers. The most frequently noted risk factors were not recognizing or addressing hazards, identified in 69% of the cases, safety equipment or personal protective equipment (PPE) not available at the worksite (43%), using a piece of equipment or a method that contributed to the worker's exposure to injury risk (e.g., insufficient blocking used to support a machine during repairs, using an attachment not designed to lift a particular type of load, or disconnecting an implement on a slope without blocking it against motion) (33%), and not controlling hazardous energy (27%) (table 5). Only those risk factors noted for more than five fatalities appear in table 5.

The distribution of injury risk factors varied by incident type. The remainder of the presentation of results will describe the most common injury risk factors identified for each incident type. Case-specific information collected during fatality investigations is used to illustrate how injury events actually occurred in the presence of particular injury risk factors.

Machine Rollovers

The absence of a rollover protective structure (ROPS) contributed to 27 of the 31 (87%) rollover fatalities. In two other rollover deaths the machine was equipped with a ROPS, but the victim was not wearing a seat belt and was not restrained inside the area enclosed by the ROPS when the machine overturned. All three tractor rollovers in which adolescents were the victims (ages 10, 12, and 16) occurred on public highways. In two of these incidents, the operating speed was a factor, and the investigator determined that the operator had over-corrected by steering too sharply to the left as the tractor went off the road to the right. In one of these fatalities, the tractor seat was set at the maximum distance from the brake pedals, making it difficult for the 12-year-old driver to operate the brakes safely.

Not recognizing or addressing the potential for rollover, and not following safe driving procedures were additional risk factors for the machine rollovers. For incidents in which a tractor was operated on a slope, specific risks included driving across the slope, driving into a steeply sloped area to avoid an obstruction, and operating a tricycle-type tractor on a steep slope. Other factors associated with rollovers included operating the machine under muddy or icy conditions, carrying a heavy load in a raised loader bucket, and towing multiple implements.

Machine Runovers

In contrast to rollover fatalities, which were fairly evenly distributed by age, only two of the 17 victims in runover fatalities were younger than age 50. In two of these instances, the victim dismounted from the tractor without setting the brakes because limited mobility made it difficult to reach the brakes. In three other cases, the victim attempted to start a tractor while not in the operator's seat. In four instances, positioning of the tractor on sloping terrain increased the injury risk while performing a task that could probably have been performed more safely on a level surface. In each of these cases, the victim dismounted from the tractor and was run over when the tractor began to roll. These four workers ranged in age from 59 to 70 years.

Machine Entanglements

In contrast to the runover fatalities, the victims of machine entanglements were most often younger adult workers; all but four were between 25 and 54 years of age. Control of hazardous energy and non-recognition of injury hazards were contributing factors in 16 of the 18 (89%) machine entanglements. Nine of the entanglements occurred as the worker was repairing, cleaning, servicing, or adjusting machinery. Seven were associated with transferring or loading grain or feed. In four cases, the victim's clothing was pulled into the operating machinery.

Falls

The most commonly observed injury risk factors for fall fatalities were not recognizing or addressing fall hazards (seven cases), and using equipment or a work method that contributed to injury risk (five cases). Eight of the 13 workers killed in falls (62%) were age 60 or older. Four of the six falls from ladders occurred in silos; three of these were fixed ladders. In four of the six ladder incidents, the victim was wearing smooth-soled shoes that may have contributed to the risk of a fall. Accumulation of moist corn and hay on climbing surfaces was identified as a contributing factor in two instances. Five other incidents were falls from vehicles. One victim was riding on the hitch point of a hay wagon, another on a drawbar between a tractor and a chopper box. Two other fatalities were falls from stationary farm wagons in which the victims were engaged in unloading bales of hay.

Grain Engulfments

In the eight grain engulfments, the most common injury risk factors pertained to not following confined space entry procedures. Deviations from these procedures noted in FACE investigations included no standby person (six incidents), no PPE such as lifelines or harnesses (six incidents), and not controlling hazardous energy by disconnecting, locking out and tagging power to an auger (three incidents).

Electrocutions

In the seven electrocutions investigated, the predominant risk factors were related to hazard recognition, maintenance, energy isolation, and the method used to perform the task. In three of the five incidents in which a piece of equipment or pipe contacted an overhead power line, it appeared that the task could have been done in a different location, away from the power line. In the other two cases, access to a hayloft and grain bin was adjacent to overhead power lines. Two other electrocutions occurred during servicing of turkey feeder equipment and a bale conveyor. Neither piece of equipment was de-energized before work began.

Struck by Object or Equipment

In 12 of the 15 cases (80%) in which the victim was struck by an object or by equipment not under power, the equipment or work method was identified as an injury risk factor. Most were associated with not blocking against motion, or with the method used to secure a load or implement. Cases associated with not blocking against motion included wagons that rolled forward after being unhitched and ran over workers who tried to control them; and machinery under repair that fell because insufficient support was provided, or because a safety catch was not engaged. Fatalities associated with unsecured or poorly secured loads involved transporting a section of a tree in a loader bucket without securing the load, and a worker who was riding in a raised loader bucket that was not securely attached to the lift arms.

Discussion

FACE investigations represent one of the largest compilations of agricultural fatality investigations assembled to date, but interpretation of results is limited by several factors. These investigations constitute a case series, with no comparison to a control group. Analysis of these data provides valuable information about injury risk factors and circumstances, but no causal inferences can be drawn (Gordis, 1996). Further, the majority of the investigations took place in the upper Midwest. Had these investigations been conducted in a different group of states, different injury risk factors might have been identified. Distribution of victims by race and ethnicity, cause of death, and employment characteristics might also have differed. Another factor is that although the investigations were conducted using a standard protocol, and every attempt was made to ensure consistency in assessment of injury risk factors, the fact remains that these investigations were conducted by a number of different individuals with expertise in a variety of subject areas. Although general conclusions about risk factors were quite consistent across investigators, some recommendations for prevention emphasized behavioral aspects of fatalities, others engineering and design issues. For all these reasons, the results of this research may not be generalizable to agricultural fatalities in the United States.

A comparison of the causes of death was done to assess the degree to which the fatalities investigated by FACE were representative of all agricultural production deaths occurring in the 14 states participating in the State FACE program. The 119 cases investigated were compared with the 785 agricultural production fatalities reported through FACE surveillance between 1990 and 1996. The biggest difference was that a larger proportion of machinery-related deaths was investigated (57% vs 47%), and a smaller proportion of motor vehicle-related deaths (6% vs 16%) (National Institute for Occupational Safety and Health, 1997). This overrepresentation of machinery deaths may reflect the FACE program's deliberate

emphasis on investigation of these cases. Machinery incidents are emphasized by FACE because they were the second leading cause of occupational fatalities in the United States during the 1980s (Jenkins et al., 1993; Pratt et al., 1996). Particular attention to machinery-related incidents in agriculture is supported by their high incidence reported in the literature, with tractors identified as a primary source of injury (Bobick and Jenkins, 1992; Etherton et al., 1991; Murphy, 1985a; Murphy, 1985b; Myers, 1989; National Safety Council, 1995; Pratt et al., 1996).

Multiple injury risk factors were associated with the majority of the incidents investigated. In most cases a combination of behavioral and environmental factors was present. In general, there was no single overriding factor without which the incident would not have occurred. More commonly, there was a group of conditions and events that together created circumstances under which the event could occur. Most of the workers whose deaths were investigated by FACE were performing routine farm tasks which they and their co-workers had performed without injury numerous times in the past. What remains unknown in some cases is whether these fatalities resulted from one-time deviations from the usual safe work practices, or whether the task was customarily performed under the same circumstances present during the incident. Farmers often work alone, and many of the fatalities investigated by FACE were unwitnessed. Thus, information about the frequency of the task and the manner in which it was performed is often less likely to be available for agricultural fatalities than for incidents occurring in other industries.

The fact that a number of these incidents were unwitnessed also contributes to the potential for misinterpretation of the results. The objective of FACE investigations is to identify work situations associated with fatalities for the purpose of furthering injury prevention efforts. Recommendations are typically directed at employers. In the case of these agricultural fatalities, the victim was often the employer. However, the investigations do not necessarily demonstrate that the presence of conditions conducive to injury directly resulted from the actions of the victim. In evaluating the incidents described here, this important point may be easy to lose sight of because many incidents were unwitnessed, because the victim was the only individual mentioned in the report, and because the victim was in the majority of cases a self-employed farmer.

The FACE investigations included many cases in which the need to control hazardous energy would appear to have been obvious, and for which the appropriate equipment is available and procedures are well-documented. Examples include disengaging the PTO before dismounting a tractor, starting a tractor only while sitting in the operator's seat, and blocking hydraulically operated equipment against motion before performing maintenance. Included in this group is a small number of cases in which safety devices were defeated or bypassed. The information available for these cases does not fully explain these circumstances. Farmers must cope with considerable economic and time pressures, many of which are beyond their control. The degree to which these factors affect the ability to evaluate risks is not well understood.

Because there is a behavioral component to the use of safety equipment, manufacturers can play an important role in facilitating consistent use of safety equipment. It is important that manufacturers continue to refine existing safety equipment to enhance convenience, develop new concepts that require minimal effort on the part of the worker in order to be effective, and continue to develop retrofit safety equipment for older machines. The increased risk of injury resulting from bypassing safety features should be addressed by machine safety programs.

The structure of agriculture poses unique challenges for those developing and implementing educational programs for farmers. Compared with workers in other industries, farmers are more difficult to reach because of geographic dispersion, long and irregular work hours, and the seasonal nature of their work. The dissemination of safety information through the existing social framework of the farming community may be more effective than trying to persuade farmers to spend additional time attending training sessions. This may be particularly true for older farmers (Ambe and Murphy, 1993). Regular meetings of civic organizations, public service announcements through local media, and regular programs offered by county extension agents offer opportunities to deliver safety information. These approaches that incorporate safety messages into established activities may be particularly effective when the amount of information to be communicated is relatively small, the prevention message is straightforward, and the consequences of deviating from safe work practices are serious and obvious.

There is a vast amount of safety information available to farmers addressing most of the injury risk factors described in this article (National Technical Information Service, 1995). The findings confirm that an array of injury risk factors contributes to agricultural fatalities and that multiple factors are usually present. Agricultural safety educators know how to deliver factual information about injury prevention, but the more difficult task may be successfully communicating the importance of consistent adherence to safe work practices. Continued emphasis on a variety of intervention strategies, including engineering controls, appears to be warranted, but this research suggests a particular need to develop hazard communication methods that will result in the adoption of consistent, effective work practices. Engineering controls, as well as educational programs which provide information, increase awareness, and emphasize the importance of performing a task safely each time it is performed, all play an important role in the reduction or elimination of risks for agricultural fatalities.

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