DISSERTATION

ANALYSIS OF AGRICULTURE INJURIES USING WORKERS' COMPENSATION DATA

Submitted by

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDOUR OUR SUPERVISION BY DAVID IRVIN DOUPHRATE ENTITLED BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF DISSERTATION

ANALYSIS OF AGRICULTURE INJURIES USING WORKERS' COMPENSATION DATA

Background

In the United States, agriculture is among the most hazardous of industries. The lack of information regarding agriculture injuries has been recognized as an obstacle to effective injury prevention efforts.

Methods

Three separate but related studies analyzed workers' compensation data to elucidate injury and claimant characteristics associated with agriculture injuries. Specific emphasis was placed on tractor-related and livestock-handling injuries.

Results

Results indicated high injury rates among workers employed by dairy farms, cattle/livestock raisers, and cattle dealers. Large proportions of injuries were associated with tractor mounting and dismounting, milking, cattle pinning/sorting, and horseback riding activities. Tractor-related and livestock-handling work injuries are a significant problem, more costly, and result in more time off work than other agriculture injuries.

Conclusions:

Injury prevention efforts should be directed at livestock-handler education, dairy parlor

and livestock-handling facility design, and tractor design characteristics related to tractor mounting and dismounting.

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DEDICATION

This dissertation is dedicated to Marin, Kyle and Reid.

PREFACE

Three separate but related studies comprise this dissertation. The following studies investigate occupational injuries among agriculture workers. All three investigations involve the analysis of workers' compensation injury claims data. This manuscript begins with a review of literature (Section One).

The first research study (Section Two) describes patterns of injury among seven different agriculture occupational sectors: dairy farms, cattle dealers, cattle/livestock raisers, grain elevator workers, bean sorting/handling, grain milling, and hay/grain and feed dealers. Also included is an analysis of injury claim rates, as well as injury characteristics stratified by injury source, cause, nature, and body part. Injury cost analysis is also included.

The objectives of Study One included the following:

1) To determine injury rates among different Colorado agriculture-related operations,

2) To determine distributions of sources, causes, types and locations of injuries among those filing workers' compensation agricultural injury claims in Colorado; and

3) To determine the costs associated with agricultural injury claims in Colorado.

The second study (Section Three) is an investigation of tractor-related injuries among agriculture workers. This study is one of several studies investigating tractor-related injures as part of the National Tractor Initiative. Characteristics, costs and contributing factors associated with tractor-related injuries are presented.

The objectives of Study Two included the following:

1) To determine the medical and indemnity costs of tractor-related and tractor overturn injuries; and

2) To determine factors associated with tractor-related and tractor overturn injuries.

The third study (Section Four) builds upon the methods and results from the first two studies to investigate livestock-handling injuries among agriculture workers. This study evaluates injury claim rates, injury and claimant characteristics and costs, as well as factors surrounding livestock-handling injury events.

The objectives of Study Three include the following:

1) To determine the costs associated with agricultural livestock-handling injuries;

1) To determine distributions of sources, causes, types and locations of agricultural livestock-handling injuries; and

2) To determine contributing factors associated with agricultural livestock-handling injuries.

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LIST OF ABBREVIATIONS

AAR	Agriculture at Risk
AHS	Agriculture Health Study
ANSI	American National Standards Institute
BLS	Bureau of Labor Statistics
CFOI	Census of Fatal Occupational Injuries
CPI	Consumer Price Index
CPSC	Consumer Project Safety Commission
FAIC	Farm Accident Injury Classification
FFHHS	Farm Family Health and Hazard Surveillance
FRI	First Report of Injury
FTE	Functional Time Equivalent
HICAHS	High Plains Intermountain Center for Agriculture Health and Safety
HMO	Health Maintenance Organization
MSD	Musculoskeletal Disorder
MSS	Musculoskeletal Symptom
NASS	National Agriculture Statistics Service
NAICS	North American Industry Classification System
NCCI	National Council on Compensation Insurance
NEISS	National Electronic Injury Surveillance System
NIOSH	National Institute for Occupational Safety and Health
NORA	National Occupational Research Agenda
NSC	National Safety Council

NTOF	National Traumatic Occupational Fatalities
OATS	Olmsted Agriculture Trauma Study
OIICS	Occupational Injury and Illness Classification System
OSHA	Occupational Safety and Health Administration
PIR	Proportionate Injury Ratio
PMR	Proportionate Mortality Ratio
ROPS	Roll Over Protective System
RRIS	Regional Rural Injury Study
SIC	Standard Industrial Classification
SOC	Standard Occupational Classification
SOII	Survey of Occupational Injuries and Illnesses
US	United States
USDA	United States Department of Agriculture

SECTION ONE

REVIEW OF LITERATURE

ORGANIZATION OF LITERATURE REVIEW

The literature review begins with a discussion of the United States (US) agriculture industry and its inherent hazards for worker injury. This is followed by a discussion of occupational injury epidemiology, followed by present agriculture injury surveillance data sources. An explanation of the Colorado workers' compensation system is then provided, followed by an explanation of narrative injury text analysis and a discussion of injury classification methodologies. Lastly, a brief presentation is provided of previous studies using workers' compensation data.

US AGRICULTURE INDUSTRY

Agriculture is one of the largest industries in the United States. According to the US Bureau of Labor Statistics (BLS), in 2004 there were about 2.1 million agriculture workers in the US including self-employed and unpaid family workers. The Agriculture, Forestry, and Fishing industrial sector is one of the few remaining areas of the national economy in which unpaid family workers remain a significant part of the workforce. Despite the inherent danger of the profession, the agriculture industry is largely exempt from federal guidelines designed to protect workers from occupational injury. The 1970 Occupational Safety and Health Act established national workplace safety standards, mandated employer cooperation, and assessed penalties for noncompliance. Although agriculture was included in the original federal regulation, an amendment in 1976 exempted all farms with fewer than eleven workers [Kelsey, 1994]. Nearly 60% of agriculture establishments in agriculture, forestry, and fishing have fewer than five employees, and roughly 95% of U.S. farms have less than 11 employees [Pratt et al., 1992].

AGRICULTURE HAZARDS

There were approximately 646 occupational fatalities in the agriculture, forestry, fishing and hunting industry sector in the United States in 2006, yielding an occupational fatality rate of 29.6 per 100,000 employed workers. The farming, fishing and hunting occupational group had approximately 289 occupational fatalities in 2006, yielding an occupational mortality rate of 29.2 per 100 employed workers. These fatality rates were highest among all industry sectors and major occupational groups [US Department of Labor, 2007]. The BLS estimates a nonfatal injury and illness incidence rate of 6.0 per 100 full-time workers in the agriculture, forestry, and fishing sector in 2006 [US Department of Labor, 2007], which ranks among the highest of all goods-producing industrial sectors.

A number of investigators have assessed agricultural work fatal and non-fatal injuries using various research methodologies and data sources such as news clippings [Cavaletto, 1989]; hospital and clinic-based surveillance [Cogbill et al., 1985, Howell and Smith, 1973, Jansson and Jacobsson, 1988, O'Connor et al., 1993, Simpson, 1984, Swanson et al., 1987]; and medical records reviews with mail and telephone follow-up [Fuortes et al., 1990]. Other investigators have analyzed death certificate data, either by itself [Karlson and Noren, 1979, Salmi et al., 1989, Smith et al., 1983, Stallones, 1990] or in combination with telephone and mail follow-up [Seltzer et al., 1990], to examine farm-work related deaths. More recent population-based surveillance research of farm-work injuries has taken place at the state and local level such as the Olmsted Agricultural Trauma Study (OATS) [Gerberich et al., 1991], Regional Rural Injury Studies I and II [Carlson et al., 2005, Carlson et al., 2006, Gerberich et al., 2001, Gerberich et al., 1994, Gerberich et al., 1993, Gerberich et al., 1996, Gerberich et al., 1998, Hard et al., 2002, Lee et al., 1996, Paulson et al., 2006], the Farm Family Health and Hazard Surveillance Project (FFHHS) [Browning et al., 1998, Browning et al., 2001, Browning et al., 1999, Crawford et al., 1998, Hallman et al., 1997, Hwang et al., 2001, Lewis et al., 1998, Osorio et al., 1998, Osorio et al., 1998, Park et al., 2001, Pederson et al., 1999, Stallones and Beseler, 2003, Stallones et al., 1997, Xiang et al., 1999, Xiang et al., 1998], the Agriculture Health Study (AHS) [Sprince et al., 2003, Sprince et al., 2002, Sprince et al., 2007, Sprince et al., 2003, Sprince et al., 2003], and the Keokuk County Rural Health Study [Zwerling et al., 2001, Zwerling et al., 1997].

A wide variety of hazards for injury characterizes the farming work environment. These risk hazards include machinery, work from heights, animals, water, poisonous gasses and chemicals, and electricity [McCurdy and Carroll, 2000, VonEssen and McCurdy, 1998]. Researchers have found machinery, animals/livestock, and falls are among the more common sources of agriculture-related injuries [Brison and Pickett, 1992, Browning et al., 1998, Crawford et al., 1998, Gerberich et al., 1998, Hoskin et al., 1988, Layde et al., 1995, Nordstrom et al., 1995].

Agricultural machinery has been identified as a principal cause of farming-related injuries [Cordes and Foster, 1988, Gerberich et al., 1998, Hard et al., 2002, Layde et al., 1995, May, 1990] and the cause of death or disability in many cases [Etherton et al., 1991, Hard et al., 2002, Purschwitz and Field, 1990]. Tractors have been associated with a large number of nonfatal injuries [Bancej and Arbuckle, 2000, Brison and Pickett, 1992, Cordes and Foster, 1988, Fuortes et al., 1990, Gerberich et al., 1998, Hard et al., 2002, Layde et al., 1995, Lee et al., 1996, May, 1990] and the majority of fatal farm injuries [Etherton et al., 1991, Hard et al., 2002, Stallones, 1990]. Tractor fatalities result from being run over or crushed by the tractor, entanglement in moving parts of the tractor, accidents on roadways, and tractor overturns, which involve tipping the tractor sideways or backwards and crushing the operator [Reynolds and Groves, 2000]. Tractor overturns are the largest contributor to these fatalities [Cole et al., 2006, Erlich et al., 1993, Jackson, 1983, Purschwitz and Field, 1990, Reynolds and Groves, 2000].

Because of the increasing mechanization of farms over the past half century, and the high fatality rate associated with injuries due to farm machinery and tractors [Bernhart and Langley, 1999, Carlson et al., 2005, Cole et al., 2006, Etherton et al., 1991, Hopkins, 1989, Lee et al., 1996, McFarland, 1968, McKnight and Hetzel, 1985, Simpson, 1984], most studies of farm injuries have focused on injuries due to machinery or tractors. Animal-related injuries are also, however, an important occupational hazard of farming [Boyle et al., 1997, Calandruccio and Powers, 1949, Cummings, 1991, Hard et al., 2002, Hoskin and Miller, 1979, McCurdy and Carroll, 2000, Sprince et al., 2003]. As is the case for most farm work injuries, research is limited that has addressed the risk factors and events surrounding animal-related farm injuries that might suggest safety interventions [Layde et al., 1996].

Previous studies have indicated higher injury rates are also associated with certain farm environment characteristics, specifically the presence of animals or livestock [Pickett et al., 1995, Stallones, 1990]. Animal/livestock injuries account for between 12% and 33% of injuries on the farm [Brison and Pickett, 1992, Cleary et al., 1961, Cogbill et al., 1985, Gerberich et al., 1998, Hoskin et al., 1988, Layde et al., 1995, Lewis et al., 1998, Myers, 1990, Nordstrom et al., 1995, Pickett et al., 1995, Pratt et al., 1992, Sprince et al., 2003, Zhou and Roseman, 1994]. Animal-related injuries are common in settings where working with heavy and powerful animals is required. Risk factors associated with animal-related injuries include work activities that increase exposure and proximity to farm animals. Boyle, et al. [1997] reported that dairy cattle workers spending more than 30 hours per week milking dairy cattle have up to a 20-fold increased risk for injury; a four-fold increased risk was found to be associated with trimming or treating hooves. Abrasions/contusions and sprains/strains/torn ligaments represented more than one-quarter of all reported livestock-handling injury cases [VonEssen and Donham, 1999]. Another study indicated that the most common livestock-related worker injuries are: 1) multiple kicks, primarily to the lower extremities resulting from working in and around poorly constructed or inadequately designed facilities such as chutes and gates, 2) lacerations, usually to the hands resulting from performing elective minor surgical procedures such as castrating and dehorning, 3) crushing type injuries that involve bruised or broken ribs resulting from loading and off-loading cattle and horses into a chute complex, with the operators inside the chute structure, and 4) minor bruises, broken arms and fingers, and even loss of fingers resulting from using improper restraints and hands [Hendricks and Adekoya, 2001].

Research reports have established that tractors and livestock-handling activities are major contributors to agriculture injuries. However, the development of effective prevention strategies has been hampered by the lack of understanding of the contributing factors of tractor and livestock-handling work injuries. Further research is needed that identifies specific factors associated with activities involving tractors and livestock-handling. The identification of specific contributing factors can lead to injury prevention strategies.

OCCUPATIONAL EPIDEMIOLOGY

It has been recommended that in order to prevent occupational injuries, epidemiological research must progress beyond methods originally used for acute or chronic diseases such as the calculation of injury rates [Park, 2002]. Injury rate calculation across nominal categories (e.g. department or job classification) can identify where hazards are concentrated but provides little insight into their nature. For occupational injury research, exposure assessment requires increased sophistication because exposures comprise multiple, transient factors and complex work activities. Frequently reported in occupational injury literature are risk factors such as age, gender, seniority, or prior injury which are merely confounders or effect-modifiers of unknown exposures [Park, 2002]. Current occupational epidemiological approaches are largely descriptive in nature and place excessive emphasis on the calculation of rates, complicated study design, and statistical analysis [Park, 2002].

Calculating occupational injury and illness rates follows the tradition of classical infectious and chronic disease epidemiology [Bailer et al., 1998, Robertson, 1998]. In most industries rate calculations are the fundamental basis for causal inference on work-relatedness for occupational diseases. However this does not apply in the agriculture industry. Agency reported injury and illness rates for agriculture, such as those reported by the Bureau of Labor Statistics, often underestimate the number of persons at risk and the number of persons suffering injury or illness [McCurdy and Carroll, 2000]. The US agriculture industry is characterized by migrant and temporary hired workers, and farm owners who are in the profession for many years, often lifetimes. Occupational illness surveillance in agriculture can be expected to underreport occurrences of illnesses with long latency (especially when the association with work exposures is weak or unknown), or if an employee has changed employers or occupations [Murphy et al., 1996].

Despite their narrow scope and descriptive nature, injury rate calculations and analyses have been used to characterize the presence of injury hazards. Injury rates allow for the comparison of industrial sectors, estimation of costs and impacts, and the setting of regulatory priorities and allocating research resources [Bailer et al., 1997, Kisner and Fosbroke, 1994, Myers and Fosbroke, 1994, Myers et al., 1998]. Injury rates also allow for the prioritizing and targeting of exposure-identification efforts and permit the identification of employees in high-risk workplaces or industrial sectors [Bailer et al., 1997, Douphrate et al., 2006, Husberg et al., 1998, Kisner and Fosbroke, 1994, Lipscomb et al., 2004, Loomis et al., 1999, Lowery et al., 1998, Magnetti et al., 1999, McCullough et al., 1998, Miller and Kaufman, 1998, Myers and Fosbroke, 1994, Myers et al., 1998, Peek-Asa et al., 1999, Sahl et al., 1997, Suruda et al., 1995, Warner et al., 1998]. Injury rates also facilitate the development and testing of hypotheses. Rate comparisons based on statistical models can reveal relative weights to specific risk factors and combinations when multiple relevant and sufficient exposures have been identified [Cohen and Lin, 1991, Collins et al., 1999].

Injury rate calculations across nominal categories (e.g., department, job classification or industry) identify where hazards are concentrated but provide little insight into their nature or etiology. Traumatic injury exposures often follow an erratic time course with episodes of hazard spikes followed by durations of zero hazard exposures. This is evident in occupational settings such as agriculture. The farm work environment is characterized by a wide variety of tasks and hazards for injury at different times of the day, week and year. The calculation of injury rates by exposure category in this type of setting would require an exhaustive, continuing observational study of all worker activity, including responses to unusual process failures, unforeseen situations and diverse maintenance problems. This type of investigative project would be a formidable task and is generally infeasible [Mittleman et al., 1997, Park, 2002]. One study did, however, calculate injury rates for different farm work activities by conducting personal interviews of farm operators. Stallones and Beseler [2003] described the farm work patterns and the relationship between hours spent working on specific farm tasks and task specific work related injuries among male and female farm residents in Colorado. A cross sectional survey of farm operators and spouses using personal interviews was conducted. Farm work activity injury rates were computed. Despite the inherent recall and reporting biases associated with personal interviews, this study is one example of how injury rates can be computed for specific tasks in a diverse working environment such as agriculture.

Because of the inherent difficulty of measuring exposures, researchers often report on exposure confounders and effect-modifiers such as age, gender, seniority, or fatigue [Boyle et al., 1997, Glazner et al., 1999, Kisner and Fosbroke, 1994, Lee et al., 1993, Mac Crawford et al., 1998, Sahl et al., 1997, Zwerling et al., 1998] and substance abuse [Dell and Berkhout, 1998, Leigh, 1996, Pollack et al., 1998]. These variables are found statistically significant because these attributes are often associated with or modify unmeasured causal risk factors. However, meaningful conclusions cannot be made without exposure measures. In a survey of 42 peer reviewed journals from 1970 to 1992, Veazie et al. [1994] found that environmental exposures were the risk factors least often studied.

Traditional analytical tools of occupational epidemiology are increasingly being applied to investigate the injury experience recorded in administrative or "passive" employer information or surveillance systems [Sorock et al., 1997] and in national databases [Smith, 2001]. Such efforts produce valuable information, but unfortunately do not achieve the detail needed to identify injury causes such as inadequate machine guarding, defective machine design or performance, high-risk work procedures, or high production demands. The failure to identify injury causes and contributing factors may result in a lack of effective injury prevention measures. Park [2002] recommends that in order to identify actual injury hazards, greater attention should be given to exposure assessment by systematically analyzing injury cases and case-series. The case-series approach serves as a valuable indicator of occupational hazards, primarily in situations where the health outcome is rare and there is a characteristic exposure that can be identified as the probable cause [Checkoway et al., 2004] .

As part of the National Occupational Research Agenda (NORA), the National Institute for Occupational Safety and Health has called for the development of innovative analytic approaches in the evaluation of risk factors for occupational traumatic injuries [NIOSH, 1998]. A more recent innovative research design which has been used to investigate occupational injuries is the case-crossover design. A group of researchers concluded in a 1996 workshop on methodological challenges to the study of occupational injuries that the case-crossover design is a potentially useful new method to meet this need [Burdorf et al., 1997, Sorock et al., 2001]. A case-crossover study is a research method used to determine if an injury was triggered by something unusual that happened just before the injury event [Maclure and Mittleman, 2000]. In this design, subjects are used as their own controls, eliminating confounding factors that differ between individuals [Maclure, 1991]. The case-crossover design has recently been used to investigate occupational injuries such as traumatic hand injuries [Sorock et al., 2001], injuries related to working extended hours in manufacturing [Vegso et al., 2007], and sharps-related injuries among healthcare workers [Fisman et al., 2003].

Occupational injury surveillance and research designs have progressed in quantifying the extent of injuries. In most industries, there are still recommendations to improve occupational injury surveillance efforts, but no longer a plea for improved capability to better count the number of work-related deaths and injuries [Stout and Linn, 2001]. Good estimates of lost workday injuries exist. High-risk industries and occupations have been identified, demographics and causes of injuries have been established, and high risk groups are well documented. Surveillance recommendations are now focused on increasing and improving the detail of exposure data in those high-risk industries, occupations and working groups [Linn, 1995] with the goal of developing more effective injury prevention measures. However, occupational injury research in agriculture is an exception. Past efforts to initiate nonfatal injury surveillance systems have been useful in identifying traumatic injuries associated with agricultural production as a major public health problem. These efforts have unfortunately not been sustained over time to track any changes in the agriculture industry [Hard et al., 2002]. The agriculture injury problem needs to be addressed through comprehensive approaches that include further delineation of the extent of the problem.

To have a more profound impact on workplace safety especially in agriculture, new approaches to injury prevention need to be developed. Meehan [1999] suggests safety professionals must strive to address the myriad of factors that lead to occupational injuries and illnesses. The injured body part is simply the final manifestation of whatever went wrong before the injury-producing event. The focus of occupational injury research should be to determine what elements combined to produce the injurious incident.

AGRICULTURE INJURY SURVEILLANCE

No comprehensive data system exists to identify the extent of the farm safety problem or the potential risk factors associated with injury illness on US farms [Gerberich et al., 1991]. Authors have reported the difficulties in quantifying the magnitude of the farm injury problem [Ehlers et al., 1993, May, 1990]. Authors have also reported the limitations of the usual sources of data used to estimate the incidence of farm injury [Hard et al., 2002, Hwang et al., 2001, May, 1990, Merchant, 1991, Purschwitz and Field, 1990]. Limitations in the existing agency data sources mask the extent of the agriculture injury problem, and little agreement has been reached on the annual estimates of farm injuries, illnesses, and fatalities [Toscano and Windau, 1991]. Variations in injury, illness and fatality estimates are due largely to differences in definitions, the worker populations included, age criteria, methods of case ascertainment, data collection methodology and types of information collected. Comparisons are further complicated by the lack of standardized reporting categories [Stallones, 1994].

The lack of adequate data to identify the population at risk has hampered efforts to monitor farm injuries and illnesses. In the broadest sense, this population includes farm operators, domestic hired workers, foreign nationals, contract workers, and unpaid family and other workers as well as those who live on farms [McCurdy and Carroll, 2000]. No single uniform database identifies the total number of people at risk and the various demographic characteristics of that population at the national level. Existing differences in estimates of the number of agriculture workers in the US has a direct effect on the estimated rates of injuries on farms.

National agriculture injury data are produced by the US Department of Labor, US Consumer Product Safety Commission, US Department of Health and Human Services, and the National Safety Council. Other population-based epidemiologic surveillance projects which study the health and safety hazards associated with agriculture production include the Olmstead Agricultural Trauma Study (OATS), the Regional Rural Injury Study (RRIS), the Agriculture Health Study (AHS), the Keokuk County Rural Health Study, and the Farm Family Health and Hazard Surveillance projects (FFHHS). The aim of these surveillance projects is to identify demographic and exposure risk factors for farm injury, in addition to other health and safety outcomes. Another source of agriculture injury information is workers' compensation claims data. Workers' compensation data provides policy holder, claimant and injury characteristics, and claim cost data for hired farmworkers who file a workers' compensation injury claim. Each of these data sources are discussed in the following sections.

National Safety Council

The surveillance of occupational fatalities in the agriculture industry was initiated by the National Safety Council (NSC), which provided annual estimates of agricultural work deaths sporadically during the 1940s and then consistently from the 1950s onward [Hard et al., 2002]. The NSC also estimates unintentional deaths by injury (homicides and suicides excluded) of persons in the civilian work force, 14 years and older, with the exception of private household workers. For most of the 1970s and early 1980s, NSC data represented the best source of agricultural fatality data in the US. The NSC estimates were not developed using scientific sampling procedures, and the reliability of the estimates is unclear [Runyan, 1993].

National Traumatic Occupational Fatalities System

The National Institute for Occupational Safety and Health (NIOSH) in the US Department of Health and Human Services began a surveillance project in 1985 to quantify the number of US occupational deaths due to trauma [Murphy et al., 1996, Myers, 1990] This project was known as the National Traumatic Occupational Fatalities (NTOF) System. The NTOF was a census of death certificates from all 52 agencies reporting vital statistics in the United States. Each agency provided NIOSH with copies of death certificates that met the following criteria: the age of the victim was 16 years of age and older, injury was an immediate underlying or contributing cause of death, and the "injury at work" item on the certificate was marked "yes" [Murphy et al., 1996, Myers, 1990] The NTOF had both advantages and limitations in detecting agricultural deaths [Myers, 1990]. Advantages included the following:

1. information contained on death certificates, including the coding of the cause of death, was consistent from State to State,
2. all workers (operators, hired, and unpaid family) were included because a death certificate is filed for each US death,
3. the "injury at work" item assisted in denoting those agricultural deaths that were occupational, and
4. certificates were easily accessible [Gerberich et al., 1991, Myers, 1990].

Major limitations included the following:

1. occupational deaths involving juveniles under the age of 16 were not reported in the NTOF,
2. certain manners of death (e.g., motor vehicle deaths) and some occupational groups (e.g., farmworkers, especially part-time farmers holding other jobs) were underreported by death certificates,
3. the industry and occupational information on the death certificate reflected the victim's usual work history and may not have reflected where the person was employed at the time of death [Myers, 1990], and
4. information collected on certificates was frequently misclassified or missing [Gerberich et al., 1991, Myers, 1990]. The misclassification of an "at work" death on a farm often resulted due to a lack of standard definitions for workers and worker activities [Stallones et al., 1995]. Studies suggest that death certificates are only between 70 and 80 percent efficient in detecting occupational deaths [Runyan, 1993].

Murphy et al. [1990] compared the NTOF classification system with one based on death certificates, a newspaper clipping service database and supplemental information obtained from next of kin in Pennsylvania. The investigators provided evidence of a 30% error in the NTOF method which resulted in a 20% undercount of agricultural work injury deaths and an overcount by the NSC system of approximately 35 percent [Murphy et al., 1990]. The NTOF surveillance program ceased in 1995 and NIOSH adopted the Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries surveillance system to monitor occupational injury fatalities.

Census of Fatal Occupational Injuries

In February 1991, the BLS established the Census of Fatal Occupational Injuries (CFOI) as an ongoing data collection program [Toscano and Windau, 1991]. The CFOI was published for the first time in 1992 and was designed to provide a more systematic, verifiable count of all fatal occupational injuries and to obtain descriptive data on the circumstances surrounding these events. The data are collected by the Federal-State Cooperative System using death certificates, State and Federal workers' compensation reports, motor vehicle traffic fatality reports, coroner or medical examiner reports, work-related fatality reports from the Occupational Safety and Health Administration (OSHA), Mine Safety and Health Administration data, Employment Standards Administration data, and other sources. Independent source documents, or a source document and a follow-up questionnaire, are used for determining work-relatedness [Hard et al., 2002]. The CFOI includes data on work-related fatalities resulting from both injuries occurring in agricultural establishments with one or more employees, as well as those involving self-employed farmers and their families. Although States are using independent data sources to identify and substantiate work-related fatalities, some fatal injuries at work are missed by the BLS census [US Department of Health and Human Services, 2004].

Survey of Occupational Injuries and Illnesses

The Bureau of Labor Statistics in the US Department of Labor publishes annual estimates of occupational injuries and illnesses for industries in the private sector [US Department of Health and Human Services, 2004]. The Survey of Occupational Injuries and Illness (SOII) is based on a survey of about 176,000 private sector establishments stratified by industry and employment size [US Department of Labor, 2007]. Data are collected from records maintained by employers in accordance with the Occupational Safety and Health Act of 1970. Although agriculture was included in the original federal regulation, an amendment in 1976 exempted all farms with ten or less workers [Kelsey, 1994]. Self-employed individuals are excluded from the survey. Published statistics include the number and incidence rate per 100 full-time employees for workplace injuries and illnesses. Industries are classified according to the 2002 North American Industry Classification System (NAICS) and occupations are classified according to the 2000 Standard Occupation Classification (SOC) system [US Department of Health and Human Services, 2004]. Farm injury and illness data are published for the broader category of agriculture, forestry, and fishing [US Department of Labor, 2007].

Bureau of Labor Statistics SOII data is vulnerable to underreporting. Small firms are likely to underreport or not report at all [Burrough and Lubov, 1986, Seligman et al., 1988]. Small firms with less than 11 employees are more likely than medium and large firms to be newly formed and frequently go out of business [Brown et al., 1990], resulting in an underreporting of work injuries. New owners might not be aware of

OSHA recordkeeping laws [Leigh et al., 2004]. Bureau of Labor Statistics penalties for poor recordkeeping and OSHA penalties rarely, if ever, are levied on small businesses [Courtney and Clancy, 1998, McGarity and Shapiro, 1993, Weil, 1991]. Paperwork could also be a greater relative burden on small than large firms [Leigh et al., 2004]. There are also economic incentives to underreport injuries to BLS. Firms seeking government contracts could fear being denied a contract if their injury rate is too high [Glazner et al., 1998]. Second, a recorded high injury rate could trigger an OSHA inspection [Courtney and Clancy, 1998, Weil, 1991]. Third, firms could seek to minimize reported injuries so as to maintain an image of safe places to work [Leigh et al., 2004]. The economic theory of compensating wage differences suggests that firms maintaining a safe image need not pay the high wages other firms pay with poor safety images [Leigh and Garcia, 2000]. The theory states that less desirable jobs should pay some form of wage premium, implying that workers facing greater risks in terms of the probability of death or injury should receive higher wages than those in safer jobs [Martinello and Meng, 1992]. An alternative available to employers is to improve workplace health and safety, as this enables them to reduce or eliminate the need to pay a premium for injury risk [Purse, 2004].

Bureau of Labor Statistics SOII data have two major limitations for farm injury research. First, farm establishments employing fewer than 11 people or only immediate family members are not included in either the injury/illness or fatality data [Gerberich et al., 1991] Roughly 95% of US farms have less than 11 employees [Pratt et al., 1992]. Myers [1990] reported that OSHA covers less than 11% of the farming operations and only 49% of the hired farm labor force. Thus, SOII data undercount the number of farm injuries by omitting farms employing few hired workers or none at all. Second, the data do not include injuries or illnesses for the self-employed. While SOII data is useful for tracking injury incidence in other industries, these data are of limited use in the agriculture industry because of the underestimation of the incidence of farm-work injury.

Product Summary Reports

The National Institute of Occupational Safety and Health collects information about nonfatal work-related injuries and illnesses treated in US hospital emergency departments through the National Electronic Injury Surveillance System (NEISS) in collaboration with the US Consumer Product Safety Commission (CPSC). The US CPSC publishes estimates of product-associated injuries on an annual basis. These estimates are based on reports of product-associated injuries treated in hospital emergency rooms participating in the NEISS. Product-associated injuries are those related to machinery, chemicals, or other manufactured products. Falls and animal-related injuries are not included. In addition to estimates of the number of injuries, the NEISS also includes data on injuries by age group, and identifies if the victim was treated and released or hospitalized [US Department of Health and Human Services, 2004].

Product Summary Reports have several limitations as they relate to agriculture-related injuries. First, four injury groups are not counted in this data set: those who are treated in a doctor's office; those who either ignore or treat their own injuries; those injured by falls, natural irritants, non-manufactured products, or animals; and those who die before reaching the hospital. Second, data are reported for product-related injuries only. Third, the sample is small and not representative of all US emergency rooms [Gerberich et al., 1991]. Fourth, the commission's policy on disseminating national estimates eliminates reporting of some product-associated injuries. The Commission policy is to disseminate only national estimates meeting minimum criteria [Runyan, 1993]. Despite these limitations, these data do permit the identification of developing trends as to how the number of injuries that required hospital treatment have changed over time for the most frequently reported products (such as farm tractors and farm wagons) [Runyan, 1993].

Agriculture Surveillance Research

A little more than two decades ago, few health and safety professionals in the US devoted their efforts to those involved in production agriculture [Donham and Storm, 2002]. Few organizations and programs specifically addressed the injury and illness dilemma in agriculture, and limited funding and coordination were two major challenges at the time.

In September of 1988, an eight-day conference involving a total of 170 scholars and policy makers was held in Iowa City and Des Moines, Iowa. This conference was named "Agriculture Occupational and Environmental Health: Policy Strategies for the Future." Five specific conference objectives included the following: 1) to summarize state-of-the-art knowledge about research programs that help create a safe and healthy agricultural work environment, 2) to integrate the viewpoints of farmers and farm workers, the private sector, and public institutions into formulation of a policy agenda for agricultural occupational and environmental health, 3) to identify research and service needs and pertinent policy issues, 4) to formulate policy strategies and implementation methods, and 5) to communicate results of policy strategy discussions to key legislator, policy makers, farm constituency groups, farm families, and the general public [National Coalition for Agricultural Safety and Health, 1989].

The product of this conference was a document entitled *Agriculture at Risk, A Report to the Nation* [National Coalition for Agricultural Safety and Health, 1989]. The Agriculture at Risk document (AAR) measured the magnitude and significance of the agriculture injury and illness problem, as well as recommended research and legislative priorities to address the problem. The AAR document cited data from the NSC which showed the two US industries with the highest death rates due to injury were agriculture and mining. The AAR report noted that epidemiologic studies indicated the NSC data underestimated farm injury rates by as much as 50%. In addition, a wide range of farm-related diseases had been documented in several epidemiological studies, but adequate population-based rates were not available at the time. Accurate rates were needed for specific types of injury and disease, according to type and size of farm, demographic characteristics, and other risk factors, to better target prevention and intervention efforts. To obtain these rates, the AAR report recommended CDC and NIOSH conduct health and hazard surveys for agriculture workers. Several population-based surveillance programs for occupational disease and injuries, targeting farms, farmers, farmworkers, and farm families were initiated based on recommendations in the AAR document. Among those surveillance programs were the Olmsted Agriculture Trauma Survey, Regional Rural Injury Studies, Farm Family Health and Hazard Surveillance Survey, Keokuk County Rural Health Study, and the Agriculture Health Study.

Olmsted Agricultural Trauma Survey

In 1987, researchers at the University of Minnesota introduced a new approach for conducting combined fatal and nonfatal agriculture injury surveillance. The Olmsted Agricultural Trauma Survey (OATS) was a telephone interview-based survey of farm operators in Olmsted County, Minnesota. Adult farm operators were interviewed and asked to report injuries which had occurred on their agriculture operation as well as identify farming-related exposures within the last calendar year. Injury information collected through OATS was compared with Mayo Clinic health care records [Hard et al., 2002]. In general, the results of the telephone survey were found to provide a realistic view of the injury occurrences on farms in Olmsted County and provided an effective means of collecting these data. Gerberich et al. [1991] found animals were a major source of farm work-related injury, responsible for approximately 18% of the reported injuries in this study cohort. A majority of these animal-related injuries were due to dairy cattle. Gunderson et al. [1990] reported that in Olmsted County, fewer than 5 % of all farming-related injuries involved hospitalization, however 87% involved contact with a health care worker, indicating that surveillance sources of data cannot be based on hospital records alone. Gunderson et al. [1990] reported that other sources of farm-work injury data are needed to accurately count the number of nonfatal injuries.

Regional Rural Injury Studies I and II

Based on the success of the OATS, in 1990 University of Minnesota researchers expanded the scope of the telephone survey approach to a five-state random sample of farming operations through a grant from the Centers for Disease Control and Prevention [Gerberich et al., 1994, Gerberich et al., 1994, Gerberich et al., 1993]. This survey, known as the Regional Rural Injury Study-I (RRIS-I), covered the states of Minnesota, Nebraska, North Dakota, South Dakota, and Wisconsin. Modifications were made to the survey which included reducing the recall period for injury events to six months. This data collection was shown to be an effective way to collect farm injury information over a large geographic area [Gerberich et al., 1994, Gerberich et al., 1994, Gerberich et al., 1993, Gerberich et al., 1996, Gerberich et al., 1991]. The OATS and RRIS-I also demonstrated the value of the USDA-NASS Master List Frame of Farm Operations for identifying farms in the five states, and the usefulness of collecting these data directly from the farm operators/primary heads of households [Hard et al., 2002]. Many published studies have resulted from the RRIS-I project. Gerberich et al. [2001] identified the incidence and consequences of both farming and non-farming related injuries and the potential risk factors for farming related injuries among children and youth, aged 0–19 years. Lee et al. [1996] investigated socioeconomic variables and various exposures related to tractor-related injuries. Gerberich et al. [1996] reported on penetrating hand trauma injuries. Gerberich et al. [1998] reported on the magnitude and risk factors for machine-related agriculture injuries [Gerberich et al., 1998]. The authors of this study calculated injury rates for sociodemographic variables and various exposures pertinent to large farm machinery (excluding tractors). Among the total farming-related injury events, 20% were related to large machinery use. Several variables were found to be significantly associated with elevated injury rate ratios including hours worked per week on farm, operation of specific machinery, male gender, and certain marital status categories (i.e. married, separated/widowed/divorced). The majority of injury events occurred while persons were lifting, pushing, pulling, adjusting a machine, or repairing a machine. Among all injured persons, 34% were restricted from regular activities for one week or more and 19% were restricted for one month or more.

Boyle et al. [1997] investigated specific activities associated with livestock operations. Subjects for this case-control study were sampled from participants in the RRIS-I project. The primary aim of this study was to identify which dairy cattle operation activities (i.e. milking, feeding, cleaning barns, trimming and treating feet, dehorning, calving) were associated with an increased or decreased risk of injury. Milking was found to have the greatest increase in risk for injury. An increased rate ratio associated with trimming or treating hooves was also found.

In 2001, The University of Minnesota initiated a new survey named Regional Rural Injury Study-II (RRIS-II) [Hard et al., 2002]. This survey followed similar methodology to that of the RRIS-I and included the same five states. The research design employed an eligible cohort of approximately 4,000 farm households, including children 19 years of age or less, and involves unique methods for collecting data, simultaneously, for both risk factors (using a case-control design) and incidence/consequences of agriculture injuries.

One study in particular sought to identify the magnitude, consequences, and potential risk factors for fall-related injury among agricultural operation households. Paulson et al. [2006] reported a fall-related injury rate of 48.3 per 1000 persons. Fall consequences included lost agricultural and other work time. Increased risks for falls included residence in other states, male gender, and a prior injury history. Decreased risks were among those less than 35 years of age and those who worked 40 hours or less per week.

Carlson et al. [2005] extracted data from the 1999 RRIS cohort database to investigate tractor-related injuries. Of the 2,557 injuries reported by the cohort in the study, a total of 156 injury events (6%) were associated with tractors. Three events involved tractor rollovers. No fatal tractor-related injuries were reported. Among the reported activities at time of injury event, 33.1% involved mounting/dismounting, 11.7% involved general tractor repairs, and 10.4% involved driving the tractor. Nearly half of the injuries resulted in lost work time on the agriculture operation, 18% resulted in 1 day or less, 29% in 1 or more days, and 16% in 1 or more weeks. In this study, sprains and strains were found to be the most common types of tractor-related work injury, while the back, fingers and/or thumbs, and spinal cord or spine were the most frequently injured body parts. The overall tractor-related work injury rate was 9.6 events per 1,000 persons per year. Increased personal risk was observed for males with prior agriculture injury experience.

Farm Family Health and Hazard Survey

The NIOSH Farm Family Health and Hazard Surveillance (FFHHS) Cooperative Agreement Program was developed to respond to Congress's concern that agricultural workers and their families experience a disproportionate share of disease and injury associated with the chemical, biological, physical, ergonomic, and psychological hazards of agriculture [NIOSH, 2007]. The FFHHS survey program responded to the Congressional mandate and to the AAR document. The information available on the excess mortality and morbidity experienced by farm workers lacked the detailed descriptors needed for the design of focused intervention programs. Moreover, there was little population-based data available on physical, chemical and biologic hazards that exist on farms [National Coalition for Agricultural Safety and Health, 1989]. The FFHHS obtained population-based prevalence and incidence data for farmers and farm families on disease, injury, workplace exposures, and access to health care, according to commodity, size of farm, demographic characteristics, non-farm employment, and other risk factors.

NIOSH established cooperative agreements with education and health agencies in six states, New York, Kentucky, Ohio, Iowa, Colorado, and California, to collect questionnaire data, hazard observation data, and medical screening data focusing on identifying health risks to the American farm family. The NIOSH FFHHS initially had two primary survey objectives: 1) to describe the health status of agricultural workers and their families, and 2) to describe work-related risk factors and conditions of exposure to potentially hazardous agents and events [NIOSH, 2007]. NIOSH provided general guidelines to the six survey states to conduct basic health screening, injury surveillance, and hazard surveillance within each state. The modules covered in the surveys included demographics, medical care access, injuries, musculoskeletal conditions, respiratory conditions, hearing loss, skin conditions, mental health, and neurotoxic effects. Each survey incorporated some or all of the standardized modules, while also including survey components unique to the needs of the farming population and surveillance needs in each state. The surveys also differed with respect to coverage of selected sub-populations (for example, farm children) and selected farm commodities. Geographic coverage varied from a sample of counties to an entire state [Hard et al., 2002]. The FFHHS surveys were descriptive rather than research-oriented in nature in order to establish a quantitative baseline of the conduct of future agricultural health and hazard research programs.

Manuscripts and presentations, primarily prepared by researchers from the participating FFHHS institutions, represent the primary types of output from the project. Over 70 publications have resulted from the FFHHS program. Among the many journal articles, authors have reported on skin conditions [Park et al., 2001], hypertension [Heath et al., 1999], respiratory symptoms [Champney et al., 1996, Gomez et al., 2004, Sprince et al., 2000] low back pain and injury [Park et al., 2001, Sprince et al., 2007, Xiang et al., 1999, Xiang et al., 1999], joint pain [Gomez et al., 2003], and hearing loss among US farmers [Beckett et al., 2000, Choi et al., 2005, Choi et al., 2005, Gomez et al., 2001, Hwang et al., 2001, Sprince et al., 2000]. Authors have also reported on depression and stress among the farming population [DeArmond et al., 2006, Elliot et al., 1995, Kidd et al., 1996, Scarth et al., 2000, Scarth et al., 1997, Stallones and Beseler, 2004, Stallones et al., 1995]. Several authors have researched pesticide/herbicide exposure and poisoning [Beseler and Stallones, 2003, Kettles et al., 1997, Merchant et al., 1996, Stallones and Beseler, 2002, Stallones and Beseler, 2002]. Stallones and Xiang [2003] examined alcohol consumption patterns and work-related injuries among farm residents.

Authors associated with the FFHHS initiative have reported on farm-related injuries and hazards. Pederson et al. [1999] reported results from the Agricultural Hazard Surveillance program in Ohio. Related to livestock-handling injuries, the authors found a lack of emergency exits (passovers) from livestock handling areas (85.4%) indicating farm operators may view the potential need for egress as a low priority, even in large animal operations. The authors also reported 80% of those working on a farm had not received training in the prevention of occupational injuries or illnesses. Over 99% reported not receiving any on-site occupational health or safety consultation, or any on-site measurement or evaluation of exposure to dusts, gasses, fumes, or physical agents (such as noise).

A subjective assessment tool (the Site Rank System) was developed to predict the health and safety status of farm operations as part of the Iowa Farm Family Health and Hazard Surveillance Project [Jones et al., 1999]. Two components of the Site Rank System (operator attitude and operator practices) were created to provide a means whereby the behavior of principal farm operators could be assessed relative to fundamental health and safety principles. The other two components (status of facilities and status of equipment) provided a means to assess the state of the physical facilities and equipment on the farm. The Site Rank System was found to have been assigned consistently, but little correlation was found between Site Rank System scores and in-depth medical and environmental data gathered from the farm operations. However, self-reported injuries which occurred to the farm operators correlated with low Site Rank System scores.

Lewis et al. [1998] carried out a stratified cluster mail survey of Iowa farms to examine the associations between farm related injuries and possible risk factors. Livestock work had the highest percentage (33%) of activity at time of injury among farmers in the study cohort. Overexertion/strenuous movement represented the highest percentage injury types. Three factors were found to be significantly associated with injury: younger age, having an impairment or health problem limiting work, and hand or arm exposure to acids or alkalis.

Crawford et al. [1998] utilized a case-control study design to investigate risk factors for agriculture injuries among Ohio farm operators. The overall rate of injury found in this study was 5 per 100 person-years. More than 60% of all injuries were associated with farm machinery (22.1%), overexertion or straining (20.4%) and falls (20.0%). This study utilized the Farm Accident Injury Classification System (FAIC) [Murphy et al., 1993], which classifies injuries according to specific farm-related circumstances at the time of event, including agricultural production (FAIC-1). The majority of all reported injuries (63.8%) were FAIC-1 injuries, while 14.5% were classified as nonagricultural, 9.4% occurred in the home, and 19% were unclassifiable. A noteworthy finding in this study was the relationship between self-reported neurotoxic symptoms and injury, suggesting that those with more reported symptoms were at greater risk for injury.

Osorio et al. [1998] utilized farm owner/operator and farm worker interviews and on-site farm surveys to evaluate commodity-specific farm injuries and hazards in two highly agricultural regions in California with a high proportion of migrant farm labor. High prevalence of musculoskeletal problems was found to occur in the lower back (24%), in the upper back (19%), and in the wrist (18%). Among the injured workers, 27% missed at least one day of work, and 46% sought treatment from a licensed medical care provider. Only 70% of the injured workers reported receiving training on the work task that was associated with their injury. In addition, only 22% of the injured workers knew of a workers' compensation report being filed by their employer. In another investigation, a network of medical care providers and local agencies in two California counties provided case reports for investigation [Osorio et al., 1998]. Of the injury cases, 85% were male and 85% were Hispanic origin. The two leading causes of injuries resulting in fatality were motor-vehicle accidents involving tractors and agriculture machine/tractor episodes. Overexertion (14%) and falls (11%) were the most prevalent type of injury event.

Stallones et al. [1997] were the first to investigate information related to off-farm paid work practices and pesticide exposures in relation to the risk of farm work-related injuries. This study provides estimates of the risk of injury associated with these exposures among Colorado male resident farm operators. The number of days of off-farm employment (50-149 days) and having a primary cash crop of large animals including beef, dairy, and feedlot operations were found to be significantly associated with the risk of farm work-related injuries.

Data from the telephone portion of the New York State FFHHS were used to study the incidence and predictors of severe farm injuries. Hwang et al. [2001] reported significant risk factors for sustaining at least one severe farm injury were younger age, the presence of hearing loss or joint trouble, working more hours per day, being the owner/operator of the farm, and being from a farm with higher gross sales.

Studies have focused on farm operator gender, older farmers, and children. Park et al. [2001] examined work-related injury rates and risk factors among Iowa male farm operators and found a cumulative farm injury incidence of 10.5%. Number of hours working with animals and depressive symptoms were associated with the incidence of work-related injuries. Xiang et al. [1998] assessed non-fatal agricultural injuries and associated risk factors among female farmers in Colorado. Risk factors assessed included age, number of years in farming, primary cash crop and annual cash value on farm, depressive symptoms, organophosphates use on farm, having children less than six years of age, and having children working on the farm. Significantly associated with farm work injuries were depressive symptoms, more than 30 years experience in agriculture, and age between 30 and 39. The animal-handling injury rate was 8.3 per 200,000 working hours. Browning et al. [2003] investigated farm injuries among Kentucky children under 18 years of age. Boys aged 16 to 18 years had the highest injury rate (9.2 per 100 children), and farm machinery, cattle and horses, falls from heights, and contact with inanimate objects were the primary external causes of nonfatal farm work injuries. Among children injury causes, 17.2% involved machinery and 13.8% involved animals. Browning et al. [1998] investigated the risk for injury among older farmers. Kentucky farmers aged 55 years and older had a crude injury rate of 9.03 injuries per 100 farmers over a one year study period. The leading external causes of farm injury among this cohort were falls (24.9%), machinery (22.5%), wood-cutting (14.6%) and animal-related events (14.3%). Farmers working on farms with beef cattle or farms with beef cattle and tobacco had a statistically significant increased risk for farm-related injury [Browning et al., 1998]. Xiang et al. [1999] reported that the leading external cause of injury involved livestock among older Colorado male farmers age 60 years and older.

Few FFHHS studies address tractor-related work injuries. Browning et al. [1999] reported that among family-owned farms in Kentucky with at least one tractor, an estimated 55.6% do not have a tractor equipped with a rollover protective structure. Few tractors that were 10 years old or older were found to be equipped with seat belts, and no tractors that were more than 20 years old were equipped with seat belts. Wilkins et al. [2003] reported that among 1,044 tractors on 306 Ohio farms, only 34.4% were equipped with rollover protection.

Although rollover protective structures (ROPS) are effective in protecting tractor operators from fatal injuries during tractor rollovers [Centers for Disease Control and Prevention, 1993, Lehtola et al., 1994, Thelin, 1990], most tractors in the United States are not equipped with ROPS [Centers for Disease Control and Prevention, 1993, Kelsey et al., 1996, Lehtola et al., 1994] . Beginning in 1985, tractor manufacturers in the United Sates agreed to sell only tractors with ROPS; however, many older tractors without ROPS remain in use. To determine the prevalence of the use of rollover protective structures (ROPS), beginning in 1992, the FFHHS program collected state-based data on tractor age and use of ROPS from Iowa, Kentucky, New York and Ohio. Data was collected from 1992 to 1997. Results of the survey indicate that 80%-90% of tractors in use in the four states were manufactured before 1985 and less than 40% are equipped with ROPS. Results indicate that the proportions of tractors with ROPS varied inversely with the age of the tractors, and the numbers of older tractors in use at the time of the survey were substantial [Centers for Disease Control and Prevention, 1997].

Keokuk County Rural Health Study

The Keokuk County Rural Health Study is a population-based, prospective study of health status and environmental exposures of a large stratified random sample of residents in one rural Iowa county. The study, conducted within The University of Iowa's Great Plains Center for Agricultural Health, focuses on injury and respiratory disease. In addition, it monitors health care delivery, geriatric, reproductive, and mental health, and other health outcomes, as well as behavioral risk factors for disease and injury. Injury and disease prevalence is investigated in relation to occupational, agricultural, and other environmental exposures [Great Plains Center for Agriculture Health, 2007].

Among the many published reports that have resulted from the Keokuk County Rural Health Study, authors have reported on chronic disease and injury among farmers [Merchant et al., 2002], environmental exposure [Reynolds et al., 1997], pesticide use [Reynolds et al., 1998], physical and emotional partner abuse [Murty et al., 2003], and suicide ideation [Turvey et al., 2002].

Sanderson et al. [2006] recently described the tractor-related responses from participants Keokuk County Rural Health Study. Only 39% of the 665 tractors identified in the study were equipped with ROPS. Tractor age was associated with the presence of ROPS; 84% of tractors manufactured after 1984 were ROPS-equipped; whereas only 3% of tractors manufactured before 1960 were ROPS-equipped. Only 4% of the farmers reported that their tractors had seatbelts and they wore them when operating their tractors.

Agriculture Health Study

Another population-based surveillance project is the Agriculture Health Study (AHS). This project began in 1994, and will continue to gather information for a number of years about the health of pesticide applicators and their families, details of farm practices, and information on lifestyle and diet on a periodic basis. This study explores potential causes of cancer and other diseases among farmers and their families and among commercial pesticide applicators. The goals are to investigate the effects of environmental, occupational, dietary, and genetic factors on the health of the agricultural population [National Institutes for Health, 2007].

Among the many AHS reports, investigations regarding agriculture injury and illness surveillance methodology [Alavanja et al., 1996, Blair et al., 2002, Engel et al., 2002, Lynch et al., 2005, Tarone et al., 1997], exposure assessment[Coble et al., 2005, Coble et al., 2002, Gladen et al., 1998, Hoppin, 2005], health outcomes [Blair et al., 2005, Blair et al., 2005, Lee et al., 2007], diet [Keating et al., 2000] and injury have been reported in scientific literature [Sprince et al., 2003, Sprince et al., 2002, Sprince et al., 2007, Sprince et al., 2003, Sprince et al., 2003].

Sprince et al. [2003] conducted a case-control study among the AHS cohort of Iowa farmers. Utilizing a questionnaire format, several potential risk factors for agriculture injury were assessed. Significant associations were found between farm work-related injury and weekly farming hours, the presence of large livestock, education beyond high school, regular medication use, wearing a hearing aid, and younger age. Sprince [2003] reported significant associations between fall-related farm injury and age between 40 and 64 years, physician diagnosed arthritis/rheumatism, difficulty hearing normal conversations, and taking medications regularly. Among the sources of fall-related injury identified in this study, 22.4% involved cattle or large livestock, and 10.6% involved tractors. Sprince et al. [2007] assessed risk factors for low back injury requiring medical advice or treatment among Iowa farmers. Using a case-control study design, the authors reported four risk factors significantly associated with low back injury: age less than 45 years, physician diagnosed asthma, education beyond high school, and difficulty hearing normal conversation. Among the cases of low back injury in this study, 20.3% involved cattle or large livestock, and 13.0% involved tractors. Sprince et al [2002] utilized a case-control design to assess risk factors for machinery-related injuries among Iowa farmers. Significant associations between machinery-related injury and hours worked per week on farm work, fewer years of farming experience, wearing a hearing aid, and alcohol consumption habits. Among the 228 machinery-related injuries identified in this study, 14.5% were tractor related. Using a case-control design, Sprince et al. [2003] assessed risk factors for animal-related injury among Iowa large-livestock farmers. Significant associations were found between animal-related injury and the use of a hearing aid, doctor-diagnosed arthritis or rheumatism, and younger age. Among the 124 animal-related injury cases identified, 56.5% were cattle related. Among the events causing injury, 47.6% resulted from an assault by an animal.

State Workers' Compensation

Workers' compensation databases are another source of injury data. These data can provide information on persons covered under respective state compensation programs who incurred work-related injuries or illnesses. Workers' compensation is administered according to individual state statutes and enforced by state government agencies, therefore workers' compensation coverage varies by state. Employers are required to have workers' compensation coverage for all hired workers. Business owners may elect not to have workers' compensation coverage on themselves. Therefore, agriculture workers' compensation injury claim data represents hired farmworkers and may not include operation owners. Workers' compensation data may be especially valuable for characterizing potential risk in small businesses such as farms that employ less than 11 workers. Workers' compensation data sets contain valuable administrative, claimant, injury and economic information. Workers' compensation data include policy holder payroll information, location and county of business, and medical and indemnity claim cost information. Claimant data includes age, gender, and time from hire to injury claim, time from injury to return to work, injury location, nature, cause and source. Injury event descriptions are also included in workers' compensation data.

To properly analyze workers' compensation data one must understand its limitations. Workers' compensation data sets are descriptive in nature. Without denominator data, injury data sets do not lend themselves to risk-oriented analysis. In addition, workers' compensation data sets are dependent on injured workers filing workers' compensation injury claims to the workers' compensation provider. Economic incentives to both underreport and overreport injury claims exist. Economists argue that the more generous the indemnity payment the more likely workers will report greater numbers of workdays lost. Because wage-replacement benefits essentially compensate individuals for not working, employees have an incentive to exaggerate the severity of existing injuries, miss more work than necessary, and/or to inaccurately attribute an injury to work. This risk is termed "moral hazard" and arises out of information asymmetries, where the worker has full knowledge of the cause and severity of his/her injury but the employer does not [Butler and Worrall, 1991]. There is also a moral hazard risk with workers' compensation medical benefits for those employees without other medical insurance or who have insurance with a co-payment or deductible. Because of the risk of moral hazard, there is a common perception that an individual with a work-related problem is likely to file a workers' compensation claim [Biddle and Roberts, 2003]. Rosenman et al. [2000] reported that the strongest predictors of who would file a workers' compensation claim were those factors associated with the severity of the condition. Other factors found to predict workers' compensation injury reporting were increased length of employment, lower annual income, and worker dissatisfaction with coworkers.

Contrary to the common perception of overreporting of injuries to a workers' compensation provider, studies have demonstrated underreporting in workers' compensation records and other government registries. Workers' compensation systems create incentives to underreport. Firms that are workers' compensation experience-rated and report an increasing number of injuries over time could face increases in their workers' compensation premiums [Leigh et al., 2004]. Studies have demonstrated undercounting in workers' compensation records and other government registries. Studies by Biddle et al. [1998], Morse et al. [1998], Rosenman et al. [Rosenman et al., 2000], and Shannon and Lowe [2002] suggest the percentages of people who could qualify for workers' compensation benefits but who never file are 55%, 79% , 75%, and 35% respectively. There is considerable evidence based on research studies with differing study designs that musculoskeletal disorders are in general, underreported, and workers' compensation data does not accurately reflect prevailing musculoskeletal occurrence rates [Biddle et al., 1998, Herbert et al., 1999, Lipscomb et al., 1997, Morse et al., 2005, Morse et al., 2001, Morse et al., 1998, Pransky et al., 1999, Rosenman et al., 2000].

For nonfatal injuries, economic incentives discourage employees from reporting. Employees could be fearful that their employers will label them "accident-prone" or they would be denied a promotion or laid off if they report too many injuries [O'Loughlin, 1993]. Workers might fear a workers' compensation claim or litigation surrounding a claim (which is public information) could harm their chances of finding a new job. Workers' might also not be knowledgeable of the workers' compensation system and reporting procedures [Rosenman et al., 2000]. The injured worker might not know whom to ask about applying for workers' compensation apart from the boss. Workers could also receive an annual bonus if none in their work group report a workers' compensation claim for a year [Payne, 2001], which might discourage a worker from reporting an injury. Social stigmas associated with filing a workers' compensation claim may influence workers to not report their injury. This stigma would be similar to that associated with applying for welfare [Moffitt, 1983]. Finally, some workers, especially men, could feel it is a sign of weakness to make a workers' compensation claim [Leigh et al., 2004]. Conway and Svenson [1998], Azaroff et al. [Azaroff et al., 2002], and Webb et al. [Webb et al., 1989] offer additional reasons for underreporting. An underreporting of injuries to workers' compensation would result in an underestimation of injury rates.

Workers' compensation data are typically limited to coded data based on the First Report of Injury (FRI) [Lipscomb et al., 2004]. Completion of a FRI is often required by state statute to file a workers' compensation claim. These reports contain narratives describing the circumstances of injury, but the information in these reports is rarely used in systematic analysis [Bondy et al., 2005]. These injury reports are completed by administrative staff, the injured worker, or supervisor in the process of filing a compensation claim. Injury claims are then coded and entered into an injury claims database by the workers' compensation provider. Codes include a designation for body part injured, nature of injury (cut, sprain, fracture), the type of event causing the injury (fall, overexertion) and the source of the injury (ladder, animal, power saw) [US Department of Labor, 1992]. These codes have been used by all states participating in the supplemental data system of the Bureau of Labor Statistics (BLS) since 1976, and they form the basis for comparisons of workers' compensation data on injuries [Lipscomb et al., 2004]. Workers' compensation claim data also include cost information regarding injury claims that are not available in other injury data sets. Medical costs include all expenses paid for the medical treatment of each injured worker. These expenses include costs associated with physician visits, hospital treatments if needed, rehabilitation, and medications. Indemnity costs include wage replacement and payments for permanent impairment and disfigurement.

Workers' compensation databases are categorized according to the National Council on Compensation Insurance (NCCI) coding system [National Council on Compensation Insurance, 2003] for industries and occupations. Manual class codes are numerical codes used by the workers' compensation industry to classify occupations and their job responsibilities. The job classifications define specific types of work such as dairy farm workers or cattle or livestock raisers. Class codes allow for comparisons between businesses in the same classifications and against the entire classification sector as a whole.

Colorado Workers' Compensation

Workers' compensation insurance is the only disability insurance Colorado employers are required to provide for employees under state law. Any business with one or more employees must carry workers' compensation insurance. Sole proprietors and partners in a business are not considered employees and are not required to be covered on a policy. There are no exclusions or partial exclusions for workers' compensation coverage of agriculture operations in Colorado. Family members are not covered under workers' compensation coverage if they are not on the payroll of the policy holder [Colorado Department of Labor and Employment, 2007].

For employees who are injured on the job or develop occupational diseases, workers' compensation insurance pays for medical expenses and partial wage replacement during periods of temporary disability (if an employee is unable to return to work within three days of the injury). Workers' compensation insurance may also provide permanent impairment benefits for those who qualify. The cost of workers' compensation insurance is paid entirely by the employer and may not be deducted from an employee's wages. All Colorado workers' compensation insurers provide benefits to workers with a work-related injury or illness in accordance with the Colorado Workers' Compensation Act. The Act defines an occupational injury or illness, as a work-related injury or illness that occurs within the course and scope of employment where employment is the reasonable cause and excludes those that do not result from hazards the worker would have been equally exposed to outside of employment. A lost time claim occurs when a worker misses more than three scheduled work shifts due to the injury. When an injured worker's claim has been accepted as being work-related, the insurance provider pays the necessary, related, and reasonable medical expenses prescribed by the employer's designated medical provider. These expenses may include surgery, dental, nursing, hospital, home health care, rehabilitation, chiropractic care, prescriptions, medical supplies, and travel within certain limitations. After missing three scheduled work shifts, the injured worker is entitled to compensation for lost wages paid at two-thirds of their usual wage [Colorado Department of Labor and Employment, 2007].

NARRATIVE TEXT ANALYSIS

One approach to identifying risk factors contributing to occupational injury is to analyze narrative descriptions of injury events provided in documents related to the injury, such as a FRI associated with a workers' compensation claim. Description analysis involves the usage of narrative text fields to identify factors associated with an injury event. Narrative text analysis does not quantify risk, however, narrative description analysis can provide important information about potential points of intervention [Bondy et al., 2005]. For example, NIOSH researchers have successfully used narrative fields from both the NTOF and NEISS databases to investigate the etiology of specific types of occupational injury and death, such as forklift rollovers and logging deaths [Stout, 1998, Stout and Jenkins, 1995]. Narrative text analysis was utilized to investigate military drownings and injuries involving transport operators [Bell et al., 2001, Lincoln et al., 2000]. In construction, narrative text analysis has been used to investigate falls from suspension scaffolds, trench cave-ins, roof bolting injuries, falls through skylights and roof openings, ladder falls, and slip or tip incidents [Althouse et al., 1997, Cohen and Lin, 1991, Lipscomb et al., 2004, Stout, 1998]. The circumstances surrounding motor vehicle crashes in construction work zones have been analyzed using text from insurance claims records [Sorock et al., 1996].

The sources of narratives used in these types of injury etiology studies have included death certificates, emergency room reports, accident injury reports (AIR) [Althouse et al., 1997, Wiehagen et al., 2001], and workers' compensation insurance claims [Lipscomb et al., 2004, Sorock et al., 1996]. Narratives often contain enough detail to identify information about etiological factors contributing to occupational injuries that is not otherwise available [Dement et al., 2003]. In addition, even when provided short narratives, researchers generally have found information from narrative data to be more accurate and complete than data about the same events recorded in administrative sources [Bell et al., 2001, Jenkins and Hard, 1992, Sorock et al., 1996].

Narrative text analysis is a form of data analysis. Narrative data are in the form of words rather than numbers. The statistical method of narrative analysis classifies data about a group of incidents (e.g., injury cause, type or source) into various classifications. Preventive efforts can be based on the most frequent patterns of characteristic and occurrence [Lincoln et al., 2004]. The taxonomic or categorical process involves the classification of data into hierarchical groups according to common patterns and individual differences. The objective of narrative text analysis is to present a broad picture of what exists and to indicate the relative importance of different scenarios according to how frequently they occur [Shepherd et al., 2000].

INJURY CLASSIFICATION

Narrative text analysis requires a systematic method of injury classification. Several injury classification methodologies exist. The BLS system for the classification of occupational injuries is a widely used methodology. The classic epidemiologic model has been used for many years and is referred to frequently in epidemiologic literature [Mausner and Kramer, 1985]. Other models include Davies and Manning's Merseyside Accident Information Model [Davies et al., 1998], the Lincoln reconstruction template [Lincoln et al., 2004], and Haddon's matrix [Conroy and Fowler, 2000, Haddon, 1968, Haddon, 1972, Haddon, 1980, Higgins et al., 2001].

The BLS utilizes the Occupational Injury and Illness Classification System (OIICS) which provides a set of procedures for selecting and recording facts relating to an occupational injury or illness. This coding scheme was originally developed for use in the Census of Fatal Occupational Injuries and the Survey of Occupational Injuries and Illnesses. The BLS system includes two variables relating to the injury itself. The "Nature of Injury or Illness" describes the physical characteristics of the injury or illness, and "Part of Body" identifies the part of the body directly affected by the nature. Three variables describe the process of the injury. The "Injury Source" identifies the object or substance that directly inflicted the injury or illness. The "Event or Exposure" describes the manner in which the injury or illness was inflicted by the source. The "Secondary Source" identifies the other object or substance that contributed to the event or exposure. By focusing the event codes on the manner in which the injury was produced by the immediate source, the BLS system may fall short of correctly identifying the initial energy exchange. In addition, since, at most, only two items may be coded as sources of injury, some contributing factors may not be identified. The BLS taxonomy is very detailed and lengthy, comprising many pages of codes and instructions which may lead to misclassification [Bondy et al., 2005].

The classic epidemiologic model is considered to consist of three components: agent, host and environment (Figure 1.1). The tripartite model implies that each component must be analyzed and understood for comprehension and predictions of patterns of a disease or injury [Mausner and Kramer, 1985]. The host is the person injured. Host characteristics that may be classified include age, sex, race, religion, customs, occupation, marital status, family background, or previous diseases [Gordis,

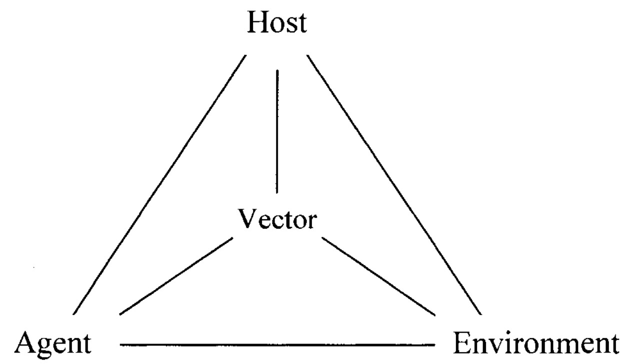

Figure 1.1. The epidemiological triad of disease [Gordis, 2004]

2004]. Environmental factors may influence the susceptibility of the host. Environmental factors that may be classified include temperature, humidity, altitude, crowding, work station setup, and noise [Gordis, 2004]. Agents of injury include the various forms of energy including, biologic, mechanical, thermal, chemical, electrical, ionizing radiation, or too little energy in the case of asphyxiation [Gordis, 2004, Robertson, 1998]. A fourth component, vector, is the vehicle that may convey the energy that causes the injury.

Feyer and Williamson [1991] developed a comprehensive classification system, which allowed for an operational analysis of the events preceding an injury. This classification system was originally applied to the analysis of information surrounding the occurrence of all traumatic work-related fatalities in Australia from 1982 to 1984. The coded information included factors immediately antecedent to the fatality, and factors which contributed to the occurrence of the event. The events leading up to the injury, their interrelationships, and their contributions to causing the injury were all analyzed. The results contributed to the formulation of preventive strategies.

Davies et al. [1998] advanced the Feyer and Williamson [1991] model by incorporating a structured data collection technique that captures the components of injury events in a consistent format. Better known as the Merseyside Accident Information Model (MAIM), this system was developed in the form of a diagrammatic representation of all injurious events. The MAIM classification system was designed to collect all available information on causation.

Data are structured into a sequence of events, the activities and significant movements of the casualty, and movements of environmental objects or factors. These are defined as the "components" of events. The MAIM model represents an "accident" as a series of events, starting with the first unforeseen or unintended event and proceeding through an indeterminate set of events to the outcome. Each event is described in terms of a subject, a verb, and optionally a direct object. This injury classification method is highly dependent on extensive interviews with injury victims, which provide very complete information about details of the injury event [Davies et al., 1998].

Lincoln [2004] restructured and attempted to simplify the MAIM model into a template which attempts to reconstruct the series of events leading to injury using nine key elements: general activity, specific task, contributing factor, precipitation mechanism, primary source, secondary source, injury event/exposure, and outcome. This classification system gives different weight to different factors: source, secondary source, and contributing factor. It requires a sophisticated coding process and may not be appropriate for short injury reports such as First Reports of Injury, where complete information is not typically available. It also shares the inherent limitation of the BLS system that contributing factors in complex injury events may be missed since only one is coded [Bondy et al., 2005].

Haddon's matrix [1968] is another injury classification model. The matrix expands upon the classic tripartite epidemiologic model [Gordis, 2004, Mausner and Kramer, 1985, Robertson, 1998]. This tool originally involved classifying factors contributing to motor vehicle injuries into three categories: human, vehicle/equipment, and environment; and three time periods: before, during, or after a crash. Haddon later refined the matrix to its current form, listing the domains as follows: human (or host); vehicles and equipment (vehicles for transmitting the agent); physical environment; and socioeconomic environment [Haddon, 1972, Haddon, 1980]. Haddon identified the host (or person injured); the agent, which he defined in terms of energy transferred to the host by either an inanimate vehicle (e.g., a firearm or automobile) or an animate vector (e.g., an assailant or animal); and the environment consisting of elements of the physical surroundings that contribute to the occurrence of potentially injury-producing events or to actual injury (e.g., the physical characteristics of the roadway, building, playground, athletic field, factory or worksite). The social environment refers to the sociopolitical variables affecting the process, which could include cultural norms or mores (e.g. tolerance of corporal punishment or alcohol consumption), political environments (e.g., willingness to adopt regulatory interventions that restrict the freedom of motorcyclists or gun owners), the legal environment (e.g. the presence or absence of seat belt usage laws; practices regarding enforcing drunk driving laws; regulations regarding occupational safety), and the organizational environment (e.g. the presence or absence of health and safety policies; the presence or absence of modified work duty for injured workers).

This matrix has been used both to conceptualize etiologic factors for injury and to identify potential preventive strategies, making it a useful tool not only for guiding epidemiological research but also for developing interventions [Runyan, 2003]. Pineault et al. [1994] established the inter-rater reliability of classifying the pre-injury variables, and demonstrated that Haddon's matrix could be applied to different types of industries and injuries.

By utilizing Haddon's matrix [1980], a researcher can identify a range of potential risk, and protective factors and/or strategies for prevention that are directed at each of the factors and have an influence during the different phases. The model's utility lies in its facilitation of brainstorming in an interdisciplinary group that encourages development of innovative injury prevention ideas [Runyan, 2003]. Once potential interventions are identified, the task becomes one of choosing among the many options. A third dimension to Haddon's matrix was developed by Runyan [1998] to facilitate a systematic decision-making process among interventions developed in the two dimensional model. Therefore, it extends Haddon's matrix to a third dimension. This additional dimension incorporates concepts which represent key values that might be considered when choosing intervention strategies (e.g., effectiveness, equity, freedom, cost, and stigmatization). This third dimension was created to help decision-makers judge the relative merit of alternative intervention options.

Haddon's matrix is less scenario-oriented than are some other structured review tools, such as the MAIM [Davies et al., 1998]. This tool does not attempt to capture the chain of events leading to an injury, but rather includes all factors in three general time categories. This model reflects the belief that countermeasure priorities should not be pursued in the same order as the sequence of events leading to the injury. Haddon [1972] found the chain of events less relevant than the totality of contributing factors in identifying targets for injury prevention. Haddon argued that even a very detailed description of the sequence of events leading to an injury did not translate directly into a set of potential points of intervention.

WORKERS' COMPENSATION STUDIES

Previous studies have utilized workers' compensation and narrative text analysis to investigate specific occupational injuries. Glazner et al. [2005] used Haddon's matrix as a framework for analyzing injury event descriptions in a workers' compensation database involving construction injuries. The authors also conducted an economic analysis of injury claim costs. This study identified environmental factors as contributing more than any other factor to slip/trip injuries, and building materials contributing to more than 40% of injuries among workers in carpentry, concrete construction, glass installation, and roofing.

Other studies combined payroll data, injury characteristic data, and injury event descriptions of injuries from the construction of Denver International Airport to create a more comprehensive picture of falls from heights [Lipscomb et al., 2004]. Text descriptions were coded using Haddon's matrix to identify circumstances surrounding falls. The authors were able to identify that slips/trips preceded one-third of falls from height, often involving motor vehicles or heavy equipment. Another third involved movement or collapse of work surfaces usually ladders or scaffolds. The authors concluded that heavy equipment engineering modifications were called for and workers in street/roadway construction site development needed fall protection training.

A similar study by Lipscomb et al. [2006] investigated injuries associated with slips and trips in construction. Slips contributed to the vast majority (85%) of same-level falls and over 30% of falls from height, as well as significant numbers of musculoskeletal injuries sustained after slipping or tripping but without falling. The most common contributing factors were environmental in nature including conditions of walking and working surfaces, terrain and weather. The authors concluded that due to the very dynamic nature of construction work, reducing slips and trips would require a focus on environmental and organizational solutions that evolve as the site changes and the construction project evolves.

Researchers have analyzed workers' compensation data to investigate the injuries in agriculture settings. Villarejo [1998] determined injury incidence rates among California hired farmworkers using workers' compensation injury claims. Aggregate wages and average weekly earnings for each risk classification code were used to determine annual average employment and full time equivalents (FTE). Injury incident rates were highest for stock farm/feed yard workers and dairy farm workers. Beaumont et al. [1995] observed the long-term mortality experience of California agriculture workers who filed workers' compensation claims for respiratory diseases, pesticide illnesses, and injuries. Mortality findings were compared to US death rates. It was concluded that respiratory disease claimants in agriculture had a significantly elevated risk of mortality from respiratory diseases and the risk was highest 5-9 years after injury claims were filed. Demers and Rosenstock [1991] reviewed workers' compensation data of farm workers in the state of Washington between 1982 and 1986 to characterize the nature of work-related illnesses and injuries among farm workers, and compared injury rates to those of nonagricultural workers. Washington agriculture workers were found to be at higher risk than other workers in the state for both occupational injuries and illnesses. Heyer et al. [1992] reported on workers' compensation claims for work-related injuries among children under the age of 18 who were employed as hired farmworkers in the state of Washington. Minors employed as hired farmworkers accounted for a disproportionately large share of serious injuries and disabling injury claims. Belville et al. [1993] reported on workers' compensation claims for occupational injuries among adolescent workers in New York State and noted that the highest rate of paid claims was among manufacturing and agricultural workers. Finally, Cooper and Rothstein [1995] reported on child labor violations and occupational injuries involving children in Texas. They found 1,097 claims for workers' compensation filed by minors in 1991.

CONCLUSION

Farmers have been recognized to be at high risk for both fatal and nonfatal injuries. Sources of injury data have been limited in revealing the magnitude of US agriculture injury. Because of the inherent challenges in conducting injury research in the agriculture industry, the continued development of relevant surveillance systems and novel research designs using various data sources is paramount. The analysis of workers' compensation data has been shown to be an effective research means to help describe occupational injuries. The application of workers' compensation data analysis to investigate injury in agriculture has been limited. Research using workers' compensation data to investigate injury in agriculture may facilitate the development of effective injury prevention strategies.

SECTION TWO

WORKERS' COMPENSATION EXPERIENCE OF COLORADO AGRICULTURE WORKERS, 2000-2004

SUMMARY

This study was the first of three using workers' compensation data to investigate farm injuries. A five-year history of injury claims data was provided by Pinnacol Assurance, the leading workers' compensation provider in Colorado. Seven occupational sectors analyzed in this study were divided into agriculture and agri-business classifications. The agriculture classification included dairy farms, cattle/livestock raisers, and cattle dealers. The agri-business classification comprised agriculture support services including grain elevator operators, grain milling, bean sorting/handling, hay/grain and feed dealers.

Descriptive statistics were conducted on injury and claimant characteristics. Injury claim rate analysis for each agriculture sector was also conducted. Time at risk was estimated using policy payroll data and national industry-specific occupational wage estimates. Injury characteristics were stratified by source, cause, nature, and body part.

A total of 3,093 injury claims from the seven sectors were analyzed in this study. High rates of injury claims were found in all agriculture sectors. Injuries involving livestock-handling, machinery, and falls or slips represented high proportions of injury causes.

Studies Two and Three of this dissertation build upon the methods and results of this initial study. The manuscript for this study was published in a peer-reviewed journal. A copy of this manuscript is found in Appendix A. Journal citation and publisher copyright information is as follows:

> Workers' Compensation Experience of Colorado Agriculture Workers, 2004-2004, Douphrate, D, Rosecrance, J, and Wahl, G, *American Journal of Industrial Medicine*, Volume 49, Issue 11, pages 900-910, © 2005, Wiley-Liss, Inc.

SECTION THREE

TRACTOR-RELATED INJURIES:

A CASE-BASED STUDY OF WORKERS' COMPENSATION DATA

ABSTRACT

Background

Tractors are responsible for approximately one-half of agriculture fatalities and injuries in the US. This case-based study uses workers' compensation data to investigate tractor-related agriculture injuries. This study determined the costs, consequences and contributing factors associated with tractor-related injuries.

Methods

Tractor-related injury claim data from Colorado (from 1992 to 2004) and California (from 2000 to 2005) were used in this study. Descriptive analysis of injury claim characteristics and factors associated with tractor-related injury events was conducted. Medical and indemnity claim costs associated with tractor-related injuries were analyzed. The epidemiological agent-host-environment model was used to analyze injury event descriptions.

Results

A total of 757 tractor-related injury claims from Colorado (n=642) and California (n=115) were analyzed. A total of 24 tractor-overturn injury events were also analyzed. Twenty percent of injury events occurred while workers were mounting or dismounting the tractor while an additional 10% of claims indicated the worker fell, jumped, or slipped off a tractor.

Conclusions

The finding of a large percentage of tractor-related injuries associated with mounting and dismounting activities corroborates previous studies, and suggests the need to further investigate tractor design characteristics associated with these injury events.

INTRODUCTION

Agriculture is one of the most injurious industries in the United States (US). The development of effective injury prevention strategies has been hampered by a lack of information regarding agriculture injuries [Zhou and Roseman, 1994]. Increased attention has been paid to identifying and correcting injury hazards on the farm. Three major causes of agriculture injury are consistently reported in the literature: farm machinery, falls, and animal-related injuries [Brison and Pickett, 1992, Nordstrom et al., 1995, Pratt et al., 1992, Zhou and Roseman, 1994].

Previous studies have indicated that machinery is a primary cause of farm-related injuries [Cordes and Foster, 1988, Gerberich et al., 1998, May, 1990] and the cause of death or disability in many cases [Etherton et al., 1991, Purschwitz and Field, 1990, Stallones, 1990]. Etherton et al. [1991] found tractors to be responsible for 69% of machinery-related fatalities, while Gerberich et al. [1998] reported that 23% of machinery-related non-fatal injuries were attributable to tractors. Tractor overturns have been reported as the primary cause for the majority of tractor-related fatalities [Erlich et al., 1993, Jackson, 1983, Purschwitz and Field, 1990].

Tractor fatalities result from being run over or crushed by the tractor, entanglement in moving parts of the tractor, crashes on roadways, and tractor roll-overs, which involve tipping the tractor sideways or backwards and crushing the operator [Reynolds and Groves, 2000]. Tractors are also associated with a large number of non-fatal agriculture injuries [Bancej and Arbuckle, 2000, Brison and Pickett, 1992, Cordes and Foster, 1988, Fuortes et al., 1990, Layde et al., 1995, Lee et al., 1996, May, 1990]. In 2005, a rate of 2.4 non-fatal, days-away-from-work tractor injuries per 10,000 full-time workers was reported for the natural resources and mining industry [US Department of Labor, 2006]. The 2005 non-fatal, days-away-from-work tractor injury rate was based on injuries that were recognized, diagnosed and reported for operations with 11 or more employees. Since roughly 95% of US farms have less than 11 employees [Pratt et al., 1992], this injury rate is likely an underestimate of all tractor injuries among the agricultural population.

Although tractors are consistently identified as a major source of agricultural injury, many studies present tractors and machinery in one category, limiting the specificity of risk factor identification that can be attributed to tractors [Carlson et al., 2005]. Information is also limited regarding the spectrum of tractor-related injuries, including nonfatal events [Lee et al., 1996]. This paper presents a case-based research project which investigated tractor-related agricultural injuries. The objectives of this study were to analyze workers' compensation claims data to: 1) determine the medical and indemnity costs of tractor-related and tractor overturn injuries, and 2) determine factors associated with tractor-related and tractor overturn injuries. This study was one of several investigations which comprised the NIOSH Agricultural Centers *National Tractor Safety Initiative: Costs of Tractor Operator Injuries from Overturns and Highway Collisions* project. The objective of this multi-center project was to determine the cost of farm tractor overturn injuries and identify who bears these costs. Individual studies in this project used recently collected data about the frequency and severity of tractor overturn injuries to estimate the costs associated with these events and losses averted by retrofitting unguarded tractors with rollover protective structures (ROPS) or replacing them with ROPS-equipped tractors. Results from this study can be combined with data from other initiative projects to estimate the total cost associated with tractor-related injuries, as well as tractor-overturns. The results of this study are critical for estimating the total cost of agricultural tractor-related injuries.

METHODS

Data Source

Injury claims data were provided by Pinnacol Assurance (Colorado), and by State Compensation Insurance Fund of California. For more than 90 years Pinnacol Assurance has been providing workers' compensation insurance to Colorado businesses. Pinnacol has a premium market share of more than 50% for all industries and insures approximately 60,000 Colorado businesses and their employees [Pinnacol Assurance, 2007]. State Compensation Insurance Fund of California has provided workers' compensation coverage in California for more than 90 years, and also has a premium market share of more than 50%.

State Workers' Compensation

The California and Colorado Divisions of Workers' Compensation are state agencies responsible for administration and enforcement of workers' compensation laws in their respective states. State statutes require all employers to have workers' compensation coverage if they have one or more employees. In both states, business owners or partners are not required to have workers' compensation coverage. Corporate officers must be included in a workers' compensation policy in California, but may elect to reject coverage in Colorado. Therefore, the data include employed workers in Colorado and include workers and corporate officers in California but may not include corporate officers in Colorado and owner/operators in either state.

Workers' compensation benefits in both states include payment for medical expenses, wage-replacement, permanent impairment or disfigurement, and death benefits. Medical benefits include payment for all expenses associated with physician visits, hospital treatments if needed, rehabilitation, diagnostic testing, and prescription medications. Wage-replacement benefits (indemnity) include payment of lost wages, up to two-thirds of the injured worker's normal earnings. In both Colorado and California, an injured worker is eligible for indemnity benefits after three lost days of work due to injury.

Data Sample

Colorado closed claims for injuries occurring from the period of January 1, 1992 through December 31, 2004, and California closed claims for injuries occurring from the period of January 1, 2000 through December 31, 2005 were included. Colorado and California claims represented the agricultural industry only. Pinnacol Assurance and State Fund of California provide workers' compensation coverage for more than 50% of agricultural businesses that are required by law to purchase workers' compensation coverage in their respective states.

Electronic injury claims data used in this study were derived from First Reports of Injury (FRI). In both states, completion of an FRI is a workers' compensation administrative requirement when filing a claim and injury data may be provided directly by the injured or by their foreman, supervisor, or business owner. Colorado injury data included injury information (injury by nature, source, and body part), employer industry codes (Standard Industrial Classification [SIC] codes), and occupational risk classification codes [class codes] to assign types of occupational tasks. A description of the injury event taken from the FRI provides a narrative account of the injury event. Medical and indemnity cost information was included. California injury data included injury information (injury nature, source, and body part), employer SIC codes, medical and indemnity claim costs, and injury event descriptions.

Tractor-Related Injury Case Definition

Since workers' compensation data were used in this study, work-relatedness of each injury claim was assumed. A tractor-related injury claim was defined as any unintentional work-related injury resulting from any activity involving a tractor. A tractor-rollover injury claim was defined as any unintentional work-related injury resulting from any activity involving a tractor rollover, tip, or upset. Injury claim cases are events where persons were injured. Injury severity was based on data provided for each injury claim. Therefore, no minimum level of injury severity was required for inclusion in the analysis.

Data Collection

Claims data were extracted from state databases using criteria determined by the respective state workers' compensation provider. The initial focus of the investigation was on tractor overturn injuries. The California database was queried with the intent of identifying claims involving tractor overturns in agriculture (SIC Code 01). The following injury cause codes were used by the California workers' compensation provider to query the database for possible tractor-rollover claims: "Collide With Other Vehicle," "Collide With Fixed Object," "Vehicle Upset," and "Motor Vehicle Miscellaneous." All claims from January 2000 through December 2004 identified as possible tractor-rollover claims were electronically transmitted to the authors for further analysis. The focus of the investigation was then expanded to include all agricultural tractor-related injuries. The Colorado database was queried by the workers' compensation provider with the intent of identifying all agriculture tractor-related claims. For Colorado, all claims in SIC group Agriculture Production-Crops (SIC code 01) were queried. Colorado agricultural claims from January 1992 through December 2004 were electronically transmitted to the authors for analysis. All claims data were extracted from Oracle [Oracle Corporation, 2002] relational databases using Hyperion Explorer 6.6.4 [Hyperion Solutions Corporation, 2004]. Strict confidentiality of all claims data was enforced throughout the investigation, and personal identifiers were removed prior to electronic transmission of data. The Colorado State University Human Subjects Review Committee reviewed and approved this study.

Identification of Tractor-Related Injuries

Injury event descriptions of Colorado and California injury claims were analyzed to identify tractor-relatedness. A text-search was conducted on each injury claim description. Potential tractor-related injury claims were identified by locating the index terms "tractor", "truck", "steering", "driver", "driving", "climbing", "riding", "implement", "control", "trailer", "run over", "snow plow", "rolled", "rollover", "flipped", "hill", "incline", "throw", "tipped", and "tip over". After identification of each index term, each description was reviewed to determine if the claim was tractor-related.

Data Analysis

Descriptive analyses included the frequency of claims by injury nature, body part, and month of injury. Chi square analysis was used to investigate seasonality of tractor-related injuries. Descriptive analyses also included the costs (medical and indemnity) associated with each tractor-related injury claim. Injury event narrative descriptions were analyzed using the classic agent-host-environment epidemiological model [Gordis, 2004] to identify major circumstances leading to tractor-related injuries. An injury is the product of an interaction of the *host* (person injured), an *agent* that injures, and the *environment* that promotes the exposure. A *vector* or *vehicle* transmits the energy from the agent to the host. Agents of injury have been identified as the various forms of energy: mechanical, thermal, chemical, electrical, ionizing radiation, or too little energy in the case of asphyxiation [Gibson, 1961]. This model has been applied in infections disease and injury research, and this approach to workers' compensation claims analysis of agricultural injuries has not been presented in scientific literature. All data analyses were performed using SAS PC software version 9.1.2.

RESULTS

From the Colorado workers' compensation provider, a total of 23,484 injury claims from 1992-2004 were provided for analysis. After event description analysis, a total of 642 tractor-related injury claims were identified (Figure 3.1). From these tractor-related injuries, 11 involved tractor-overturns including one fatality. From the California workers' compensation provider, a total of 2,317 injury claims from 1994-2004 were provided for analysis. After event description analysis, a total of 115 tractor-related injury claims were identified (Figure 3.2), with 11 involving tractor overturns. Among the California tractor-related claims, 12 involved fatalities (1 of these involved a tractor rollover).

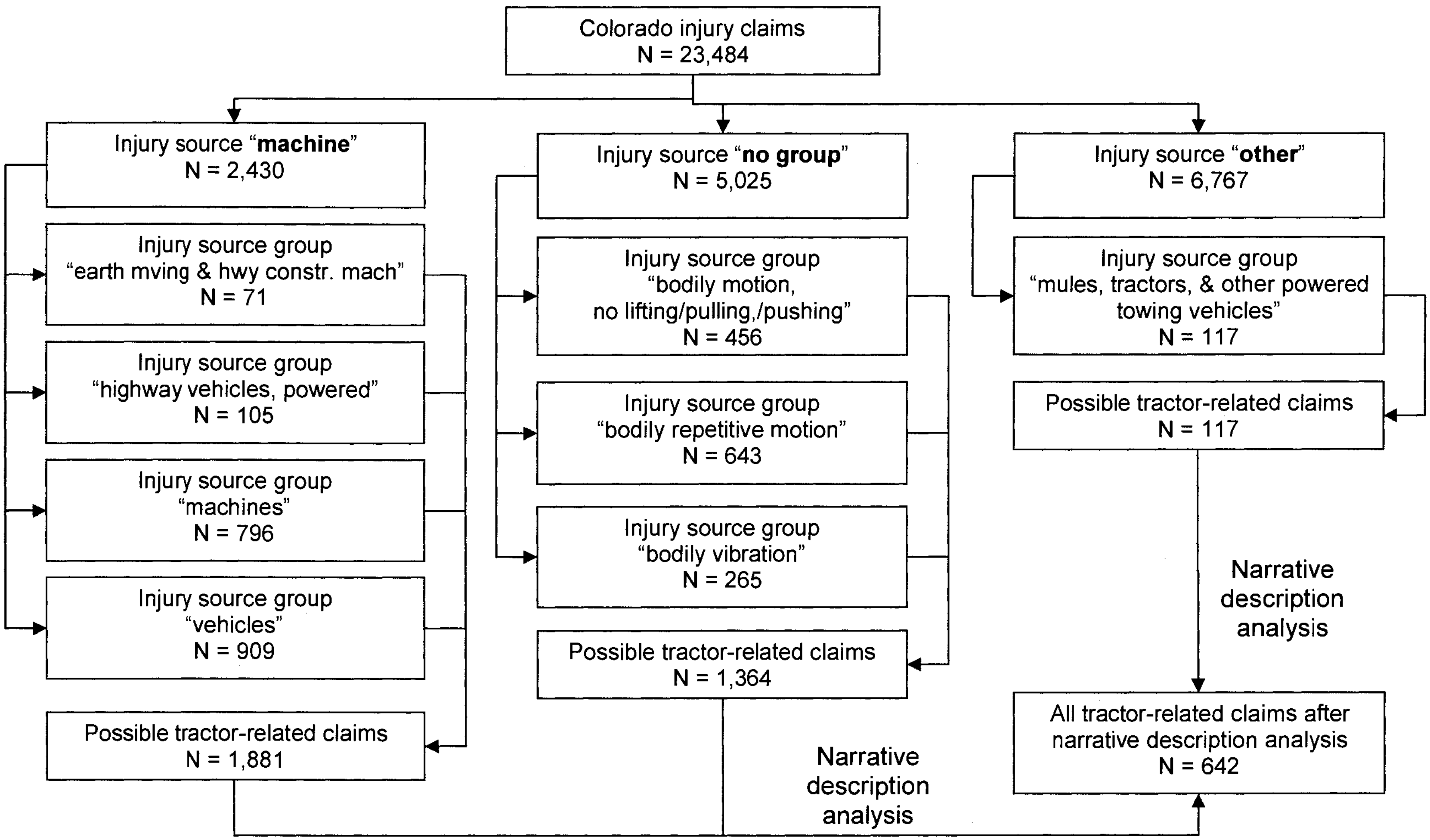

Figure 3.1. Identification of Colorado tractor-related injuries.

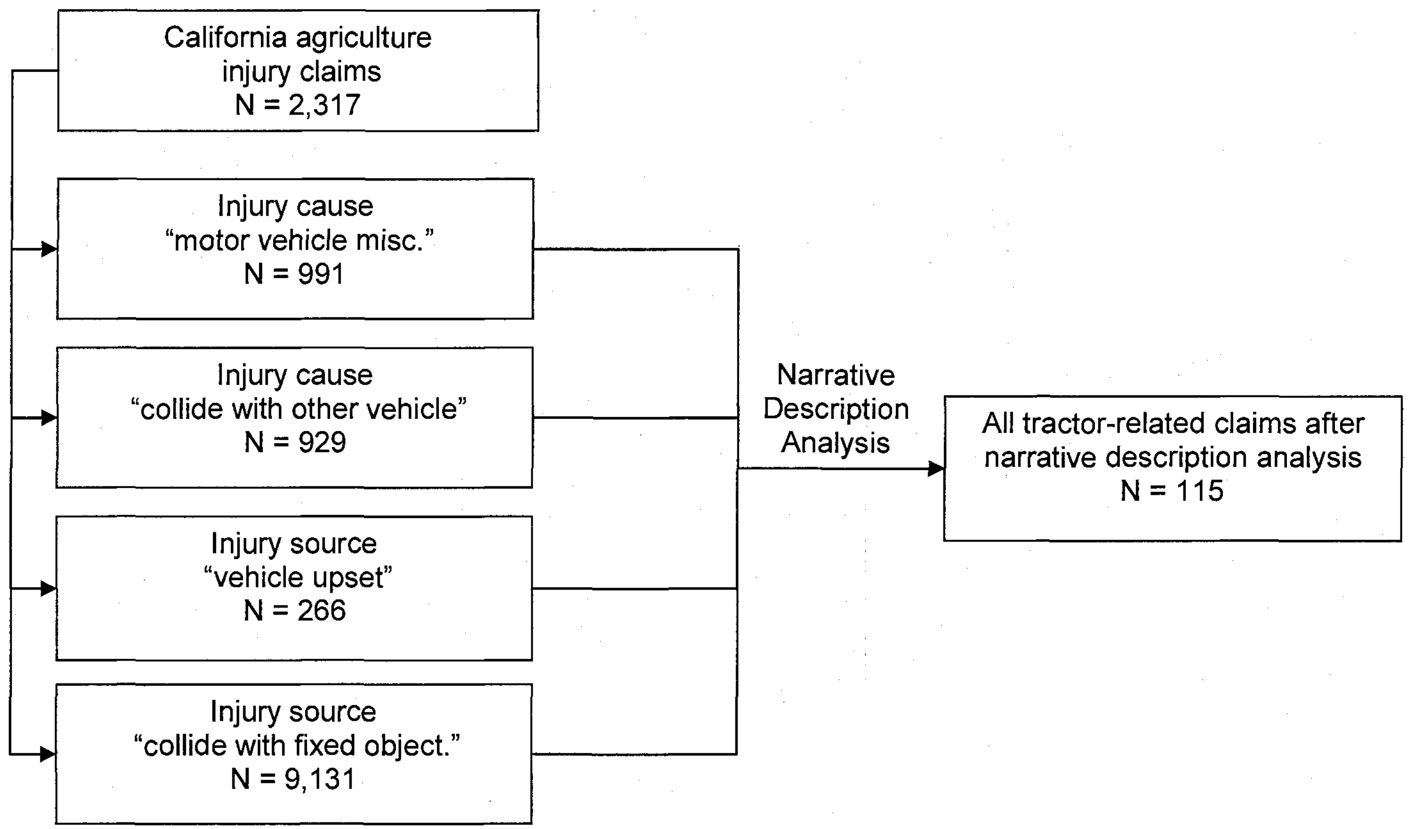

Figure 3.2. Identification of California tractor-related injuries.

Injury Characteristics

Table 3.1 presents the distribution of tractor-related anatomical injuries. Body parts primarily injured from tractor-related events were both lower (29.7%) and upper extremities (24.7%), the spine and back (12.2%), multiple body parts (9.1%) and the face (7.4%). The major types of injuries (Table 3.2) included sprains/strains (33.5%), followed by contusions (24.8%) and fractures/dislocation (9.9%); lacerations (12%), foreign bodies (3.3%) and other injuries (3.8%) comprised the remaining major proportions. Of the 130 mounting/dismounting related injuries, 35% involved the ankle and 15% involved the knee. Table 3.3 presents injury nature and body part injured of tractor overturn injuries.

The highest proportion of tractor-related injuries (65.8%) occurred from April through September, while a quarter of injuries occurred in May and June. Only 19.3% of injuries occurred from November through February (Table 3.4). Chi square goodness of fit analysis revealed significant non-uniform monthly variation of tractor-related injuries (chi square = 82.11, 11 df, $p < .001$), and Edwards' chi square analysis [Edwards, 1961] revealed a significant seasonal variation of tractor-related injuries (chi square = 75.79, 2 df, $p < .001$) Seasonality of tractor-related injuries was modeled based on a fitted regression model [Edwards, 1961]. Figure 3.4 presents the seasonality of tractor-related injuries by plotting actual versus predicted injuries based on modeled seasonality.

Claim Costs

Nearly three-quarters of the 642 Colorado tractor-related injury claims were medical-only claims (71.8%) (Table 3.5). More than one quarter (28.1%) of all claims had medical as well as indemnity costs. The median medical claim cost for Colorado claims was $319, and the median indemnity claim cost was $0. The median medical plus indemnity cost total for Colorado tractor-related injury claims was $335. The California dataset was not separated by medical from indemnity claim costs, but a summed total of the combined costs was provided for each claim. The median and mean medical plus indemnity cost for California tractor-related injury claims were $3,162 and $48,454, respectively. Table 3.6 presents cost data for tractor-overturn injuries. The median and mean medical plus indemnity cost for Colorado tractor overturn injury claims were $28,764 and $338 respectively, and the median and mean medical plus indemnity cost for California tractor overturn injury claims were $65,062 and $37,150 respectively.

Contributing Factors

Narrative analysis of injury event descriptions shed light on factors associated with tractor-related injury claims. Table 3.7 presents contributing factors of tractor-related injuries and includes only Colorado injury claims. Colorado descriptions included an average of 3.9 factors to classify as an agent, host or environment factor. California injury descriptions were much more concise, averaging 1.1 factors that were used for classification. Fifteen percent of claims involved tractor maintenance. Nearly 8% of claims indicated the worker was attaching an implement or load, and 7% of injuries occurred while the worker was driving the tractor. A large proportion (20%) of descriptions indicated the worker was mounting or dismounting the tractor at the time of injury. In addition to mounting/dismounting activities, a total of 63 claims (10%) indicated the worker fell, jumped, or slipped off a tractor. A total of 15 claims indicated that the worker was injured as a result of being hit by a tractor bucket, and 8 claims indicated a tractor rolled over a worker. Seven claims involved a body part getting caught in a power take off (PTO). Despite limited environmental information, cold, ice, snow, mud, and driving on slopes or over holes were frequently mentioned. A weather-related factor was mentioned in 5% of the claims, and 4.5% of claims mentioned a terrain factor. Seven of the 13 Colorado tractor-overturns involved driving on an incline or slope. Nearly 8% of claims identified the location of the injury event as taking place between the tractor and implement.

DISCUSSION

This study represents one of the first of its kind to document agriculture tractor-related injuries using workers' compensation data. This study provides information on the costs, characteristics and contributing factors associated with tractor-related injury claims among Colorado and California agriculture workers. Although tractor-related injuries have frequently been described as an important problem among agricultural populations, few studies have been population-based or have analyzed particular risk factors [Carlson et al., 2005, Lee et al., 1996] . Despite differences in the present methods as compared to previous studies, comparisons can be made with other studies specific to injury characteristics and contributing factors.

The agent-host-environment model provided a framework to identify factors associated with tractor-related injuries. Host (worker) factors were divided into job activity and worker action factors. Among job activities, 15% of claims resulted while the worker was performing maintenance on the tractor at the time of injury. Nearly 8% of injury claims were associated with attaching an implement to a tractor, and 7% of claims were associated with driving a tractor. Similar findings have been reported in other studies. Carlson et al. [2005] reported that performing general tractor repairs accounted for 11.7% of tractor-related injuries, and 10.4% involved tractor driving. Another 8% involved hitching or adjusting a load. Lee et al. [1996] reported 17% of tractor injuries involved adjusting or hitching a load, and another 12% involved tilling, cultivating or planting. Maintenance work may involve lifting heavy objects such as tractor tires or machinery, resulting in overexertion injuries. This is supported in the present study by data indicating that 32% of injury events involving tractor maintenance as being classified as sprain or strain injuries. Lifting aids such as mechanical hoists can be used for lifting heavy objects such as tractor parts or tires, reducing the physical stress on the worker. Reducing the physical demand associated with lifting may reduce the risk for overexertion injury.

Worker action was a second host classification used in the present study. A notable proportion (20%) of descriptions indicated the worker was mounting or dismounting the tractor at the time of injury. A total of 63 claims (10% of claims) indicated the worker fell, jumped, or slipped off a tractor resulting in an injury. Seven claims specifically mentioned slippery tractor steps. In the present study, 50% of mounting dismounting injuries was to the ankle or knee. Our finding that a high percentage of injury claims were associated with tractor mounting or dismounting activities is consistent with other findings [Gerberich et al., 1991, Juha, 1992, Waller, 1992]. Tractors and falls have been identified as important causes of injury in agriculture [Bancej and Arbuckle, 2000, Brison and Pickett, 1992, Gerberich et al., 1993, Layde et al., 1995, Nordstrom et al., 1996, Pickett et al., 1999]. Notable proportions of agriculture injuries have also been linked to falls from tractors [Day, 1999, Lee et al., 1996, Pickett et al., 1999]. Elkington [1990] reported that 11% to 19% of machinery-related injury events in a Southeastern Minnesota county were associated with falls, including those from tractors. Lee et al. [1996] noted that over 40% of injuries in their investigation occurred while mounting or dismounting a tractor, and Carlson et al. [2005] reported 33.1% of tractor-injuries were attributed to the same activity. The need to further investigate tractor design and safety, especially relevant to mounting and dismounting tractors, has been discussed previously [Carlson et al., 2005, Gerberich et al., 1998, Gerberich et al., 1991, Lee et al., 1996, Waller, 1992] and our findings further support this need. The American Society of Agricultural Engineers (ASAE) has developed a series of voluntary safety standards for the design, manufacture and use of agricultural machinery, equipment and systems. ASAE Standard S318.10 provides safety information for the normal operation and service of agricultural equipment. Regarding the mounting and dismounting of a tractor, all agricultural equipment should have steps and handholds that make it easy for the operator to get on or off the tractor. The height of the first tractor step should not be more than 27 inches off the ground, and the distance between steps should be between 12 and 16 inches. Steps should be at least 10 inches wide. All steps should have a slip-resistant surface, and should be kept free of oil, grease, mud and other debris [American National Standards Institute, 2006] These design specifications may not be accommodating the current population of operators and should be re-evaluated using an updated anthropometric database reflective of the population of tractor users/operators. Refer to Figure 3.3 for an example of a tractor step that presents a slip hazard.

Future research should address not only the percentage of tractors in operation which meet these recommended standards, but also if these recommendations provide the necessary protection against tractor mounting or dismounting injuries. Tractor operators have reported a problem of tractor steps being high above the ground which contributed to mounting and dismounting injuries [Lee et al., 1996]. Another factor to be considered is step visibility. Poor step visibility may contribute to improper foot placement which

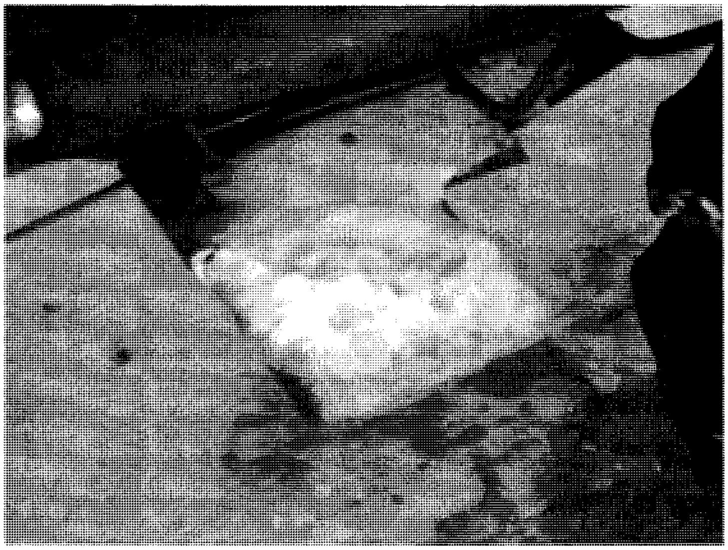

Figure 3.3. Snow covered tractor step creating a slip hazard.

may result in slips or falls. This is especially relevant for older tractor operators since age-related changes in visual acuity, contrast sensitivity, visual fields and depth perception have been identified as risk factors for falls [Black and Wood, 2005]. A human factor analysis of tractor step visibility is warranted.

Many agents of injury were identified, and several involved movement of the tractor or component parts. Tractors are potentially dangerous types of machinery, and moving parts present opportunities for injury. When using any self-propelled machine and before attempting any adjustments, maintenance, repair, or unclogging operations, the engine should be stopped and the operator should remain in the tractor seat until all machine elements have ceased movements. Tractor operators may not follow these safety guidelines for the sake of time, and any safety solution should consider the tendency toward this behavior. Fellow workers should remain clear of all moving tractor parts when in operation. Tractor operators should also be aware of environmental hazards such as mud, ice, snow, frozen ground, and unlevel terrain. These factors should be considered before they affect the operation of the tractor or the operator's safety.

Data analysis revealed a significant non-uniform, seasonal trend of tractor-related injuries. Nearly 66% of tractor-related injuries occurred between April and September (50% of year) correlating with increased tractor usage during cultivating, planting, and harvesting activities. The months of May and June combined represented 26% of injuries. Lee et al. [1996] reported 68% of tractor-related injury events took place between April and September, and 32.3% took place in May and June combined. Results from the present study are also consistent with other studies that have considered farming-related injuries in general [Gerberich et al., 1993, Gerberich et al., 1991].

Findings specific to anatomical locations and types of injuries are similar to those findings from population-based efforts that have also addressed tractor-related injuries. Lee et al. [1996] reported 20% of tractor-related injuries involved the upper extremities, 33% involved the lower extremities, and 28% involved the back and spinal cord. Lee et al. [1996] also reported 31% of tractor-related injuries involved sprains, strains and torn ligaments, followed by contusions (17%) and fractures/dislocations (15%). Carlson et al. [2005] reported almost one-fourth of tractor-related injuries were to the back (24%) and 19% were to the fingers and/or thumbs. Carlson et al. [2005] also reported that tractor-related injuries involved sprains and strains (41%), contusions (23%), and fractures/dislocations (23%). Findings from the present study in relation to body part injured and injury type are consistent with findings from previous investigations which addressed farm-related injuries in general [Gerberich et al., 1993, Gerberich et al., 1991].

Several authors have reported that the physical and financial burdens of non-fatal tractor-related injuries, when measured by health care costs/and or lost productivity are substantial [Carlson et al., 2005, Gerberich et al., 1993, Gerberich et al., 1998, Gerberich et al., 1991, Hartling et al., 1997, Lee et al., 1996]. Carlson et al. [2005] reported nearly 30% of tractor-related injuries resulted in a day or more of lost work on the operation, with 16% involving a week or more of lost work. In addition, 29% of tractor-related injuries resulted in more than 1 day, but less than a week, of restricted general activity; while 26% resulted in a week or more. Lee et al. [1996] reported 42% of tractor-related injuries resulted in a day or more of lost work on the operation, with 28% involving a week or more of lost work. The present study found 28% of Colorado tractor-related injury claims received indemnity benefits. Our findings suggest that over a quarter of Colorado hired workers missed a minimum of 3 calendar work-days as a result of a tractor-related injury since state statute allows indemnity benefits after missing a minimum of 3 days of work suggesting a more severe injury.

As in previous studies of workers' compensation claims cost [Cheadle et al., 1994, Courtney et al., 2002, Dempsey and Hashemi, 1999, Hashemi et al., 1998, Hashemi et al., 1998, Hashemi et al., 1997, Murphy and Courtney, 2000], the distribution of claim cost was skewed (Table 3.5). Studies examining workers' compensation injury costs have found mean costs to exceed median figures by as much as 23.2 times [Courtney et al., 2002, Dempsey and Hashemi, 1999, Hashemi et al., 1998, Hashemi et al., 1997]. The mean cost of a Colorado tractor-related injury claim was 25.0 times higher than the median cost of a tractor-related injury claim. The mean cost of a California tractor-related injury claim was15.2 times higher than the median cost of a tractor-related injury claim. These results indicate that a small number of claims accounted for a high percentage of the cost in each state dataset. Colorado mean indemnity claims cost was 1.91 times the mean medical claims cost and the overall mean medical plus indemnity claim cost was 3.24 times higher than the medical claims cost, suggesting that indemnity cost, rather than medical treatment cost, was the principal cost driver of injury claims. The overall median indemnity claim cost of $0 in the Colorado dataset indicates that at least half of workers who filed a tractor-related injury claim did not lose enough time from work to qualify for wage replacement under the Colorado compensation system. Leigh et al. [1997] constructed a ranking of occupations based upon the costs of job-related injuries and illnesses associated with workers' compensation claims. Data was drawn from the Bureau of Labor Statistics, Supplementary Data System. For this study, Supplementary Data System data included workers' compensation injury and illness data from eight states: Arkansas, Colorado, Delaware, Iowa, New York, North Carolina, Oregon and Wisconsin. The authors reported that farming, forestry, and fishing occupations had an average medical plus indemnity claim cost of $368, and ranked fourth highest of average injury costs by occupation. Authors did point out that their cost estimate likely did not adequately reflect the true costs of injuries and illnesses associated with these occupations because workers' compensation data often under-represents farming, forestry and fishing occupations.

The Colorado and California datasets contained 13 and 11 tractor overturns respectively. The median Colorado medical cost of tractor overturn claims ($288) was lower than the median for tractor-related injury claims ($319). There was no difference between overall median medical plus indemnity claim costs of tractor overturns ($338) from tractor-related claims ($335). Claims cost data involving tractor overturns indicate higher costs than tractor-related injury claims in general. Mean indemnity claims cost for tractor-overturn claims was 5.41 times the mean medical claims cost and the overall mean medical plus indemnity claim cost was 6.42 times higher than the medical claims cost. The mean indemnity claims cost was much higher for tractor-overturn injury claims ($24,283) than that for tractor-related claims ($4,932) suggesting that tractor-overturn injuries were more serious in nature and resulted in more lost-time.

California claims costs were higher than in Colorado. This variation may be the result of differences in state regulated medical fee schedules for the treatment of work-related injuries and other factors. In both Colorado and California, injured workers were eligible for disability benefits after a 3 day waiting period, and the total temporary disability rate was two-thirds of average weekly earnings. Indemnity payments are dependent on average weekly earnings which may vary in each state and agriculture sector. Higher California claim costs may reflect higher agriculture wages in California. A comparison between California and Colorado indemnity costs was not possible because indemnity costs were not separated from medical costs in the California claim data provided. Miller and Levy [1997] reported substantial interstate variation in payments across states for the treatment of different types of injuries under workers' compensation. Specific factors that were found to influence costs include a higher percentage of urban population, regional trauma care centers, the presence of Health Maintenance Organizations, and a higher percentage of general practitioners, all of which are associated with lower payments.

Study Limitations

This study had the same limitations as other workers' compensation studies. Workers' compensation data are susceptible to underreporting of injury claims. Studies by Biddle et al. [1998], Morse et al. [1998], Rosenman et al. [2000], and Shannon and Lowe [2002] reported the percentages of people who could qualify for workers' compensation but who never filed were 55%, 79% , 75%, and 35% respectively. Studies have revealed that musculoskeletal disorders were in general, underreported, and workers' compensation data did not accurately reflect prevailing musculoskeletal occurrence rates [Biddle et al., 1998, Herbert et al., 1999, Lipscomb et al., 1997, Morse et al., 2005, Morse et al., 2001, Morse et al., 1998, Pransky et al., 1999, Rosenman et al., 2000]. Fan et al. [2006] reported several occupation and industry groups reported a higher proportion of work-related injury or illness but lower workers' compensation claim filing. . By industry, agriculture/forestry/fishing and construction ranked higher in reporting work-related injury or illness and lower in workers' compensation claim filing. By occupation, farming/forestry/fishing ranked highest in reporting work-related injury or illness and second lowest in workers' compensation claim filing. Osorio et al. [1998] reported evidence of underreporting among farm workers in California. Injury reporting is vulnerable to a variety of filtering effects, and employer state differences in reporting and recording practices for workers' compensation may also influence the results [Smith et al., 2005, Webb et al., 1989]. The degree to which results from California and

Colorado apply to other states or jurisdictions is unknown, and should be approached with caution. Seasonal, commodity, and terrain variations exist across states, and injury patterns may be influenced by these variances. Claims data represent hired workers, and may not include agriculture operation owners and family members who work on the farm.

The possible misclassification of claim information by workers' compensation provider coders was not assessed due to restriction in access to the primary claim FRI documents for the purposes of claimant confidentiality. As a result, the possibility of misclassification of claims data exists. Zakaria et al. [2003] assessed the accuracy of claims coding and found an overall accuracy of 86% with respect to nature of injury and part of body injured.

Indemnity cost data would not take into account disability among workers who did not satisfy state waiting periods for wage replacement benefits. Therefore, our results likely underestimate actual indemnity expenses experienced by those injured in a tractor-related event. Medical and indemnity costs do not encompass all dimensions of financial burden to the industry due to injury. Burden also includes indirect costs such as lost productivity, increased absenteeism, higher employee turnover, and recruitment of replacement workers [Shah et al., 2005]. Financial burden is felt by the injured worker in the form of lost wages and productivity.

In the present study, narrative descriptions of injury events were analyzed using the agent-host-environment epidemiological model. Narrative descriptions were dependent on information accuracy, detail, and completeness provided in the FRI of each injury claim. Narrative descriptions were therefore subject to information bias which was not able to be controlled in the present study.

Study Strengths

There are several reports in the literature in which workers' compensation claims data have been successfully utilized to investigate agricultural injuries and illnesses among hired farmworkers [Belville et al., 1993, Cooper and Rothstein, 1995, Demers and Rosenstock, 1991, Heyer et al., 1992, Villarejo, 1998]. This study was the first to utilize workers' compensation claims to specifically investigate agricultural tractor-related injuries. The strengths of this study include the ability to analyze medical and indemnity costs associated with tractor-related injuries, as well as the identification and examination of a large sample (n=757) of tractor-related injuries. Other population-based studies analyzed smaller numbers of tractor-related injuries [Carlson et al., 2005, Lee et al., 1996]. This study also demonstrates the application of the agent-host-environment epidemiological model to the analysis of workers' compensation data.

CONCLUSION

Through an analysis of 757 tractor-related workers' compensation injury claims, it was possible to evaluate specific characteristics and consequences of non-fatal tractor-related injuries among hired farmworkers. While not population-based, this case-based study of workers' compensation data regarding tractor-related injuries adds to the knowledge base of previous efforts pertinent to non-fatal tractor-related injuries in agriculture. The workers' compensation data analyzed in this study helped identify contributing factors to tractor-related injuries and associated costs (medical and indemnity). The finding of a large proportion of injury claims associated with tractor mounting and dismounting activities suggests a need to further investigate specific tractor design characteristics. The cost data in this study will be combined with data from other National Tractor Safety Initiative projects to more accurately estimate the total costs associated with tractor-related injuries, as well as tractor-overturns. The results of the present study can be utilized in the development of safer tractor design characteristics.

Table 3.1. Body part locations of 757 tractor-related injuries (642 Colorado and 115 California)

Body Part Group	Body Part	N	%
Arm	Elbow	12	1.6
	Lower Arm	13	1.7
	Shoulder(s)	22	2.9
	Upper Arm (Incl. Clavicle & Scapula)	16	2.1
	Arm Total	**63**	**8.3**
Chest	Chest (Incl Ribs, Sternum, Soft Tissue)	27	3.6
Face	Ear(s)	1	0.1
	Eye(s)	30	4.0
	Mouth	7	0.9
	Nose	2	0.3
	Other Facial Soft Tissue	16	2.1
	Face Total	**56**	**7.4**
Foot	Ankle	68	9.0
	Foot	48	6.3
	Great Toe/Toes	14	1.8
	FootTotal	**130**	**17.2**
Hand	Finger(s)	66	8.7
	Hand	30	4.0
	Thumb	17	2.2
	Wrist	11	1.5
	Hand Total	**124**	**16.4**
Internal Organs		11	1.5
Leg	Hip	7	0.9
	Knee	53	7.0
	Lower Leg	31	4.1
	Upper Leg	4	0.5
	Leg Total	**95**	**12.5**
Lower Trunk	Abdomen Including Groin	10	1.3
	Buttocks/Pelvis	3	0.4
	Lower Trunk Total	**13**	**1.7**
Multiple Areas	Body System And Multiple Body Systems	2	0.3
	Multiple Body Parts	67	8.9
	Multiple Areas Total	**69**	**9.1**
Multiple Head Injury		12	1.6
Multiple Lower Extremities		5	0.7
Multiple Trunk		20	2.6
Multiple Upper Extremities		11	1.5
Neck	Multiple Neck Injury	16	2.1
	Neck, Soft Tissue	4	0.5
	Neck Total	**20**	**2.6**
Skull		9	1.2
Spine/Back	Disc	3	0.4
	Low Back (Lumbar & Lumbo-Sacral)	81	10.7
	Neck Vertebrae	4	0.5
	Upper Back Area	4	0.5
	Spine/Back Total	**92**	**12.2**

Table 3.2. Injury nature of 757 tractor-related injuries (642 Colorado and 115 California)

Injury Nature	N	%
Strain	208	27.5
Contusion	188	24.8
Laceration	71	9.4
Fracture	68	9.0
Sprain	46	6.1
Not described	44	5.8
Foreign body	25	3.3
Crushing	18	2.4
Burn	9	1.2
Puncture	8	1.1
Dislocation	7	0.9
All other cumulative injuries	5	0.7
Inflammation	5	0.7
Concussion	4	0.5
Hernia	4	0.5
Rupture	4	0.5
Amputation	3	0.4
Severance	3	0.4
Poisoning-chemical	2	0.3
Respiratory disorders	2	0.3
Asphyxiation	1	0.1
Dermatitis	1	0.1
Infection	1	0.1
Myocardial infarction	1	0.1
All other	29	3.8

Table 3.3. Nature of injury and body part injured of 24 tractor overturn injuries (13 Colorado and 11 California)

	N	%
Injury Nature		
Asphyxiation	1	4.2
Contusion	11	45.8
Crushed	3	12.5
Death	2	8.3
Fracture	3	12.5
Laceration	1	4.2
Multiple	3	12.5
Body Part		
Chest	1	4.2
Elbow(s)	2	8.3
Foot	1	4.2
Hand	1	4.2
Lower leg(s)	2	8.3
Low back	1	4.2
Multiple body parts	14	58.3
Shoulder(s)	1	4.2
Upper arm	1	4.2

Table 3.4. Month of 642 Colorado tractor-related injuries.

Month*	**N**	**%**
January	35	5.5
February	29	4.5
March	52	8.1
April	66	10.3
May	83	12.9
June	83	12.9
July	67	10.4
August	64	10.0
September	60	9.3
October	43	6.7
November	31	4.8
December	29	4.5

*Chi square goodness of fit test for uniformity
(chi square = 82.11, df = 11, $p < .001$);
Edwards' chi square test for seasonality
(chi square = 75.79, df = 2, $p < .001$)

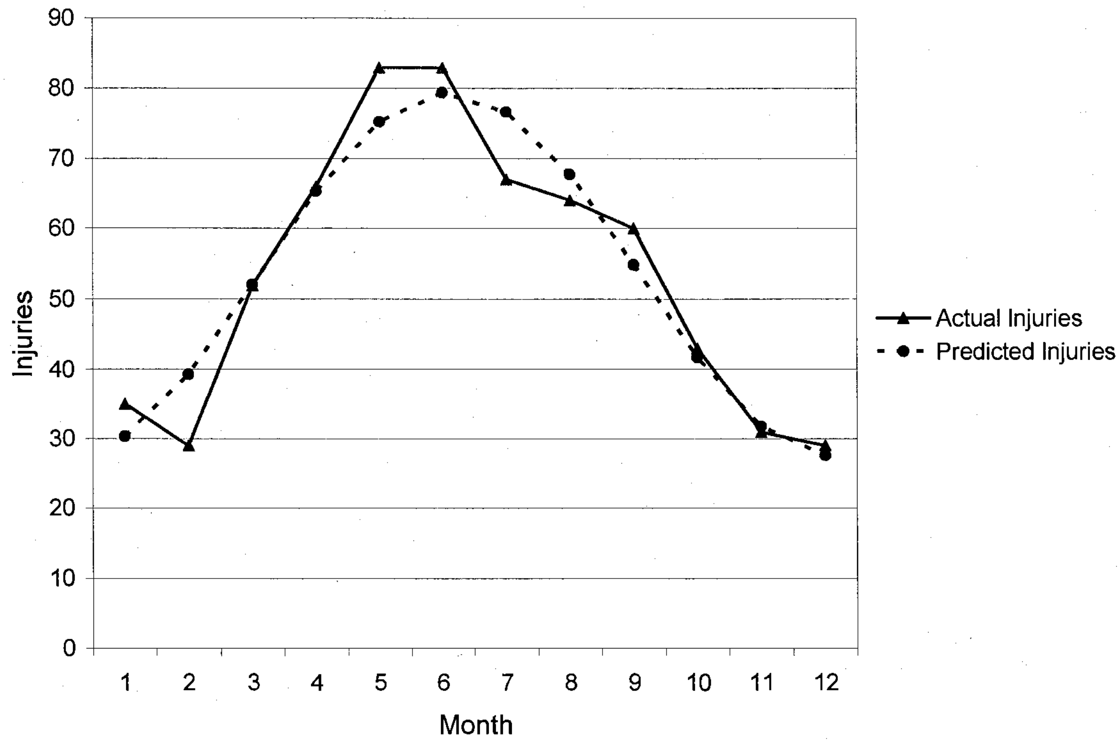

Figure 3.4. Seasonality of Tractor-Related Injuries. Plot of actual versus predicted tractor-related injuries (modeled seasonality) based on fitted regression model [Edwards, 1961].

Table 3.5. Severity and cost of tractor-related injuries.

	Colorado	California
Total tractor-related claims	642	115
Total medical-only claims	461	n/a
Total medical plus indemnity	181	n/a
Injury Costs[a]		
Medical[b]		
Mean	2,582	n/a
Median	319	n/a
Range	0 - 91,404	n/a
Indemnity		
Mean	4,932	n/a
Median	0	n/a
Range	0 - 353,739	n/a
Medical plus indemnity total		
Mean	8,361	48,454
Median	335	3,162
Range	0 - 461,231	0 - 566,898

[a] Means, medians, and standard deviations rounded to nearest whole dollar.

[b] Adjusted to 2007 US dollars.

Table 3.6. Severity and cost of tractor-overturn injury claims.

	Colorado	California
Number of claims	13	11
Injury Costs[a]		
Medical[b]		
Mean	4,481	n/a
Median	288	n/a
Range	0 -49,639	n/a
Indemnity		
Mean	24,283	n/a
Median	0	n/a
Range	0 - 261,523	n/a
Medical plus indemnity total		
Mean	28,764	65,062
Median	338	37,150
Range	0- 261,523	0 - 214,056

[a]Means, medians, and standard deviations rounded to nearest whole dollar.

[b] Adjusted to 2007 US dollars.

Table 3.7. Circumstances of 642 tractor-related injury claims among Colorado agriculture workers.

Host (worker)			Agent (tractor)			Environment		
	N	%		N	%		N	%
Job Activity			**Tractor Action**			**Weather conditions**		
Performing maintenance on tractor	97	15.1	Rollover	13	2.0	Cold	12	1.9
Hitching implement or equipment	48	7.5	Bucket hit body part	15	2.3	Ice	8	1.2
Driving tractor	46	7.2	Tires rolled over body part	8	1.2	Snow	5	0.8
Mowing/harvesting/planting/watering	10	1.6	Went into ditch	5	0.8	Dusty	5	0.8
Engaging/disengaging PTO	4	0.6	Hit worker while moving	5	0.8	Cloudy	1	0.2
Hauling hay	3	0.5	Hit from behind	4	0.6	Rain	1	0.2
Cultivating soil	3	0.5	Collided with vehicle	3	0.5			
Snow removal	2	0.3	Implement rolled over body	3	0.5	**Terrain**		
Hole digging	2	0.3	Tractor MVA with vehicle	3	0.5	Muddy	7	1.1
Unloading tractor	1	0.2	Jumped out of gear	2	0.3	On slope	7	1.1
Pulling wagon	1	0.2				Drove over hole	5	0.8
			Tractor parts			In ditch	4	0.6
Worker Action			Body part caught in PTO	7	1.1	Rugged	3	0.5
Dismounting tractor	101	15.7	Trailer tongue broke/fell	7	1.1	On highway	2	0.3
Mounting tractor	29	4.5	Face hit windshield	5	0.8	Bumpy road	1	0.2
Repeated mounting/dismounting	5	0.8	Battery exploded in face	5	0.8			
Fell off tractor	25	3.9	Body hit steering wheel	4	0.6	**Location**		
Foot slipped off tractor	23	3.6	Implement rolled over body	3	0.5	Between tractor and implement	51	7.9
Jumped off tractor	15	2.3	Lever/gear shift	3	0.5	Standing behind tractor	4	0.6
Body part hit tractor	14	2.2	Tire jack slipped	3	0.5	Standing near tractor	3	0.5
Thrown off tractor	2	0.3	Tire blew while driving	1	0.2	Driving under tree limbs	1	0.2
Pushing lever/gear	2	0.3	Seat broke	1	0.2			
Not following policy	2	0.3	Tripped over tractor	1	0.2	**Tractor conditions**		
Fell asleep driving tractor	1	0.2	Steering wheel fell off	1	0.2	Slippery steps	7	1.1
Riding in tractor bucket	1	0.2						

SECTION FOUR

LIVESTOCK-HANDLING INJURIES IN AGRICULTURE:
AN ANALYSIS OF WORKERS' COMPENSATION DATA

ABSTRACT

Background

Previous studies on farm injury have focused on injuries related to machinery or tractors. Livestock-handling injuries are also an important occupational hazard of farming, and studies examining this problem are few. This study used workers' compensation data to investigate livestock-handling injuries in agriculture. The purpose of this study was to determine the costs, consequences and contributing factors associated with livestock-handling injuries among dairy farmers, cattle/livestock raisers, and cattle dealers.

Methods

Livestock-handling injury claims from Colorado were analyzed. Claims represented dairy farms, cattle/livestock raisers and cattle dealer operations. Descriptive analyses of injury claim characteristics and factors associated with these injuries were conducted. Medical and indemnity claim cost was also determined. The agent-host-environment epidemiological model was used to analyze injury event descriptions.

Results

A total of 1,114 livestock-handling injury claims were identified for analysis. Injury claim rates (injury claims per 100 workers) were highest for cattle dealers (10.3), followed by dairy farms (9.4) and cattle/livestock raisers (8.4). Milking parlor tasks represented nearly 50% of injuries among dairy workers. Riding horseback, sorting/penning cattle, and tasks involving livestock-handling equipment such as chutes, fences and gates were associated with higher proportions of livestock-handling injuries among cattle/livestock raisers and cattle dealers.

Conclusions

Our study found that livestock-handling work injuries are a significant problem, more costly, and result in more time off work than other causes of agricultural injuries causes. Worker education involving livestock-handling and proper facility design are two injury prevention strategies that may lead to a reduction of livestock-handling injuries among dairy farmers, cattle/livestock raisers and cattle dealers.

INTRODUCTION

Farming ranks among the highest of United States (US) industries for work-related fatal and non-fatal injuries. The lack of information regarding agriculture injuries has been recognized as an obstacle for the development of effective injury prevention measures [Zhou and Roseman, 1994]. Within the past two decades, increased attention has been paid to quantifying and correcting farm-work injury hazards. Studies have consistently reported farm machinery, accidental falls, and animal-related injuries as major contributors to agricultural injury [Brison and Pickett, 1992, Nordstrom et al., 1995, Pratt et al., 1992, Zhou and Roseman, 1994].

Because of the increasing mechanization of farms over the past half century, and the high fatality rate associated with injuries due to farm machinery and tractors [Bernhart and Langley, 1999, Carlson et al., 2005, Cole et al., 2006, Etherton et al., 1991, Hopkins, 1989, Lee et al., 1996, McFarland, 1968, McKnight and Hetzel, 1985, Simpson, 1984], many studies of farm injuries have focused on injuries related to interactions with machinery or tractors. Animal-related injuries are also an important occupational hazard in farming. Animals may bite, kick, scratch, trample, crush, gore, buck or throw, or drag the livestock-handler [Langley, 1999]. Studies have demonstrated that nonfatal injury rates are elevated on farms with animals, especially on beef and diary farms [Brison and Pickett, 1992, Nordstrom et al., 1995, Pratt et al., 1992, Zhou and Roseman, 1994]. Researchers have reported that between 12% and 33% of injuries on the farm are caused by animals [Brison and Pickett, 1992, Cleary et al., 1961, Cogbill et al., 1985, Gerberich et al., 1998, Hoskin et al., 1988, Layde et al., 1995, Lewis et al., 1998, Myers, 1990, Nordstrom et al., 1995, Pickett et al., 1995, Pratt et al., 1992, Sprince et al., 2003, Zhou and Roseman, 1994] and livestock-related injuries account for the highest rate of lost work days [Thu et al., 1997].

Researchers have described the difficulties in quantifying the magnitude of farm-work injuries specifically associated with livestock-handling [Ehlers et al., 1993, May, 1990]. Few studies have addressed specifically animal-related injuries on farms [Boyle et al., 1997, Hendricks and Adekoya, 2001, Sprince et al., 2003, VonEssen and Donham, 1999]. Because of the limited research specifically addressing farm-work injuries associated with livestock-handling, little is known of the injury risk factors that might lead to the development of safety interventions [Layde et al., 1996].

A previous study analyzing workers' compensation injury claims of Colorado agriculture workers reported high claim rates among dairy farm workers, cattle/livestock raisers and cattle dealers [Douphrate et al., 2006]. Injuries involving machinery and livestock-handling represented high percentages of injury causes in these sectors. This paper presents a follow-up study which specifically investigated livestock-handling injuries among agriculture workers. The objectives of this study were to analyze workers' compensation data to determine the costs, consequences and contributing factors associated with livestock-handling injuries.

METHODS

Data Source

Pinnacol Assurance, Colorado's largest workers' compensation provider, provided the workers' compensation data used in this study. With more than 90 years of providing workers' compensation coverage in Colorado and a premium market share of more than 50 percent, Pinnacol Assurance is the leading workers' compensation provider in the state. Pinnacol Assurance insures approximately 60,000 Colorado businesses and their employees [Pinnacol Assurance, 2007].

Colorado Workers' Compensation

The Colorado Division of Workers' Compensation is the state agency responsible for administering and enforcing workers' compensation laws in the state. There are three ways that Colorado statute allows for employers to finance workers' compensation risk: commercial insurance, self-insurance, and insurance enabled by statute. Commercial insurance for workers' compensation may be purchased from over three hundred carriers authorized to conduct such business in Colorado. Colorado workers' compensation statute allows for employers, meeting rigid financial and loss control standards, to self-insure (self-fund). Pinnacol Assurance is a quasi-public insurance company enabled by Colorado statute.

Colorado statute requires any business with one or more employees to purchase workers' compensation insurance. Business owners or partners are not required to purchase workers' compensation coverage, and corporate officers may elect to reject coverage. According to the Colorado Workers' Compensation Act, injured workers must make a written report to the employer within four days of the injury event. Within the next 10 days the employer must submit a First Report of Injury (FRI) (Appendix B) to the workers' compensation provider. The workers' compensation provider then has 20 days from the date of receipt of FRI to admit or deny the claim.

Workers' compensation benefits include payment for medical expenses, wage-replacement, permanent impairment or disfigurement, and death benefits. Medical benefits include payment for all expenses associated with physician visits, hospital treatments if needed, rehabilitation, diagnostic testing, and prescription medications. Wage-replacement benefits (indemnity) include payment of lost wages, up to two-thirds of the injured worker's normal earnings. An injured worker is eligible for indemnity benefits after three lost days of work due to the injury.

Data Sample

A ten-year policy and claim history for injuries occurring from the period January 1, 1997 through December 31, 2006 was used in this study. All 12-month policies were included in the dataset, including those that did and did not have a reported injury. All injury claims were closed. Claims data represented Colorado dairy farm, cattle dealer, and cattle/livestock raising occupations.

Pinnacol Assurance provides coverage for more than 50 percent of Colorado agriculture operations that are required by law to purchase workers' compensation coverage. Historically, estimating agriculture worker populations for the purpose of injury rate calculation has been difficult. Data regarding state populations of hired workers specific to the operations of interest are not available. According to the 2002 Census of Agriculture [NASS, 2002], there were 31,369 farms in Colorado, and 7,747 farms hired 46,005 farm workers. Of the farms with hired workers, 35.9% hired one worker, 20.0% hired two workers, 18.4% hired three or four workers, 13.3% hired five to nine workers, and only 12.4% hired 10 or more workers. Approximately 77.2% of farms in Colorado employed workers for fewer than 150 days which reflects the seasonal employment pattern of Colorado crop production operations.

The dataset included details concerning each injury claim: the nature of injury; body part(s) affected; source of injury; cause of injury; demographic characteristics of the employee (age, gender, work experience); policy holder payroll; risk classification code; medical expense; indemnity paid (if any); days of paid indemnity; and a narrative description of the injury event. Claims data were taken from the FRI for each injury claim. The FRI may be completed by the injured or by the foreman, supervisor, or business owner.

Data Collection

As in all other states, Pinnacol Assurance uses a standardized set of empirically derived Risk Classification Codes (class codes) to assign occupational tasks. Four-digit class codes are outlined in the National Council on Compensation Insurance (NCCI) *Scopes Manual* [National Council on Compensation Insurance, 2003]. Class codes are used by the workers' compensation insurance industry to classify occupations and their job responsibilities and assign occupational risk. For this study, Pinnacol Assurance provided injury claims from the ten-year period for dairy farms (NCCI 0036), cattle/livestock raising (NCCI 0083) and cattle dealers (NCCI 8288). The injury claims data were extracted from an Oracle [Oracle Corporation, 2002] relational database using Hyperion Explorer 6.6.4 [Hyperion Solutions Corporation, 2004]. Claims data were electronically transmitted to the primary investigator who was provided security password access. Strict confidentiality of all claims data was enforced throughout the investigation, and personal identifiers were removed prior to electronic transmission of data. The Colorado State University Human Subjects Review Committee reviewed and approved this study.

Case Definition

A lack of uniform definitions and classification schemes has hindered farm injury research. Farms are places of business, as well as residence [Murphy et al., 1990]. As an industry, agriculture includes farm production work and agricultural services. Workers, owner/operators, managers, and a host of other codes comprise the agricultural occupations. Because of overlapping classifications, the determination of an "at work" injury is difficult in agriculture. Since workers' compensation data were used in this study, work-relatedness of each injury claim was assumed. Because workers whom the injury claims represent may also live on the farms where the injury took place, the work-relatedness of each claim could not be verified.

Agricultural work was defined in this study as agricultural production, including crops, livestock, and animal specialties, and agricultural services. A livestock-handling injury claim was defined as any unintentional work-related injury resulting from the performance of any livestock-handling related job task. Injury claim cases were episodes where there was an injury. Injury severity was based on data provided for each injury claim. Therefore, no minimum level of injury severity was required for inclusion in the analysis.

Identification of Livestock-Handling Injuries

There was no single injury code in the claims database that would encompass all potential livestock-handling injury events, therefore claims were identified using a combination of search strategies. First, the injury source data field was queried for all claim sources classified as "animals" and "animals, insects, birds or reptiles." Second, narrative text fields containing the circumstances of the injury (narrative description) were searched to identify potential livestock-handling injuries. Words used to describe livestock-handling activities were used as index terms for livestock-handling claim identification. Livestock-handling injuries were identified by locating the index terms "animal", "buffalo", "calf" "cattle", "chute", "cow", "fence." "gate", "goat", "herd", "horse", "herding", "hog", "pig", "pen", "penning", "swine", and "trailer". After locating claims using this list of words, each claim was examined to determine if the injury was a livestock-handling related claim.

Data Analysis

Incidence rates were estimated using employment payroll data of the claimant's employer (policy holder). Using information on policy payroll per calendar year, time at risk (expressed as hours worked by operation) was estimated using prevailing national industry-specific occupational wage estimates, which were obtained from the Bureau of Labor Statistics [US Department of Labor, 2005]. Conversion of payroll data to hours worked was based on the same methodologies as described by Glazner et al. [1998] and Lowery et al. [1998]. Aggregate time at risk was based on hours worked, summed from 1997 – 2006 for each operation. Total work hours were estimated by the following formula:

$$\text{Estimated Total Work Hours} = \frac{\text{Total Sector Payroll}}{\text{Median Hourly Wage}} \tag{1}$$

Overall and livestock-handling injury claim rates were calculated per 200,000 hours (equivalent to injuries per 100 workers per year) worked according to the following formula:

$$\text{Injury Claim Rate} = \left(\frac{\text{Category Claim Count}}{\text{Estimated Total Work Hours}}\right) \text{x } 200{,}000 \text{ Work Hours} \tag{2}$$

Injury claim rate confidence intervals were constructed as described by Haenzel et al. [1962] assuming a Poisson distribution.

Proportionate injury ratios (PIRs) were estimated to compare the proportion of livestock-handling injuries by risk classification code, operation size, age, gender, and experience. Similar to proportionate mortality ratio analysis, proportionate injury ratio analysis is commonly used to identify differences among groups when information regarding the underlying population is limited or not available [Lipscomb and Li, 2001]. Proportionate injury ratios and associated 95% confidence intervals were calculated using methods for calculating proportionate mortality ratios [Checkoway et al., 2004, Lipscomb and Li, 2001, Lombardi et al., 2005, Smith et al., 2006]. Statistical significance of the observed-to-expected ratios was assessed using chi square tests. The PIR was calculated by comparing the observed proportions of claims of one group of interest to that which would be expected if they were to have the same injury experience as a reference group of interest. Since proportions must equal 100%, an increase in one injury category will be offset by a decrease in another category.

To compare injury rates based on operation size, injury rates greater than zero were grouped into quartiles. Operations with rates in the upper quartile were designated "high rate"; operations with rates in the lower three quartiles were designated "low rate." Operations with injury rates of zero were designated as a separate category. The authors recognize that this category could include operations with true zero rates, as well as operations that may have experienced injuries but did not report them. These two categories of zero-rate operations were not distinguishable from each other.

High/low/zero categories were assigned independently within each operation type: dairy farms, cattle dealers, cattle/livestock raisers.

To compare injuries across occupation, gender, age, and experience two categories of medical costs and disability duration were used. High cost injuries were defined as those resulting in $5,000 or more in direct medical costs and serious disability was defined as those injuries resulting in 28 or more days of disability [Smith et al., 2006].

To evaluate if the number of small operations reporting no injuries was larger than expected, a binomial distribution was assumed to estimate the number of operations within each size class group that would be expected to experience zero injuries over the 10-year study period. This analysis included all injury causes. Size classification for this analysis was based on the average number of employees per operation. Operations with missing payroll data were excluded from this analysis. The following method [Snedecor and Cochran, 1989] was used for each operation type to estimate the expected number of zero-rate operations:

$$p = \text{Overall injury rate} = \frac{\text{Sum of all injuries within a given type of operation}}{\text{Sum of all hours worked within a given type of operation}}$$

= Probability of an injury during one-person hour worked

q = 1 - p = Proportion of hours worked in which no injury occurred.

n = Average number of hours worked per individual operation within a size class. This was calculated by summing the hours reported by all operations and dividing by N, the number of operations reporting hours worked. In the context of binomial probability, n = the number of trials (hours) during which injuries may occur, for an operation.

q^n = The expected *probability* that an individual operation observed zero injuries over all n hours, or the expected *proportion* of operations with zero observed injuries.

N = The number of individual operations reporting hours worked, within a given size class.

$N(q^n)$ = The expected frequency of zero-rate operations for a size class type.

Assumptions included the following: 1) within an operation type, the overall injury rate does not differ by size class; this suggests a null hypothesis and allows the calculation of an overall injury incidence rate, "p", for each operation type and 2) "n" was calculated as the average number of hours worked for all operations in a given size class group within an operation type. This simplifying assumption appeared reasonable, given that the size class categories were rather narrow and that hours worked were uniformly distributed within categories.

All data analyses were performed using SAS PC software version 9.1.2.

Narrative descriptions of events were analyzed to determine factors which contributed to livestock-handling injuries, and then were classified using the agent-host-environment epidemiological model [Gordis, 2004]. According to this tripartite model, an injury is the product of an interaction of the *host* (person injured), an *agent* that injures, and the *environment* that facilities the exposure. A *vector* or *vehicle* transmits the energy from the agent to the host. Agents of injury have been identified as the various forms of energy: mechanical, thermal, chemical, electrical, ionizing radiation, or too little energy in the case of asphyxiation [Gibson, 1961]. To our knowledge, this is the first study to apply this model to investigate livestock-handling injuries using workers' compensation data.

RESULTS

A total of 4,421 injury claims, representing 8,493 separate 12-month policies were included in this study (Table 4.1). The data set included 605 dairy farm policies, 7,083 cattle/livestock raiser policies and 805 cattle dealer policies. The number of injury claims included 988 from dairy farms, 2,168 from cattle/livestock raisers, and 1,265 from cattle dealers. A total of 1,114 livestock handling injury claims were identified (Figure 4.1).Injury claim incident rates are presented in Table 4.1. Injury claim rates (injury claims per 100 workers) were highest for cattle dealers (10.3), followed by dairy farms (9.4) and cattle/livestock raisers (8.4). Livestock-handling injury claim rates were highest among all injury causes in all three sectors (2.9 for dairy farms, 2.7 for cattle dealers, and 1.8 for cattle/livestock raisers).

Claim Reporting

Claim reporting based on operation size is shown in Tables 4.2 and 4.3. For small operations (i.e. 10 or less FTEs), the observed proportion of zero-injury-reporters was 77.1% (dairy farms), 85.2% (cattle/livestock raisers) and 0% (cattle dealers) (Table 4.2). The expected proportion can be subtracted from the observed proportion (right hand column of Table 4.3) to get the "proportional difference," the proportion of operations in a given size class that reported no injuries when one would expect them to report at least one injury. Results indicate that injuries may be underreported to the workers' compensation provider by as much as 37% among both large and small cattle dealer

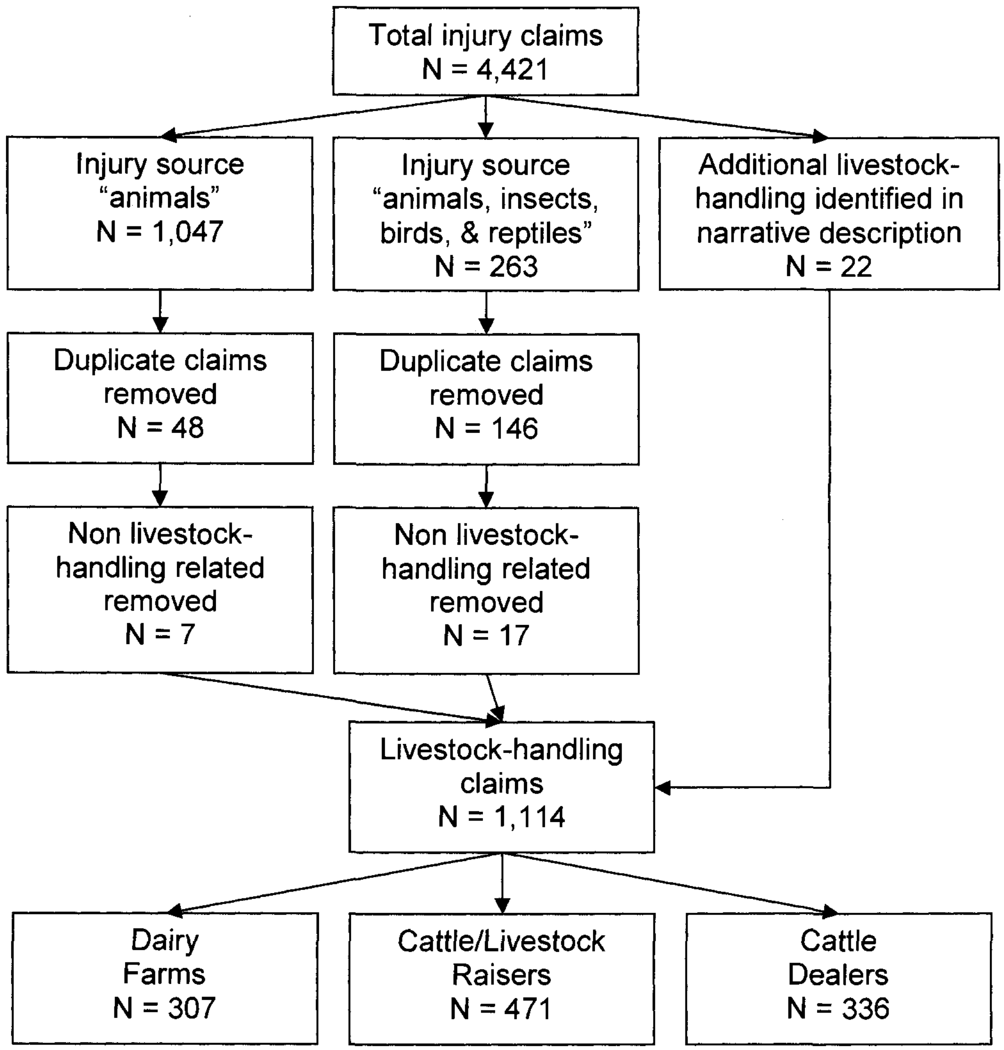

Figure 4.1. Identification of livestock-handling injuries.

operations. Results also indicate that large dairy farm operations may over report injury claims to the workers' compensation provider by as much as 16.5%, and large cattle/livestock raising operations may over report by as much as 25%. The proportional difference was closer to zero among small dairy farm operations and large and small cattle/livestock raising operations suggesting a lack of over- or underreporting of injury claims in these sectors. It is important to understand that this analysis addressed the absence of reporting when injuries were likely to have occurred.

Injury Characteristics

Livestock was responsible for the highest percentage of injury claims among all occupations (Table 4.4). Of total claims among dairy farms, 31.1% were caused by livestock. Livestock was responsible for 21.7 % and 26.6% of claims among cattle/livestock raisers and cattle dealers respectively. Falls or slips and strains represented the second and third highest proportion of injury causes among all three sectors. Table 4.5 presents nature of injury and body part injured for livestock-handling injuries in all three sectors. Contusions represented the highest percentage of injury types among all three sectors, and injuries to the wrist, hand, and fingers represented the highest percentage of injured body parts.

The average age of livestock-handling injury claimants among dairy farm workers was 32.2 years, and the average employment duration at the time of injury claim was 2.4 years. A majority of animal-related injury claims were made by males (88%), and a majority of livestock-handling injury claims were made by workers on dairy farms that employed 11 or more employees (87%) (Table 4.6). Using proportionate analyses to compare livestock-handling injuries with all other injuries among dairy farm workers, workers in operations that employed 10 or less employees reported 22% more livestock-handling injury claims than all other injury causes, although the difference was not shown to be statistically significant (Table 4.6). Workers between 25 and 34 years of age were 29% more likely to report a livestock-handling injury claim than all other injuries, and workers between 45 and 54 years of age were 58% less likely to report a livestock-handling claim than all other injuries. Twenty-six percent of livestock-handling injury claims were made by workers 24 years of age or less, and nearly 68% of livestock-handling injury claims were made by workers 34 years of age or less. The Mantel Haenszel chi square test for trend revealed a statistically significant trend (p = 0.03) of lower livestock-handling injury claims at older ages. No statistically significant trend was found for years of work experience.

The average age of livestock-handling injury claims among Colorado cattle/livestock raisers was 34.7 years and the average employment duration at the time of injury claim was 2.5 years. A majority of livestock-handling injury claims were made by males (80%), and roughly 57% of livestock-handling injury claims came from cattle/livestock raising operations that employed 11 or more employees (Table 4.7). Proportionate analyses revealed that female workers reported 44% more livestock-handling injury claims than all other injury causes. Workers between 25 and 34 years of age were 29% more likely to report a livestock-handling injury claim than all other injuries, while workers between 55 and 64 years of age were 45% less likely to report a livestock-handling injury claim than all other injuries. Results indicate that nearly 25% of livestock-handling injury claims were made by workers 24 years of age or less, and 52% of livestock-handling claims were made by workers 34 years of age or less. The Mantel Haenszel chi square test for trend revealed a statistically significant trend (p = 0.04) of lower livestock-handling injury claim reporting at older ages. No statistically significant trend was found for years of work experience among cattle/livestock raisers.

The average age of livestock-handling injury claims among Colorado cattle dealers was 36.8 years and the average employment duration at the time of injury claim was 3.1 years. A majority of livestock-handling injury claims were made by males (92%), and roughly 67% of livestock-handling injury claims came from cattle dealer operations that employed 11 or more employees (Table 4.8). Proportionate analyses revealed that workers employed by small operations reported 39% more livestock-handling injury claims than all other injury causes. The Mantel Haenszel chi square test for trend revealed no statistically significant trend ($p = 0.10$) of lower livestock-handling injury claim reporting at older ages. No statistically significant trend was found for work experience.

Claim Costs and Severity

Costs and severity of livestock-handling injuries are presented in Table 4.9. One measure of injury severity is if the injury claim involved paid lost time (indemnity). Approximately 15% of dairy farm injury claims involved both medical and indemnity payments, while 29% and 25% of injury claims involved both medical and indemnity payments among cattle/livestock raisers and cattle dealers, respectively. Cattle/livestock raisers had the highest median paid days off work, followed by cattle dealers and dairy farm workers. Median medical and indemnity costs per injury were lowest among dairy farm workers, and highest for cattle/livestock raisers. Median combined medical and indemnity costs per injury were also lowest among dairy farm workers, and highest among cattle/livestock raisers.

Injuries were classified by cost (<$5,000 versus ≥$5,000) and cause of injuries (Table 4.10). Among all injury causes that were classified as high cost (≥$5,000), livestock-handling injuries represented the highest proportion in all three sectors. Nearly 30% of dairy farm high cost injuries were livestock-handling related, while 23.7% and 27.3% injury claims were related to livestock-handling among cattle/livestock raisers and cattle dealers respectively. Injuries were also classified by severity (<28 days of paid disability versus ≥28 days of paid disability), and stratified by injury cause (Table 4.11). Livestock-handling injuries represented the highest percentage of high severity injury claims in all three sectors. Nearly 36% of all high severity (≥28 days of paid disability) injury claims involved livestock-handling among dairy farm workers, while 29.1% and 30.2% of high severity injury claims were livestock-handling among cattle/livestock raisers and cattle dealers respectively.

Contributing Factors

Narrative injury event descriptions were analyzed to further elucidate additional factors contributing to livestock-handling injuries. The agent-host-environment model was effectively used to classify the contributing factors. Of the 307 total livestock-handling injury claims among dairy farm workers, all event descriptions contained at least one identifiable factor. On average, narrative descriptions contained 3.2 contributing factors. Of the total number of livestock-handling injury claims, 79% contained at least one factor related to the host (Table 4.12). A total of 147 or 48% of livestock-handling claims mentioned that the worker was performing a milking activity at the time of injury. More specifically, 21.2% of the claims involved the worker being kicked while performing a milking task and 10.1% of the event descriptions mentioned that the claimant was attaching a milking unit to a cow's udder when he/she was kicked. In addition, 8.1% of the event descriptions mentioned the worker was stepped on when performing a milking task. Another high-percentage job activity (14.0%) involved manually pushing cows in the crowding area into the parlor at the time of the injury. Among contributing factors classified under the agent domain, cow kicks were specifically mentioned in 41% of the event descriptions, and 14% of the event descriptions mentioned the cow stepping on the worker. The injured worker was pushed by the cow in 14% of the injury event descriptions. Nearly 48% of the event descriptions mentioned that the injury took place in the dairy parlor, and 12.7% identified the location of injury as being in a dairy parlor entry pen. Also, 15.3% of the event descriptions mentioned that a milking unit was involved in the injury event.

All 471 livestock-handling narrative descriptions for cattle/livestock raisers contained at least one contributing factor. On average, narrative descriptions contained 3.5 factors classified in the model. Of the total number of livestock-handling claims, 63% contained at least one factor related to host characteristics (Table 4.13). Approximately 38% of narrative descriptions mentioned the worker was riding a horse at the time of injury. More specifically, 6.4% of claims indicated that the worker was sorting cattle while on horseback. Numerous work tasks were identified at the time of injury. Among all job tasks, branding, ear tagging, horse training, calf birthing, hoof trimming, and vaccinating were more frequently mentioned. Among cattle/livestock raisers, two main agents for injury were identified: cows and horses. Approximately 21% of narrative descriptions indicated that a cow or calf was responsible for worker injury. Narrative descriptions indicated various cow actions led to worker injury such as cow kick, stepped on, pushed, charge, run over, and kicking gate. Injury caused by calf kicking was also frequently mentioned. More than 50% of descriptions mentioned a horse being responsible for worker injury. Nearly 20% of descriptions indicated the worker was injured when he/she was bucked or thrown off a horse, and nearly 15% of descriptions mentioned the worker was injured when the horse they were riding fell. Approximately 7% of descriptions indicated the worker was kicked by a horse, and nearly 5% indicated the worker was stepped on by a horse. Various environmental locations were identified such as being in a corral or stall, or behind a cow. Environmental structures involved in the injury event were identified in injury event descriptions. A total of 17 descriptions mentioned a gate was involved in an injury event, while 11 involved a cow kicking a gate into a worker. A total of 30 narrative descriptions stated specific terrain conditions when a horse riding fall event took place. Nineteen horse falls took place when the horse stepped in a hole, and nine falls took place when the terrain was steep, slippery, or muddy.

At least one factor was identified in all 336 livestock-handling narrative descriptions among cattle dealers. On average, narrative descriptions contained 3.4 factors which were classified. Of the total number of livestock-handling claims, 77% contained at least one factor related to host characteristics (Table 4.14). Approximately 27% of narrative descriptions mentioned that the worker was riding a horse at the time of injury. More specifically, 77 claims indicated that the worker was sorting/pinning cattle while on horseback. Various other work tasks were identified at the time of injury. Pushing cattle while standing, vaccinating, loading cattle into a trailer, processing cattle, birthing, and trimming hooves were among the more frequently mentioned job tasks. Two main agents for injury were identified among cattle dealer injuries: cows and horses. Nearly 38% of narrative descriptions indicated a cow or calf was responsible for worker injury. Descriptions indicated various cow actions led to worker injury such as cow kick, stepped on, pushed, charge, run over, and kicking gate. Injury caused by calf kicking was also frequently mentioned. A total of 68 claims mentioned a horse being responsible for worker injury. Nearly 12% of descriptions indicated the worker was injured when he/she was bucked or thrown off a horse. Claims also indicated the worker was kicked, stepped on, knocked over, pushed and even bitten by a horse. Various environmental locations were identified such as being in a corral or processing barn. Sixteen injuries took place when the worker was behind a cow, and eleven claims mentioned the worker was pinned between a cow and a gate. A total of 56 narrative descriptions mentioned a corral gate being involved in the injury event, and 29 injuries involved a cow kicking a gate into the worker. Seventeen events involved a cow chute. A total of 38 horse riding falls took place when the horse stepped in a hole.

DISCUSSION

These data from one workers' compensation insurer provide unique descriptive information specific to dairy farms, cattle/livestock raisers, and cattle dealers in the state of Colorado. The injury claim rates of workers were 9.4, 8.4 and 10.3 per 100 FTEs for dairy farms, cattle/livestock raisers, and cattle dealers respectively. These 10-year injury rates are consistent with estimated 5-year injury rates for the same sectors from a previous study [Douphrate et al., 2006]. Injury rates in this study were higher than national estimates of injuries among agricultural workers, including 6.4/100 [US Department of Labor, 2004], 7.3/100 [National Safety Council, 2003], and 6.8/100 [Myers, 2001]. Previous studies have reported that official data sources underestimate occupational injury [Cormack et al., 2000, Glazner et al., 1998, Van Charante and Mulder, 1998]. The Bureau of Labor Statistics (BLS) Annual Survey is no exception, and the BLS acknowledges that many groups are excluded from the survey, including farms with fewer than 11 employees. One government estimate suggests that 0.4% of employed persons work on farms with fewer than 10 (not 11) workers [US Department of

Labor, 1995]. Pratt et al. reported that roughly 95% of US farms have fewer than 11 employees [Pratt et al., 1992].

The livestock-handling injury claim rates of workers in the present study were 2.9, 1.8 and 2.7 per 100 FTEs for dairy farms, cattle/livestock raisers, and cattle dealers respectively. Stallones and Beseler [2003] reported animal handling injury rates of 10.9 and 7.3 per 100,000 hours worked for women and men respectively on Northeastern Colorado farms. Differences in injury rates between the two studies may reflect differences in assessing actual work hours of exposure. The present study utilized payroll to estimate total FTEs on the farm. Stallones and Beseler [2003] utilized personal interviews to quantify total hours spent in specific agricultural activities such as animal handling. This method more accurately quantified work hours of exposure to specific agricultural tasks. Higher livestock-handling injury rates would be expected in the present study if more defined livestock-handling hours of exposure were able to be quantified.

Few studies have investigated injury rates among specific agricultural populations. Hwang et al. [2001] reported an injury rate of 10 per 100 person-years for dairy and livestock farmers. Pratt et al [1992] reported an injury rate of 12.6 injuries per 100 person-years in a study of 600 New York dairy farmers. A Canadian study of non-fatal farm injuries among beef and dairy farmers reported a rate of seven persons injured per 100 person-years in which the injury resulted in utilization of the healthcare system or inability to do normal dairy work activities [Brison and Pickett, 1992]. Browning et al. [1998] reported an overall injury rate of 9 per 100 farmers over a 1-year period among older Kentucky farmers, which is much higher than the rate of five per 100 farmers among New York farmers in the same age group [Pratt et al., 1992]. Nordstrom et al. [1995] reported a lower injury risk rate of 3.5/100 person years among dairy farm workers.

The present study assessed injury claim reporting among Colorado agriculture workers. Results of the present study indicate that larger dairy farm and cattle/livestock raising operations may overreport injury claims. The present study also indicates that approximately 37% of large and small cattle dealer operations may underreport injuries. Injury rates obtained in our study are comparable to other agriculture studies, but the possibility of underreporting or overreporting of injuries cannot be ruled out. An underestimation of injury rates would result if a high rate of underreporting took place. The broad objectives of workers' compensation are straightforward: to provide medical care and wage-replacement benefits to employees injured or made ill in the course of work. The availability of benefits provides a less straightforward set of behavioral incentives which may influence the reporting of an injury by a worker. Because wage-replacement benefits essentially compensate individuals for not working, employees have a potential incentive to exaggerate the severity of existing injuries, miss more work than necessary, and/or to inaccurately attribute an injury to work [Butler and Worrall, 1991]. This risk is termed "moral hazard" and arises out of information asymmetries, where the worker has full knowledge of the cause and severity of his/her injury but the employer does not [Butler and Worrall, 1991]. There is also a moral hazard risk with workers' compensation medical benefits for those employees without other medical insurance or who have insurance with a relatively high co-payment or deductible. Because of the risk of moral hazard, there is a common perception that an individual with a work-related problem is likely to file a workers' compensation claim [Biddle and Roberts, 2003]. Rosenman et al. [2000] reported that the strongest predictors of who would file a workers' compensation claim were those factors associated with the severity of the condition. Other factors found to predict workers' compensation injury reporting were increasing length of employment, lower annual income, and worker dissatisfaction with coworkers. Contrary to the common perception of overreporting of injuries to a workers' compensation provider, studies have demonstrated underreporting in workers' compensation records and other government registries. Studies by Biddle et al. [1998], Morse et al. [1998], Rosenman et al. [Rosenman et al., 2000], and Shannon and Lowe [2002] suggest that the percentages of injured workers who could qualify for workers' compensation but who never file are 55%, 79% , 75%, and 35% respectively. Research studies with differing study designs report musculoskeletal disorders are, in general, underreported and workers' compensation data does not accurately reflect prevailing musculoskeletal occurrence rates [Biddle et al., 1998, Herbert et al., 1999, Lipscomb et al., 1997, Morse et al., 2005, Morse et al., 2001, Morse et al., 1998, Pransky et al., 1999, Rosenman et al., 2000]. Fan et al. [2006] reported several occupation and industrial groups report higher proportions of work-related injury or illness but lower workers' compensation claim filing. By industry classification, agriculture/forestry/fishing and construction rank higher in reporting work-related injury or illness and lower in workers' compensation claim filing. By occupational classification, farming/forestry/fishing ranks the highest in reporting work-related injury or illness and second lowest in workers' compensation claim filing [Fan et al., 2006]. Osorio et al. [1998] reported evidence of underreporting among farm workers in California. Only 22% of injured farm workers in this state knew of a workers' compensation report being filed by their employer. Several factors may influence a farmworker when deciding to file an injury claim, and research is sparse related to injury claim reporting among agricultural populations. Future research efforts investigating workers' compensation claim reporting among agriculture workers are needed.

The present study revealed livestock-handling injuries account for the highest percentage of injury causes in all three occupations. Among dairy farm injuries, 31% were livestock-handling related. Approximately 22% of injuries were livestock-related among cattle/livestock raisers, and 27% were livestock-related among cattle dealers. Other studies have reported between 12 and 33% of injuries on the farm are caused by animals [Brison and Pickett, 1992, Cleary et al., 1961, Cogbill et al., 1985, Gerberich et al., 1998, Hoskin et al., 1988, Layde et al., 1995, Lewis et al., 1998, Myers, 1990, Nordstrom et al., 1995, Pickett et al., 1995, Pratt et al., 1992, Sprince et al., 2003, Zhou and Roseman, 1994]. Gerberich et al. [1991] reported animals were a major source of farm work-related injury, responsible for approximately 18% of the reported injuries. A majority of these animal-related injuries were due to dairy cattle. Browning et al. [1998] reported that 14.3% of injuries among Kentucky farmers aged 55 years were attributed to animal-related events (14.3%). In addition, farmers working on farms with beef cattle had a statistically significant increased risk for farm-related injury. Lewis et al. [1998] reported that livestock work had the highest percentage (33%) of activity at time of injury among farmers.

Xiang et al. [1999] reported the leading cause of injury involved livestock among Colorado male farmers aged 60 years and older. Stallones et al. [1997] reported that having a primary cash crop of large animals including beef, dairy, and feedlot operations to be significantly associated with the risk of farm work-related injuries. Sprince et al. [2003] reported significant associations between farm work-related injury and the presence of large livestock. Sprince et al. [2007] assessed risk factors for low back injury requiring medical advice or treatment among Iowa farmers. In this particular study, 20.3% of cases of low back injury involved cattle or large livestock. Sprince et al. [2003] also assessed risk factors for animal-related injury among Iowa large-livestock farmers. Significant associations were found between animal-related injury and the use of a hearing aid, doctor-diagnosed arthritis or rheumatism, and a younger age. Among the 124 animal-related injury cases identified, 56.5% were cattle related. Among the events causing injury, 47.6% resulted from an assault by an animal.

The majority of injuries in the present study were classified as medical-only claims, suggesting most injuries were less severe and did not result in lost work time. In addition, the majority of claims in each sector had medical costs of less than $5,000. The median medical plus indemnity cost of injury claim was $487 for dairy farm workers, $717 for cattle/livestock raisers, and $580 for cattle dealers. Leigh et al. [1997] constructed a ranking of occupations based upon the costs of job-related injuries and illnesses associated with workers' compensation claims. The authors reported farming, forestry, and fishing occupations have an average medical plus indemnity claim cost of $368, and ranked fourth highest of average injury costs by occupation. The authors did point out that their cost estimate likely did not adequately reflect the true costs of injuries and illnesses associated with these occupations because workers' compensation data often under-represents farming, forestry and fishing occupations. The same can be said of claim cost estimates in the present study. Leigh et al. [2001] estimated the costs of job-related injuries in agriculture in the US for 1992. Dairy farms ranked third highest among farm industries based on workers' compensation cost of injury, and livestock operations (excluding dairy and poultry) ranked sixth highest. In comparison, Rautiainen et al. [2004] reported costs associated with injuries that took place on farms enrolled in a farm safety program. The authors reported a mean injury cost of $163 among farms enrolled in the Iowa Certified Safe Farm program. Our study found that livestock-handling work injuries are a significant problem, more costly, and result in more time off work than other agricultural injury causes. In all three sectors, livestock-handling injuries accounted for the highest percentage of high-cost injuries, as well as the largest percentage of high-severity injuries.

Like previous workers' compensation claims cost studies, [Cheadle et al., 1994, Courtney et al., 2002, Dempsey and Hashemi, 1999, Hashemi et al., 1998, Hashemi et al., 1998, Hashemi et al., 1997, Murphy and Courtney, 2000], the distribution of claim cost in the present study was skewed (Table 4.9). The mean medical plus indemnity cost of a Colorado livestock-handling injury claim was 6.9, 12.2 and 23.7 times higher than the median cost among dairy farms, cattle/livestock raisers and cattle dealers respectively. These results suggest that a small number of claims accounted for a high percentage of the cost in each sector. Other studies examining workers' compensation costs have found mean costs to exceed median figures by as much as 23.2 times [Courtney et al., 2002, Dempsey and Hashemi, 1999, Hashemi et al., 1998, Hashemi et al., 1997].

Despite studies reporting a high percentage of agriculture injuries as being livestock-handling related and the presence of animals or livestock being a significant risk factor for injury, research is sparse that reports the contributing factors related to livestock-handling injuries. A literature search produced a limited number of research articles that specifically addressed livestock-handling injuries among agriculture workers. Layde et al. [1996] concluded in a study of animal-related injuries requiring medical attention that more detailed information on specific practices and patterns of animal husbandry are needed to better identify hazards associated with animal handling. Our study adds to the livestock-handling agriculture injury literature by providing information regarding the circumstances and factors surrounding livestock-handling injuries.

Among dairy farm workers, the majority of livestock-handling injuries involved large operations (more than 10 workers), male workers, younger workers, and less experienced workers. Approximately 26% of livestock-handling injury claims were made by workers aged 16-24 years, and nearly 68% of claims were made by workers aged 16-34 years. A high percentage (44%) of livestock-handling injury claims were made by workers with 0-6 months working experience. Being kicked, stepped on, or pushed by the cow were the three most frequent cattle actions that led to a worker injury. Nearly 70% of dairy farm livestock-handling injury claims involved contusions. Most injury body locations were above the waist level of the dairy worker. Nearly 27% of injuries were to the wrist, hand, and fingers, nearly 13% to the head or face, and 11% the chest. These results indicate the vulnerability of these body parts to injury due to the worker-livestock interface. Narrative description analysis confirms this finding, and clearly identifies that working in close proximity to the hind quarters of a cow while milking is a task in need of safety intervention. Nearly 50% of livestock-handling injury claims mentioned that the injury took place in the dairy parlor while performing a milking task. Boyle et al. [1997] investigated the specific activities associated with livestock operations. The primary aim of this study was to identify which dairy cattle operation activities (i.e. milking, feeding, cleaning barns, trimming and treating feet, dehorning, calving) were associated with an increased or decreased risk of injury. Milking was found to have the greatest increased risk for injury. An increased rate ratio associated with trimming or treating hooves was also found. A 21-state survey of animal-related farm injuries, Hoskin and Miller [1979] reported milking was the victim activity in the greatest number of cases. Pinske [2001] quantified the physical workload on the upper extremity for fundamental work tasks during machine milking. High muscle loads in combination with extreme positions and movements of the hand and forearm may contribute to the development of injuries among parlor workers. The increased workload on the upper extremity due to high repetitions associated with large milking herds, in conjunction with being vulnerable to being kicked or stepped on by a cow, places parlor workers at higher risk for injury.

Most modern dairy parlor operations involve the worker operating in a pit below the level of the cow. This workstation setup shields only the lower extremities from cow exposure. Performing milking tasks such as attaching milking units or cleaning the cow's udder exposes the upper half of the worker to the hind quarters of the cow, increasing the risk of being kicked (see Figures 4.2 and 4.3).

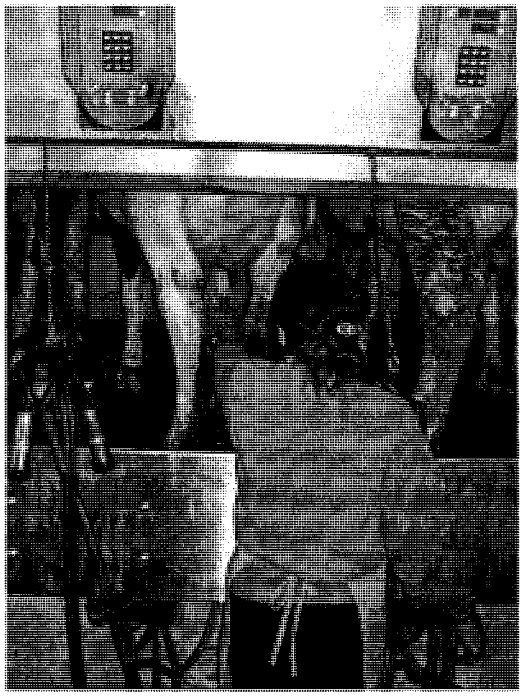

Figure 4.2. Worker performing milking task in parallel style parlor.

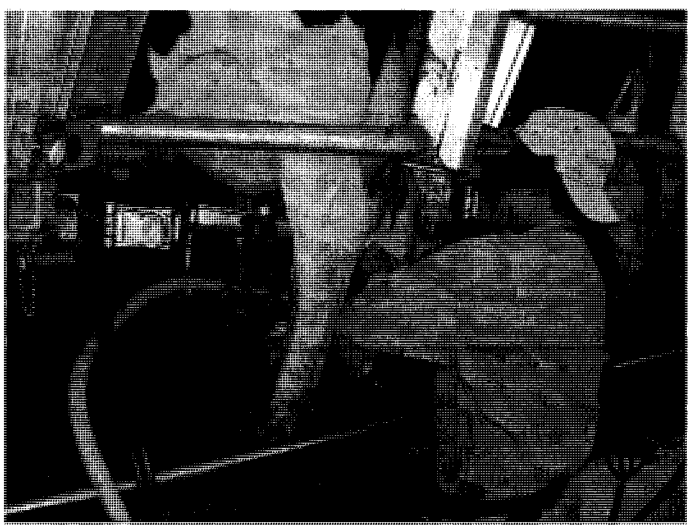

Figure 4.3. Worker performing milking task in herringbone style parlor.

In addition to the milking parlor, the present study revealed that 13% of claims indicated the injury took place in the parlor crowding area, and 14% of injury claims mentioned the worker was injured when pushing cows in the parlor line. Dairy cows access a dairy parlor through a crowding area. This area is designed to efficiently channel cattle into the parlor for milking. Workers often enter a crowding area and manually direct cows when they become congested and flow into the parlor is hindered. Workers who enter a congested crowding area place themselves at risk for being kicked, pushed or stepped on by a cow.

Results from the present study indicate that the worker-livestock interface while milking should be a target for the development of injury prevention strategies. Personal protective equipment (PPE) that protects workers arms and hands from being kicked or stepped on is one possibility. Parlor design is another avenue for intervention. Protective structures could be incorporated into the parlor design which could protect the worker from being kicked. Technical improvements of milking equipment and parlor design are needed to decrease the risk for injury. Workers should be trained in proper handling techniques. Rough or aversive handling of cows can reduce milk yield and animal welfare by causing stress [Grandin, 1997]. Cows handled aversively yield less milk, are more difficult to handle, and are more fearful of people [Rushen et al., 1999]. Cows that are less fearful are less likely to kick the milker [Hemsworth et al., 1989]. Loud noises should be kept to a minimum in the dairy parlor. In facilities such as dairy parlors, where livestock are handled, loud or novel noises should be avoided because they distress livestock and make them more agitated [Grandin, 1987].

Characteristics and contributing factors of livestock-handling injuries were quite different among cattle/livestock raisers and cattle dealers. Among cattle/livestock raisers, 39.1% of injuries involved contusions, while 11.5% and 14.2% involved sprains/strains and fractures respectively. A majority of injuries (29.1%) involved the upper extremity. Among cattle dealers, 57.4% of injuries involved contusions, while 13.1% and 7.4% involved sprains/strains and fractures respectively. Nearly 41% of injuries were to the upper extremity. Using a case-control design, Sprince et al. [2003] investigated animal-related injuries among Iowa large-livestock farmers as part of the Agricultural Health Study. Among the 124 animal-related injury cases identified, 56.5% were cattle related. Among the events causing injury, 47.6% resulted from an assault by an animal. Nearly 26% of injuries were sprains, strains and tears, and 21% involved fractures. Injuries to the hands and fingers accounted for 21% of injury locations. Significant associations were found between animal-related injury and the use of a hearing aid, doctor-diagnosed arthritis or rheumatism, and younger age. Hoskin and Miller [1979] reported 23.7% of animal-related injuries involved contusions, while 22.8% and 13.8% involved fractures and sprains respectively. Over 18% of injuries were to the leg, while 10% were to the back and hand each. Huhnke et al. [1997] investigated injuries sustained on cattle operations in Oklahoma. Contusions were the most common injury reported in over 40% of the injury events. Approximately 33% of injuries were to the upper extremity, and 32% to the lower extremity. More than 50% of those persons injured took no medical action after the injury event while 15% stopped working and sought medical help. Human error was identified as the primary cause in over 50% of the injury events. Cogbill et al. [1989] reported on 158 patients admitted to a trauma center over an 8-year period for treatment of orthopedic injuries related to the handling of horses and cows. Mechanism of injury included falls from horses, bovine and equine assaults, and animal kicks. Fractures of upper and lower extremities predominated among injury types and locations.

Among cattle/livestock raisers, nearly 38% of injuries took place when the worker was riding a horse, and sorting cattle on horseback was mentioned often. The identification of many job activities among cattle/livestock raisers demonstrates that this occupation requires workers to perform many tasks in close proximity to animals (horses and cattle). Horses were responsible for a majority of worker injuries, accounting for a larger proportion than cattle. Nearly 20% of workers were thrown off a horse, and nearly 15% were injured when the horse fell. While the use of ATV's on farms appears to be growing [Goldcamp et al., 2006], injury claim patterns indicate that horseback riding continues to be common when performing livestock-handling tasks. Adverse terrain was mentioned frequently as a factor associated with a horse falling while being ridden.

Horseback riding was also mentioned frequently among cattle dealers. Nearly 27% of injury claims among cattle dealers involved riding a horse, and approximately 22% of claims indicated the worker was penning or sorting cattle while on horseback at the time of injury. Penning or sorting cattle involves separating cattle into pins for different purposes such as branding, doctoring or transport. This task can be physically demanding on the rider, since the trained horse often turns quickly while attempting to sort or separate cattle from the herd. Cattle penning can lead to injury if the worker or horse is not trained and experienced. A total of 44 claims mentioned the rider was thrown from the horse, or the rider fell off the horse. Similar to injury event descriptions of cattle/livestock raisers, several job tasks were identified at the time of injury. Loading cattle into a trailer and pushing cattle while standing were two job tasks frequently mentioned.

Among cattle/livestock raiser and cattle dealer injuries, many environmental structures such as chutes, gates, fencing and corrals were identified indicative of cattle herd movement. Other studies have reported similar findings. Huhnke et al. [1997] reported that among 147 livestock-handling injury events, pens, alleyways and squeeze chutes were identified as the locations where most of the injury events occurred. Together, equipment and facilities accounted for approximately 25% of the perceived injury causes. Pederson et al. [1999] reported results from the Agricultural Hazard Surveillance program in Ohio. Related to livestock-handling injuries, the authors found the lack of emergency exits (passovers) from livestock handling areas (85.4%) which indicate that farm operators may view the potential need for egress as low priority, even in large animal operations.

To reduce the risk of worker and animal injury, cattle handling equipment and facilities should be designed appropriately. Crowding areas, pens, sorting facilities, alleyways and chutes should be designed to optimize animal flow and reduce animal stress. The proper design, construction and operation of livestock-handling facilities are important to insure safe working conditions for both livestock handlers [Hubert et al., 2007]. The present study identified job tasks such as branding, ear tagging and vaccinating as opportunities for worker injury. One example of a livestock-handling safety intervention for these tasks is a calf table (Figure 4.4). This piece of equipment is used for tasks such as vaccination, ear tagging and branding. The risk for injury is reduced for both the worker and animal by safely constraining the calf during the procedure.

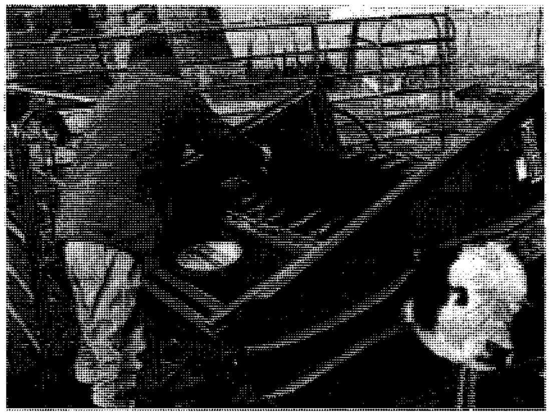

Figure 4.4. Calf table used for vaccination, ear tagging and branding [Powder River Inc., 2007].

Results from the present study also direct injury prevention efforts to worker education. Osorio et al. [1998] reported that only 70% of injured farm workers reported having been trained on the work task that was associated with their injury. Pederson et al [1999] reported that 80% of those working on a farm had not received training in the prevention of occupational injuries or illnesses. Understanding cattle behavior can help farm and ranch workers avoid dangerous situations associated with livestock-handling activities. Temple Grandin, Colorado State University animal behavior specialist, has published numerous manuscripts relating livestock behavior, equipment, and facilities. Grandin [1989] reports that an understanding of the behavior of livestock will facilitate handling, reduce stress, and improve both handler safety and animal welfare. Livestock-handlers can be seriously injured if large animals become excited or agitated. Handlers should be educated about an animal's flight zone, or "personal space," and how an animal will react when a worker enters into this area [Grandin, 1989]. Workers who ride on horseback to perform livestock-related job tasks should be experienced and educated regarding the hazards associated with such activity. As in any industry or occupation, young workers and new hires should receive proper training on horseback riding especially when riding among large herds of cattle.

Study Limitations

Study limitations include factors related to methods and systematic features of workers' compensation claims analysis. Claims data used in this study was restricted hired farmworkers, and may exclude farm owners. In Colorado, business owners may elect to decline workers' compensation coverage for themselves. In addition, small farm operations without hired workers may not be represented in the dataset.

In the present study, the possibility of misclassification of claims data exists. Due to restrictions in access to the primary FRI claim documents for the purposes of claimant confidentiality, we were unable to review these documents and assess the impact of misclassification. Zakaria et al. [2003] assessed the accuracy of workers' compensation claims coding and found an overall accuracy of 86% with respect to nature of injury and part of body injured classifications.

Indemnity cost data in the present study did not take into account disability from those workers who did not lose enough time from work to satisfy state waiting periods for wage replacement benefits (three days in Colorado). As a result, our results likely underestimate actual indemnity costs experienced by injured workers. In addition, medical and indemnity costs did not encompass all possible dimensions of the financial burden of injury. Burden also includes indirect costs such as lost productivity, increased absenteeism, higher employee turnover, and recruitment of replacement workers [Shah et al., 2005].

Workers' compensation data is susceptible to underreporting of injury claims, especially in agriculture. A common perception in the agricultural community is that if the worker can continue to work following an injury, an injury did not occur [Huhnke et al., 1997]. Minor injuries such as bruises, abrasions and even minor cuts are often considered "part of the job" [Huhnke et al., 1997]. Previous studies suggest the percentage of injured workers who qualify for workers' compensation but never file a workers' compensation claim ranges from 35% to 79% [Biddle et al., 1998, Morse et al., 1998, Rosenman et al., 2000, Shannon and Lowe, 2002]. Previous studies has shown musculoskeletal disorders are generally underreported, and workers' compensation data does not accurately reflect prevailing musculoskeletal occurrence rates [Biddle et al., 1998, Herbert et al., 1999, Lipscomb et al., 1997, Morse et al., 2005, Morse et al., 1998, Pransky et al., 1999, Rosenman et al., 2000]. Several occupational and industrial groups report a higher proportion of work-related injuries or illness but lower workers' compensation filing. By industry, agriculture/forestry/fishing and construction rank higher in reporting work-related injury or illness and lower workers' compensation claim filing. By occupation, farming/forestry/fishing ranks highest in reporting work-related injury or illness and second lowest in workers' compensation claim filing [Fan et al., 2006]. Osorio et al. [Osorio et al., 1998] reported evidence of underreporting among California farm workers. In addition, injury reporting is vulnerable to a variety of filtering effects which may have an influence on workers' compensation claim reporting

[Webb et al., 1989]. Employer and location variations in workers' compensation claim reporting and recording practices may also limit the results [Smith et al., 2005]. The present study was restricted to compensable claims in one state, which may limit the influence of reporting variation due to differing state workers' compensation statutes on claim filing. The workers' compensation data used in this study could also under-represent the true number of injury claims because both a worker and physician must recognize that his or her condition is work-related. Many agriculture workers often live on the farms that they operate or are employed by, and the differentiation between an occupational and non-occupational injury may be difficult.

In our study, the injury rate is a measure of incidence with claims as the numerator and hours of work as the denominator. An underreporting of injury claims would result in an underestimation of injury claim rates. Payroll data was used to estimate work hours of exposure, and likely resulted in an underestimation of livestock-handling injury rates. Injury rate estimation is dependent on work hours of exposure in relation to differential risk of work-related injuries [Stallones and Beseler, 2003]. More accurate assessment of work hours of exposure specific to livestock-handling would have resulted in more accurate livestock-handling injury rates. Future agricultural injury research should incorporate more accurate assessment of work hours of exposure in relation to specific agricultural tasks.

The agent-host-environment model used in this study did not include organizational factors such as culture, management style, strategic planning, goals, objectives, standard operating procedures, etc., and these factors were rarely mentioned in injury event descriptions yet are important in understanding the true injury causation as well as the effectiveness of injury prevention programs. It is possible that they played a more important role than described. Event descriptions are likely to focus on the immediate situation in which the injury occurred, and neglect mentioning other factors which may have contributed to the injury. Organizational factors such as adequacy of safety training, corporate safety culture, and so forth are unlikely to be mentioned. Failure to identify relevant factors contributing to injury is a limitation of injury report analysis [Glazner et al., 2005]. For example, one injury event description included "My boss required me to work and didn't take me to the doctor for a week." Another description included "It took a while for the ambulance to arrive." Organizational factors such as these may influence the level of severity and magnitude of cost associated with each injury.

There are also limitations associated with utilizing proportionate analyses. One limitation is that the sum of proportionate ratios must be equal to one. Therefore, the magnitude of a high ratio is offset by relative or corresponding lower magnitude of other ratios, making the ratios of the different injury categories interdependent. However, proportionate analyses (e.g., proportionate mortality ratio or PMR) which are similar to the PIR have proven to be useful as indicators of risk [Checkoway et al., 2004, Lipscomb and Li, 2001, Lombardi et al., 2005], and provided important new information in our study.

Study Strengths

A limited number of studies were identified that analyzed workers' compensation data to investigate injuries and illnesses in agriculture [Beaumont et al., 1995, Belville et al., 1993, Cooper and Rothstein, 1995, Demers and Rosenstock, 1991, Douphrate et al., 2006, Heyer et al., 1992, Villarejo, 1998]. Our study was the first to examine livestock-handling injuries using workers' compensation data. The availability of over 4,000 injury claims contained in a workers' compensation database has allowed for the identification of multiple factors contributing to a wide range of injuries sustained by workers on three separate types of livestock-handling operations. Livestock-handling job tasks differ based on type of operation, and it is imperative that operations be analyzed separately to identify injury event circumstances more accurately.

Using the agent-host-environment epidemiological model to systematically examine narrative descriptions forced the consideration of multiple elements involved in the injury. This is not the only conceptual model that could have been used. The original intent was to utilize Haddon's matrix [Haddon, 1972] to categorize injury contributing factors, but narrative descriptions did not contain sufficient data to adequately classify factors into pre-event, event, and post-event domains. This study demonstrates the utility of using the agent-host-environment model to analyze workers' compensation data.

Our study demonstrates workers' compensation data can be combined with policy-holder payroll data to estimate injury rates for specific worker sectors. This method of injury rate calculation may be more representative than BLS estimates. Researchers [May, 1990, Merchant, 1991, Purschwitz and Field, 1990] have reported that BLS injury rates underestimate the magnitude of the agricultural injury problem. Gunderson et al. [1990] reported that due to the fact that farmers are often self-employed and frequently hire fewer than 11 employees, the majority of US farms would be excluded from Occupational Safety and Health Administration (OSHA) injury data. The data set analyzed in this study did not include self-employed farmers, but did include agricultural operations which employed 10 or fewer employees. Approximately 56%, 91% and 67% of 12-month policies were businesses of 10 or fewer employees for dairy farms, cattle/livestock raisers, and cattle dealers respectively.

CONCLUSION

The present study complements previous studies specific to agricultural injury, and adds novel insight into the contributing factors of livestock-handling injuries. In the present study, nearly 50% of dairy farm livestock-handling injuries took place in the milking parlor. More focused research should investigate milking practices and parlor designs as they relate to worker safety and health. This needed research is vital given the industry trend towards large-herd, mass milk production operations. Large-herd dairy operations will present new opportunities for worker injury, and cost-effective safety interventions are needed to abate these risks. Among cattle/livestock raisers and cattle dealers, livestock-handling injury prevention efforts should be directed at livestock-handling facility and equipment design. Livestock equipment and facilities should be designed to minimize worker exposures to livestock. Worker education is another avenue to reduce the risk of injury. All workers in agriculture who handle livestock should be knowledgeable of livestock-behavior and proper handling techniques. The present study demonstrates the application of the agent-host-environment epidemiological model to the analysis of workers' compensation data. The present study determined that livestock-handling work injuries are a significant problem, more costly, and result in more time off work than other agriculture injury causes. Increased attention should be focused on livestock-handling injuries via continued research and safety intervention development.

TABLE 4.1. Summary of Employment and Injury Data for Dairy Farms, Cattle/Livestock Raisers, and Cattle Dealers, 1997-2006 Combined

	Dairy Farms	**Cattle/ Livestock Raisers**	**Cattle Dealers**
Total policies	605	7,083	805
Total policies with ≤ 10 FTEs	341	6,628	543
Total policies with > 10 FTEs	264	455	262
Total annual FTEs per policy (average for 1995-2006)	17.5	3.8	15.3
Total policies reporting injury claims	285	1,212	346
Total policies reporting animal-related injury claims	92	266	103
Total injury claims	988	2,168	1,265
Injury claim rate[a]	9.39 (8.79-10.03)	8.35 (8.00-8.71)	10.32 (9.76-10.91)
Total livestock-handling claims	307	471	336
Livestock-handling claim rate[a]	2.92 (2.60-3.27)	1.81 (1.64-1.99)	2.74 (2.46-3.05)

[a]Injury claim rate = Number of claims per 100 employees (or 200,000 work hours)

TABLE 4.2. Distribution of Injury Ratings of Livestock-Handling Operations by Size

Operation type, size	High-Rate Operations N (%)	Low-Rate Operations N (%)	Zero-Rate Operations N (%)	Total[a]
Dairy Farms				
1-10 empl	50 (14.7)	28 (8.2)	263 (77.1)	341
11+ empl	21 (8.1)	185 (71.2)	54 (20.8)	260
Cattle/Livestock Raisers				
1-10 empl	280 (4.3)	672 (10.4)	5,499 (85.2)	6,451
11+ empl	0 (0.0)	166 (36.5)	289 (63.5)	455
Cattle Dealers				
1-10 empl	200 (37.2)	338 (62.8)	0.0 (0.0)	538
11+ empl	0 (0.0)	262 (100.0)	0.0 (0.0)	262

[a]Excluding policies not reporting hours worked

TABLE 4.3. Number of Livestock-Handling Operations Reporting Hours Worked and Zero Injuries, by Operation Size vs. Expected, 1997-2006 Combined (all injuries included)

		Observed		Expected		Proportional Difference
Operation and operation size	**Operations (N)**	**Injuries (N)**	**Proportion**	**Number of injuries ($N(q^n)$)**	**Proportion (q^n)**	**Observed proportion minus expected proportion**
Dairy Farms						
1-10	341	263	0.771	247	0.724	0.044
11+	260	54	0.208	9	0.034	0.165
Cattle/Livestock Raisers						
1-10	6,451	5,499	0.852	5,410	0.839	0.013
11+	455	289	0.635	176	0.387	-0.013
Cattle Dealers						
1-10	538	0	0	200	0.372	-0.372
11+	262	0	0	96	0.367	-0.367

Table 4.4. Percentages of injury causes among Colorado Dairy Farms, Cattle/Livestock Raisers, and Cattle Dealers

	Dairy Farms		Cattle/Livestock Raisers		Cattle Dealers	
Injury cause	**Injuries**	**Percent**	**Injuries**	**Percent**	**Injuries**	**Percent**
Animals	307	31.1	471	21.7	336	26.6
Burn	21	2.1	30	1.4	23	1.8
Caught	61	6.2	83	3.8	81	6.4
Cumulative trauma	14	1.4	22	1.0	15	1.2
Cut	52	5.3	161	7.4	73	5.8
Fall or slip	139	14.7	389	17.9	199	15.7
Miscellaneous	71	7.2	94	4.3	47	3.7
Other	15	1.5	51	2.4	39	3.0
Strain	127	12.9	436	20.1	173	13.7
Strike	101	10.2	212	9.8	125	4.9
Struck	68	7.4	160	7.3	126	10.0
Vehicle	12	0.6	59	2.7	51	4.0

Table 4.5. Characteristics of livestock-handling injuries among Colorado Dairy Farms, Cattle/Livestock Raisers, and Cattle Dealers

	Dairy Farms		Cattle/Livestock Raisers		Cattle Dealers	
Characteristic	**Injuries**	**Percent**	**Injuries**	**Percent**	**Injuries**	**Percent**
Nature of injury						
Bruises, contusions	214	69.7	184	39.1	193	57.4
Sprains, strains	25	8.1	54	11.5	44	13.1
Cuts, lacerations	17	5.5	17	3.6	20	5.9
Fractures	10	3.3	67	14.2	25	7.4
Crushing	9	2.9	8	1.7	11	3.3
Puncture	5	1.6	27	5.7	5	1.5
Other* or unspecified	27	8.8	114	24.2	38	11.3
Part of body injured						
Head/Trunk						
Head[a]	7	2.3	17	1.5	10	2.1
Face[b]	32	10.4	37	6.8	28	9.5
Chest	34	11.1	30	7.2	28	10.1
Abdomen	5	1.6	8	1.1	12	1.5
Internal organs	1	0.3	4	0.2	3	0.3
Neck[c]	1	0.3	7	0.2	1	0.3
Upper back	2	0.7	4	0.4	1	0.6
Low back	13	4.2	26	2.8	25	3.9
Upper extremity						
Shoulders	15	4.9	23	3.2	15	4.5
Upper arm	6	2.0	13	1.3	6	1.8
Elbow	4	1.3	6	0.8	5	1.2
Lower arm	30	9.8	11	6.4	9	8.9
Wrist,hand,fingers	82	26.7	70	17.4	45	24.4
Lower extremity						
Hip	3	1.0	8	0.6	6	0.9
Upper leg	11	3.6	17	2.3	7	3.3
Knees	18	5.9	38	3.8	44	5.4
Lower leg	14	4.6	14	3.0	35	4.2
Ankle,foot,toes	25	8.1	62	5.3	34	7.4
Multiple body parts	1	0.3	10	0.2	4	0.3
Other or unspecified	3	1.0	66	0.6	18	0.9

*All remaining categories, each of which accounted for fewer than 7% of injuries
[a]Includes skull, brain and multiple head injury
[b]Includes ears, eyes, facial bones, mouth, nose, facial soft tissue, and teeth
[c]Includes vertebrae, soft tissue, and multiple neck injury

Table 4.6. Proportionate injury ratio (PIR) analyses of livestock-handling injuries among dairy farms comparing livestock-handling injuries to all other injuries by operation size, gender, age, and experience.

	Livestock-handling injuries (%)	**All other injuries (%)**	**Expected livestock-handling injuries[a]**	**PIR[b] (95% CI)**
Operation Size				
Large	268 (30.5)	610 (69.5)	275	0.97 (0.86-1.10)
Small	39 (35.5)	71 (64.5)	32	1.22 (0.87-1.67)
Gender				
Female	37 (32.2)	78 (67.8)	35	1.05 (0.74-1.45)
Male	270 (31.0)	602 (69.0)	272	0.99 (0.88-1.12)
Age[#]				
16-24	80 (30.8)	180 (69.2)	81	0.99 (0.78-1.23)
25-34	128 (36.8)	220 (63.2)	99	1.29 (1.08-1.53)*
35-44	70 (29.4)	168 (70.6)	76	0.92 (0.72-1.17)
45-54	15 (15.8)	80 (84.2)	36	0.42 (0.23-0.69)*
55-64	12 (29.3)	29 (70.7)	13	0.92 (0.47-1.60)
65-79	2 (33.3)	4 (66.7)	2	1.11 (0.12-4.00)
Experience				
0-6 mos.	134 (30.6)	304 (69.4)	136	0.98 (0.82-1.16)
7 mos.-2 yrs.	76 (30.9)	170 (69.1)	76	1.00 (0.79-1.25)
2 yrs.-5 yrs.	61 (35.3)	112 (64.7)	50	1.21 (0.93-1.56)
5+ yrs.	35 (26.7)	96 (73.3)	43	0.81 (0.57-1.13)
Total	307 (31.1)	681 (68.9)		

[a]Expected frequency for livestock-handling injuries by category if they had the same

[b]The proportionate injury ratio (PIR) is calculated by dividing the observed livestock-handling

[*]Statistically significant (p-value<0.05).

[#]Statistically significant Mantel-Haenszel X^2 test for trend (p-value<0.05)

Table 4.7. Proportionate injury ratio (PIR) analyses of livestock-handling injuries among cattle/livestock raisers comparing livestock-handling injuries to all other injuries by operation size, gender, age, and experience.

	Livestock-handling injuries	**All other injuries (%)**	**Expected livestock-handling injuries[a]**	**PIR[b] (95% CI)**
Operation Size				
Large	202 (20.2)	799 (79.8)	222	0.91 (0.79-1.05)
Small	269 (23.1)	898 (76.9)	249	1.08 (0.95-1.22)
Gender				
Female	92 (28.6)	230 (71.4)	64	1.44 (1.16-1.77)*
Male	379 (20.5)	1,467 (79.5)	407	0.93 (0.84-1.03)
Age[#]				
16-24	117 (21.8)	419 (78.2)	116	1.01 (0.83-1.21)
25-34	129 (26.4)	360 (73.6)	100	1.29 (1.08-1.53)*
35-44	97 (19.3)	406 (80.7)	113	0.86 (0.70-1.05)
45-54	97 (23.3)	320 (76.7)	89	1.09 (0.89-1.33)
55-64	24 (13.3)	156 (86.7)	43	0.55 (0.36-0.82)*
65-79	7 (16.3)	36 (83.7)	10	0.70 (0.28-1.44)
Experience				
0-6 mos.	257 (18.9)	1,106 (81.1)	240	1.07 (0.94-1.21)
6 mos.-2 yrs.	86 (17.6)	402 (82.4)	87	0.98 (0.79-1.22)
2 yrs.-5 yrs.	54 (16.0)	283 (84.0)	61	0.88 (0.66-1.15)
5+ yrs.	74 (16.4)	377 (83.6)	82	0.90 (0.71-1.13)
Total	471 (17.8)	1,697 (64.3)		

[a]Expected frequency for livestock-handling injuries by category if they had the same distribution by
[b]The proportionate injury ratio (PIR) is calculated by dividing the observed livestock-handling injuries
*Statisticallly significant (p-value<0.05).
[#]Statistically significant Mantel-Haenszel X^2 test for trend (p-value<0.05)

Table 4.8. Proportionate injury ratio (PIR) analyses of livestock-handling injuries among cattle dealers comparing livestock-handling injuries to all other injuries by operation size, gender, age, and experience.

	Livestock-handling injuries	All other injuries (%)	Expected livestock-handling injuries[a]	PIR[b] (95% CI)
Operation Size				
Large	226 (21.4)	830 (78.6)	286	0.93 (0.82-1.05)
Small	70 (33.5)	139 (66.5)	50	1.39 (1.09-1.76)*
Gender				
Female	26 (24.5)	80 (75.5)	29	0.90 (0.59-1.32)
Male	310 (26.7)	849 (73.3)	307	1.01 (0.90-1.13)
Age#				
16-24	62 (30.4)	142 (69.6)	53	1.16 (0.89-1.49)
25-34	93 (30.1)	216 (69.9)	81	1.14 (0.92-1.40)
35-44	67 (23.2)	222 (76.8)	84	0.80 (0.62-1.02)
45-54	81 (29.7)	192 (70.3)	72	1.12 (0.89-1.39)
55-64	26 (21.0)	98 (79.0)	37	0.71 (0.46-1.03)
65-79	7 (23.3)	23 (76.7)	9	0.81 (0.32-1.67)
Experience				
0-6 mos.	134 (27.6)	351 (72.4)	127	1.06 (0.88-1.25)
6 mos.-2 yrs.	82 (27.9)	212 (72.1)	77	1.07 (0.85-1.33)
2 yrs.-5 yrs.	51 (25.9)	146 (74.1)	53	0.97 (0.72-1.27)
5+ yrs.	69 (23.9)	220 (76.1)	80	0.87 (0.67-1.10)
Total	336 (26.6)	929 (73.4)		

[a]Expected frequency for livestock-handling injuries by category if they had the same

[b]The proportionate injury ratio (PIR) is calculated by dividing the observed livestock-handling

*Statisticallly significant (p-value<0.05).

#Statistically significant Mantel-Haenszel X^2 test for trend (p-value=0.10)

Table 4.9. Severity and costs of livestock-handling injuries among Colorado Dairy Farms, Cattle/Livestock Raisers, and Cattle Dealers.

	Dairy Farms	**Cattle/Livestock Raisers**	**Cattle Dealers**
Total medical-only claims	262	334	251
Total medical plus indemnity claims	45	137	85
Injury Severity[a]			
Days of Paid Disability			
Mean	85	104	164
Median	34	49	41
Range	2 – 1,082	1 – 1,338	1 - 1,103
Duration of Paid Disability			
0 days	262	137	251
1 day to < 7days	9	11	1
7 days to < 1 month	12	30	20
1 month or more	24	96	64
Injury Costs[b]			
Medical[c]			
Mean	1,711	5,505	6,179
Median	481	607	584
Range	0 – 33,762	0 – 403,603	0 - 348,600
Indemnity			
Mean	8,862	9,697	23,963
Median	2,523	3,499	3,042
Range	0 - 87,513	0 - 101,393	0 - 255,592
Medical plus indemnity total			
Mean	3,360	8,730	13,773
Median	487	717	580
Range	0 - 132,023	0 - 427,613	0 - 382,094

[a]Rounded to nearest whole day.
[b]Rounded to nearest whole US dollar.
[c]Adjusted to 2006 US dollars.

Table 4.10. Injury Cause Proportions (%) by Medical Cost among Colorado Dairy Farms, Cattle/Livestock Raisers, and Cattle Dealers.

	Dairy Farms		**Cattle/Livestock Raisers**		**Cattle Dealers**	
Injury Cause	**<$5000**	**≥$5000**	**<$5000**	**≥$5000**	**<$5000**	**≥$5000**
Animal	278 (31.2)	29 (29.9)	390 (21.4)	81 (23.7)	289 (26.4)	47 (27.3)
Burn	19 (2.1)	2 (2.1)	29 (1.6)	1 (0.3)	22 (2.0)	1 (0.6)
Caught	53 (5.9)	8 (8.2)	76 (4.2)	7 (2.0)	77 (7.0)	4 (2.3)
Cumulative Trauma	10 (1.1)	4 (4.1)	18 (1.0)	4 (1.2)	14 (1.3)	1 (0.6)
Cut	46 (5.2)	6 (6.2)	155 (8.5)	6 (1.8)	64 (5.9)	9 (5.2)
Fall or slip	124 (13.9)	15 (15.5)	309 (16.9)	80 (23.4)	156 (14.3)	43 (25.0)
Miscellaneous	67 (7.5)	4 (4.1)	87 (4.8)	7 (2.0)	46 (4.2)	1 (0.6)
Other	14 (1.6)	1 (1.0)	33 (1.8)	18 (5.3)	37 (3.4)	2 (1.2)
Strain	111 (12.5)	16 (16.5)	363 (19.9)	73 (21.3)	145 (13.3)	28 (16.3)
Strike	96 (10.8)	5 (5.2)	180 (9.9)	32 (9.4)	113 (10.3)	12 (7.0)
Struck	64 (7.2)	4 (4.1)	141 (7.7)	19 (5.6)	110 (10.1)	16 (9.3)
Vehicle	9 (1.0)	3 (3.1)	45 (2.5)	14 (4.1)	20 (1.8)	8 (4.7)
Total	891 (100.0)	97 (100.0)	1,826 (100.0)	342 (100.0)	1,093 (110.0)	172 (100.0)

Table 4.11. Injury Cause Proportions (%) by Injury Severity among Colorado Dairy Farms, Cattle/Livestock Raisers, and Cattle Dealers.

	Dairy Farms		Cattle/Livestock Raisers		Cattle Dealers	
Injury Cause	**High**	**Low**	**High**	**Low**	**High**	**Low**
Animal	31 (35.6)	276 (30.6)	95 (29.1)	376 (20.4)	38 (30.2)	298 (26.2)
Burn	2 (2.2)	19 (2.1)	1 (0.3)	29 (1.6)	1 (0.8)	22 (1.9)
Caught	5 (5.7)	56 (6.2)	9 (2.8)	74 (4.0)	3 (2.4)	78 (6.8)
Cumulative Trauma	2 (2.2)	12 (1.3)	3 (0.9)	19 (1.0)	0 (0.0)	15 (1.3)
Cut	3 (3.4)	49 (5.4)	8 (2.4)	153 (8.3)	1 (0.8)	72 (6.3)
Fall or slip	14 (16.1)	125 (13.9)	72 (22.0)	317 (17.2)	31 (24.6)	168 (14.7)
Miscellaneous	2 (2.2)	69 (7.7)	4 (1.2)	90 (4.9)	0 (0.0)	47 (4.1)
Other	1 (1.1)	14 (1.6)	14 (4.3)	37 (2.0)	0 (0.0)	39 (3.4)
Strain	14 (16.1)	113 (12.5)	67 (20.5)	369 (20.0)	21 (16.7)	152 (13.3)
Strike	3 (3.4)	98 (10.9)	24 (7.3)	188 (10.2)	12 (9.5)	113 (9.9)
Struck	7 (8.0)	61 (6.8)	15 (4.6)	145 (7.98)	14 (11.1)	112 (9.8)
Vehicle	3 (3.4)	9 (1.0)	15 (4.6)	44 (2.4)	5 (4.0)	23 (2.0)
Total	87 (100.0)	901 (100.0)	277 (100.0)	1,891 (100.0)	126 (110.0)	1,139 (100.0)

Table 4.12. Contributing factors of 307 livestock-handling injuries among dairy farm workers as identified by text data.

Host (worker)			Agent (animal)			Environment		
	N	%		N	%		N	%
Job Activity			**Animal action**			**Location**		
Milking	147	47.9	Cow kick	126	41.0	In dairy parlor	147	47.9
Kicked while milking	65	21.2	Cow stepped on	43	14.0	In parlor feeder pen	39	12.7
Kicked while attaching milking unit	31	10.1	Cow pushed	31	10.1	In cattle/calf pen	11	3.6
Kicked while stripping cow	8	2.6	Swung head around	11	3.6	**Equipment**		
Stepped on while milking	25	8.1	Cow pinned	10	3.3	Milking unit	47	15.3
Stepped on while attaching milking unit	16	5.2	Bull charged	5	1.6	Milking rail	16	5.2
Hit by tail while milking	2	0.7	Cow flipped/fell	4	1.3	Corral gate	13	4.2
Bringing cows to parlor			Another cow	2	0.7	Fencing	9	2.9
Pushing cows in parlor line	43	14.0	Swung tail	2	0.7	Wall	8	2.6
Herding cows to milk	16	5.2	Calf	8	2.6	Squeeze chute	5	1.6
Other Activities						Herdlock	2	0.7
Walking/standing behind cow (non milking)	13	4.2				Calf feeder	1	0.3
Calf pulling	7	2.3				Hose	1	0.3
Pregnancy check	5	1.6						
Inseminating	5	1.6						
Administering IV/shot	4	1.3						
Restraining cow	3	1.0						
Castrating	2	0.7						
Feeding cattle/calves	2	0.7						
Marking cow	2	0.7						
Chasing cow	1	0.3						
Palpating cow	1	0.3						
Pulling calf out of mud	1	0.3						
Locking up cow	1	0.3						
Slipped and fell	1	0.3						
Removing stitches	1	0.3						

Table 4.13. Contributing factors of 471 livestock-handling injuries among cattle/livestock raisers as identified by text data.

Host (worker)	N	%	**Agent (animal)**	N	%	**Environment**	N	%
Job Activity			Cow			Location		
Riding horseback	177	37.6	Cow kick	35	7.4	In corral with cattle/horses	4	0.8
Sorting cattle while riding horse	30	6.4	Cow stepped on	7	1.5	Between horses	2	0.4
Pushing cattle while standing	13	2.8	Cow pushed	2	0.4	Behind cow	5	1.1
Branding	10	2.1	Cow swung head	5	1.1	In horse stall	5	1.1
Ear tagging	9	1.9	Cow run over	16	3.4	In trailer	3	0.6
Castrating	3	0.6	Cow/bull charged	5	1.1	Equipment		
Calf pulling	5	1.1	Cow kicked gate	11	2.3	Gate kicked into worker	11	2.3
Trimming hoof	5	1.1	Calf			Squeeze chute	2	0.4
Vaccinating	5	1.1	Calf kick	19	4.0	Corral gate	6	1.3
Training horse	10	2.1	Horse			Fencing	3	0.6
Mounting horse	6	1.3	Horse bucked/threw rider off	92	19.5	Horse Riding Terrain		
Loading cattle trailer	5	1.1	Horse fell while being ridden	69	14.6	Hole	19	4.0
Saddling horse	4	0.8	Horse stepped on	22	4.7	Stream	2	0.4
Roping calf	4	0.8	Horse kick	34	7.2	Steep	3	0.6
Pregnancy check	2	0.4	Horse knocked over by animal	6	1.3	Slippery	3	0.6
Wrapping horse leg	3	0.6	Horse pushed	11	2.3	Mud	3	0.6
Washing horse	2	0.4	Horse whipped tail	3	0.6			
Feeding horse	1	0.2	Horse bite	2	0.4			
Inseminating horse	2	0.4	Buffalo					
Lifting calf	2	0.4	Buffalo kick	3	0.6			
Haltering horse	1	0.2						

Table 4.14. Contributing factors of 336 animal-related injuries among cattle dealers as identified by text data.

Host (worker)	N	%	Agent (animal)	N	%	Environment	N	%
Job Activity			Cow			Location		
Riding horseback	89	26.5	Cow kick	40	11.9	In corral with cattle/horses	5	1.5
Pinning cattle on horseback	33	9.8	Cow stepped on	10	3.0	Behind cow	16	4.8
Sorting cattle while riding horse	41	12.2	Cow pushed		0.0	Processing barn	3	0.9
Pushing cattle while standing	20	6.0	Cow swung head	20	6.0	Pinned between cow & gate	11	3.3
Branding	1	0.3	Cow run over	23	6.8	Equipment		
Ear tagging	5	1.5	Cow/bull charged	17	5.1	Gate kicked into worker	29	8.6
Castrating	1	0.3	Cow kicked gate		0.0	Squeeze chute	17	5.0
Calf pulling	5	1.5	Calf			Corral gate	27	8.0
Trimming hoof	6	1.8	Calf kick	13	3.9	Fencing	5	1.5
Vaccinating	12	3.6	Calf pushed	3	0.9	Horse Riding Terrain		
Mounting/dismounting horse	3	0.9	Horse			Hole	38	11.3
Loading cattle in trailer	26	7.7	Horse bucked/threw rider off	40	11.9	Weather		
Roping calf	2	0.6	Horse fell while being ridden	4	1.2	Cold/snow	7	2.1
Inseminating horse/cow	2	0.6	Horse stepped on	9	2.7			
Processing cattle	7	2.1	Horse kick	7	2.1			
Feeding/watering cows	4	1.2	Horse knocked over by animal	1	0.3			
Destroying	1	0.3	Horse pushed	2	0.6			
			Horse swung head	4	1.2			
			Horse bite	1	0.3			

DISSERTATION SUMMARY

The three studies that comprise this dissertation represented a unique opportunity to analyze workers' compensation data to investigate work-related injuries in agricultural settings. Innovative analytic approaches of injury claims data were employed to evaluate risk factors for traumatic agricultural injuries. The claims data used in this study provided valuable information which can be used to direct future safety intervention efforts.

Study One involved the analysis of a five-year injury claim history of Colorado agriculture and agri-business operations. Colorado agriculture operations included dairy farms, cattle/livestock raisers and cattle dealers. Agri-business operations included bean sorters/handlers, grain elevator operators, grain millers and hay grain/feed dealers. Colorado agriculture and agri-business operations were found to have higher injury rates than national agency injury estimates. Results from this study led to subsequent studies that investigated tractor-related and livestock-handling injuries in agriculture.

Study Two involved the analysis of injury claims data from both Colorado and California to investigate tractor-related injuries. Tractor overturns were included in the analysis. The workers' compensation injury data analyzed in this study helped elucidate contributing factors to tractor-related injuries and associated costs (medical and indemnity). A large proportion of injury claims was associated with tractor mounting and dismounting activities which suggests a need to further investigate specific tractor design characteristics. The cost data in this study will be combined with data from other National Tractor Safety Initiative projects to more accurately estimate the total costs associated with tractor-related injuries, as well as tractor-overturns.

Study Three involved the analysis of a 10-year claim history of Colorado dairy farms, cattle/livestock raisers, and cattle dealers to investigate livestock-handling injuries. Study Three builds upon the methods and results from Studies One and Two. This study evaluates injury claim rates, injury and claimant characteristics, and injury costs (medical and indemnity). This study also utilized the agent-host-environment epidemiological model to analyze injury event descriptions. Results revealed that livestock-handling injuries are a significant problem, more costly, and result in more time off work than other agricultural injury causes. Among dairy farms, a majority of injuries took place inside the milking parlor. Among cattle/livestock raisers and cattle dealers, large proportions of injuries involve horseback riding and livestock equipment such as fencing, corrals, and chutes. Livestock-handling injury prevention efforts should be directed at livestock-hander education and livestock-handling facility design.

Agriculture continues to be one of the most hazardous industries in the United States. The development of cost-effective safety interventions is dependent on the identification of specific work tasks associated with a high risk for injury or death. The studies which comprise this dissertation utilized innovative methods to analyze workers' compensation injury data to investigate work-related agricultural injuries. Results from these studies will be used to direct future injury prevention efforts.

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APPENDIX A

WORKERS' COMPENSATION EXPERIENCE OF COLORADO AGRICULTURE WORKERS, 2000-2004

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Workers' Compensation Experience of Colorado Agriculture Workers, 2000–2004

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Background *Agriculture is among the most hazardous of occupations. The lack of information regarding agriculture injuries or fatalities has been recognized as an obstacle for effective injury prevention. Workers' compensation claims data for non-fatal injuries among agriculture and agri-business workers in the State of Colorado between the years of 2000 and 2004.*

Methods *Workers' compensation claims are utilized to estimate injury claim incidence rates, determine the distributions of sources, causes, types and body locations of injuries, and estimate the costs of these injuries.*

Results *Colorado agriculture and agri-business workers (e.g., cattle dealers, cattle or livestock raisers, dairy farmers) have high rates of injury claims, especially in sectors that involve interaction with animals or livestock. Grain milling operations had a high rate of injury claims among agri-business operations. Injuries related to animals, strains, machinery, and falls or slips were the most frequent among all occupations analyzed.*

Conclusions *Understanding the occurrence of injuries among Colorado agriculture and agri-business workers is critical to implementing and evaluating effective intervention programs for specific agriculture-related occupations. The development of safety interventions that address the worker–animal interface, fall protection systems, machinery usage, and overexertion prevention strategies is recommended.* Am. J. Ind. Med. 49:900–910, 2006. *© 2006 Wiley-Liss, Inc.*

KEY WORDS: ***agriculture; injuries; workers' compensation; agribusiness***

INTRODUCTION

Agriculture is among the most hazardous of occupations [McCurdy and Carroll, 2000]. The lack of information regarding agriculture injuries or fatalities has been recognized as an obstacle for effective injury prevention [Zhou and Roseman, 1994]. The National Safety Council (NSC) estimated approximately 730 occupational fatalities in the agriculture sector in the United States for 2002 (a 2% increase from the preceding year), yielding an occupational mortality rate of 21.0 per 100,000 workers. This mortality rate is second only to the mining and quarrying industrial sector with 29.1 deaths per 100,000 workers. The NSC also estimates 40,153 non-fatal occupational injuries and illnesses involving days away from work in the agriculture, forestry, and fishing sector in 2001, yielding an injury incidence rate of 7.3 per 100 full-time workers. This injury rate is third highest behind the manufacturing and construction industry divisions with 8.1 and 7.9 injuries per 100 full-time employees, respectively. The agriculture industry had the third highest injury rate in 2002 despite the fact that it was

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responsible for employing the second fewest number of U.S. workers [National Safety Council, 2003].

The U.S. Department of Labor, Bureau of Labor Statistics (BLS) estimates that the agriculture, forestry, fishing, and hunting division had an injury rate of 6.4 injuries per 100 persons in 2004 [US Department of Labor, 2005]. BLS data are the primary sources of data on injuries in the agriculture industry but are currently being reported by North American Industry Classification System (NAICS). NAICS codes do provide a limited degree of industrial specificity in the traditional agriculture sector, but specific agri-business operations are not well represented. Specific agri-business occupations cannot be identified as easily through BLS data and must be identified through other means.

Present Study

This investigation involved the analysis of workers' compensation claims data for non-fatal injuries among specific agriculture and agri-business workers in the State of Colorado between the years of 2000 and 2004. The objectives of this study were to determine injury rates among different Colorado agriculture-related occupations, to determine the distributions of sources, causes, types, and locations of injuries among those filing workers' compensation injury claims, and to determine the costs of agriculture-related injuries in Colorado.

A research partnership was established between the investigators at Colorado State University and Pinnacol Assurance, a workers' compensation insurance carrier headquartered in Denver, Colorado. Pinnacol Assurance has been doing business in Colorado for more than 85 years and has a market share of more than 50%. It insures approximately 75% of all agricultural operations in Colorado. Pinnacol Assurance did not provide any financial support to this project.

MATERIALS AND METHODS

Data Sources

Workers' compensation coverage varies between states. Workers' compensation insurance is the only disability insurance that Colorado employers are required to provide for their employees under state law; any business with one or more employees must carry workers' compensation insurance. Sole proprietors and partners in a business are not considered employees and are not required to be covered on a policy. There are no exclusions or partial exclusions for workers' compensation coverage of agriculture operations in Colorado. Family members are not covered under workers' compensation coverage if they are not on the payroll of the policy holder.

For employees who are injured on the job or develop occupational diseases, workers' compensation insurance pays for medical expenses and partial wage replacement during periods of temporary disability (if an employee is unable to return to work within 3 days of the injury). Workers' compensation insurance may also provide permanent impairment benefits for those who qualify. The cost of workers' compensation insurance is paid entirely by the employer and may not be deducted from an employee's wages. Pinnacol Assurance, like all Colorado workers' compensation insurance providers, provides benefits to workers with a work-related injury or illness in accordance with the Colorado Workers' Compensation Act. The Act defines occupational injuries and illnesses, as a work-related injury or illness that occurs within the course and scope of employment where employment is the reasonable cause and excludes those that do not result from hazards the worker would have been equally exposed to outside employment. A lost time claim occurred when a worker missed more than three scheduled work shifts due to the injury. When an injured worker's claim had been accepted, the insurance provider pays the necessary, related, and reasonable medical expenses prescribed by the employer's designated medical provider. These expenses included surgery, dental, nursing, hospital, home health care, physical therapy, chiropractic care, prescriptions, medical supplies, and travel within certain limitations. After the injured worker misses three scheduled work shifts, he/she would be entitled to compensation for lost wages. An injured worker is paid two-thirds of their lost wages.

After obtaining approval from the University Human Subjects Review Committee, injury claims data for the period of January 2000 to July 2004 was obtained. Strict confidentiality of all claims data was enforced throughout this investigation. Claims data was electronically transmitted to the investigators who were provided with security password access. The insurance carrier removed all personal identifiers.

Specific agriculture occupations were divided by National Council on Compensation Insurance (NCCI) coding in the claims database [National Council on Compensation Insurance, 2003]. Class codes were numerical codes used by the workers' compensation insurance industry to classify occupations and their job responsibilities. The claims data were derived from first report of injury forms, medical cost data, medical reports, and company profiles. Workers' compensation policies are purchased on 12-month intervals that began anytime between January and December. Only closed injury claims in a completed policy year were included. Because total claim expenses had yet to be determined for open claims (pending claims at the time of the study), they were omitted. Open injury claims constituted a very small percentage of total injury claims, and the inclusion of closed injury claims only in the dataset was not believed to influence the results of this study.

The three classifications of agriculture occupations chosen to be included in the study were dairy farming, cattle/livestock raising, and cattle dealers. The four classifications of agri-business occupations that were chosen for inclusion were grain milling, bean sorters/handling, hay grain and feed dealers, and grain elevator operations. These classifications were chosen because they represented the larger commodities and operations in the state [Colorado Department of Agriculture, 2003].

Data Analysis

The injury claims data was extracted from an Oracle (Oracle Corporation, Redwood Shores, CA) relational database using Hyperion Explorer 6.6.4 (Hyperion Solutions, Sunnyvale, CA) [Oracle Corporation, 2002; Hyperion Solutions Corporation, 2004]. Database management was conducted with Microsoft Excel (Microsoft Corporation, Redmond, WA) [Microsoft Corporation, 2003]. The database consisted of claimant information including worker's age, gender, employment duration, time of injury, injury anatomical location, source and cause of injury, type of injury, and employer payroll. An injury descriptive analysis was conducted for all agriculture operations individually and combined.

Average annual injury claim incidence rates were calculated. Using information on policy payroll per calendar year, time at risk (expressed as hours worked by trade) was estimated using prevailing national industry-specific occupational wage estimates, which were obtained from the BLS [US Department of Labor, 2006]. This was accomplished by placing the NCCI occupational classifications into closely matched NAICS and SOC (Standard Occupational Classification) groups (Table I). For the purposes of estimating median hourly wages, dairy farm workers (NAICS 112120-Dairy Cattle and Milk Production) and cattle/livestock raisers (NAICS 112111-Cattle Ranching and Farming) were classified in SOC 45–2093, Farmworkers, Farm and Ranch Workers. Cattle dealers (NAICS 424500-Farm Product Raw Material Merchant Wholesalers) were classified in SOC 45–2093, Farmworkers, Farm and Ranch Workers. Grain milling workers (NAICS 311200-Grain and Oilseed Milling) were classified in SOC 51–9021, Crushing, Grinding, and Polishing Machine Setters, Operators, and Tenders. Bean sorting/handling workers (NAICS 111000-Crop Production) were classified in SOC 45–2041, Graders and Sorters, Agriculture Products. Hay grain/feed dealers and grain elevator operators (NAICS 424500-Farm Product Raw Material Merchant Wholesalers) were classified in SOC 53-0000, Transportation and Material Moving Occupations since this SOC represented the highest percentage (32.3%) of workers in this NAICS classification [US Department of Labor, 2005]. Total work hours were estimated using Formula 1. The average annual injury claim incidence rate was estimated using Formula 2 [Dement and Lipscomb, 1999], and was expressed as claims per 200,000 work hours or the equivalent of claims per 100 full-time workers [National Safety Council N, 2003]. Uncommon events in populations, such as the occurrence of specific diseases or injuries, are usually modeled using a Poisson distribution. Poisson confidence intervals are commonly used for the estimation of incidence rates of injuries or illnesses [Selvin, 1996; Rothman and Greenland, 1998; Gail and Benichou, 2000]. The normal approximation of the Poisson distribution was used to estimate 95% confidence intervals (95%CI) for injury claim rates. Ninety-five percent confidence intervals for average annual injury claim incidence rates per 200,000 working hours over the study period were calculated using Formula 3.

TABLE I. Selected Colorado Agriculture-Related Trade Titles and Hourly Wages

NCCI[b] title of trade category	NCCI Code	2004 NAICS	2004 SOC	BLS median hourly wage[a]
Agriculture				
Dairy farms	0036	112120	45–2093	8.57
Cattle/livestock raising	0083	112112	45–2093	8.57
Cattle dealers	8288	424500	45–2093	7.71
Agri-business				
Grain milling	2014	311200	51–9021	14.45
Bean sorting/handling	8102	111000	45–2041	7.94
Hay grain/feed dealers	8215	424500	53–0000	10.34
Grain elevator operators	8304	424500	53–0000	10.34

[a]U.S. dollars.
[b]NCCI, National Council on Compensation Insurance.
NAICS, North American Industry Class Scheme.
SOC, Standard Occupational Classification.
BLS, Bureau of Labor Standards.

$$\text{Estimated Total Work Hours} = \frac{\text{Total Sector Payroll}}{\text{Median Hourly Wage}} \tag{1}$$

$$\text{Claim Rate} = \left(\frac{\text{Category Claim Count}}{\text{Estimated Total Work Hours}}\right)\times(200,000 \text{ Work Hours}) \tag{2}$$

$$95\%\text{ CI} = \text{Claim Rate} \pm 1.96\sqrt{\text{Claim Count}} \times \left(\frac{200,000 \text{ Work Hours}}{\text{Estimated Total Work Hours}}\right) \tag{3}$$

An economic analysis was also conducted to determine the mean costs of each type of injury based on injury source, cause, type, and body part. Medical and indemnity costs were combined to determine the mean total cost of each specific injury claim.

Medical costs included all expenses paid for the medical treatment of each injured worker. These expenses included, but were not limited to, physician visits, hospital treatments if needed, rehabilitation, and medications. Indemnity costs included wage replacement and payments for permanent impairment and disfigurement. Medical claims were defined as those claims involving medical expenses only. Indemnity claims were defined as those claims involving both medical and indemnity expenses.

RESULTS

A total of 3,093 workers' compensation claims were analyzed. These injury claims were represented by 5,661 policies from 7 agriculture and agri-business sectors between January 2000 and July 2004 (Table II). As noted, cattle/livestock raising had the highest number of policies and claims as well as the highest total payroll. Cattle dealer operations had the second highest number of polices and grain elevator operations had the lowest number of claims, policies, and total payroll.

Claimant Characteristics

Age, work duration prior to injury, as well as gender were all analyzed (Table III). Bean sorting/handling operations had the highest percentage of injured female claimants of all operations analyzed, while hay grain/feed dealer operations had the lowest percentage of injured female workers. Dairy farms had the lowest average employment duration prior to injury and grain milling operations had the highest average employment duration prior to injury. Distributions of agriculture-related injury claims were also analyzed (Table IV).

TABLE II. Distribution of Total Claims, Total Policies, and Total Policy Payroll of Colorado Agriculture-Related Operations, 2000–2004

	Total claims		Total policies		
	N	%	N	%	Total payroll
Agriculture					
Dairy farms	451	14.6	379	6.7	89,872,765
Cattle/livestock raising	1,101	35.6	4,151	73.3	233,922,898
Cattle dealers	769	24.9	494	8.7	111,257,160
Agri-business					
Grain milling	322	10.4	105	1.9	78,921,321
Bean sorting/handling	168	5.4	119	2.1	39,561,117
Hay grain/feed dealers	173	5.6	303	5.4	52,271,262
Grain elevator operators	109	3.5	110	1.9	36,333,593
Total	3,093		5,661		$642,140,116

TABLE III. Injury Claimant Characteristics of Colorado Agriculture-Related Operations, 2000–2004

	Average Age (sd)[a]	Average work duration in years (sd)[a]	Work duration range (years)	% Male
Agriculture				
Dairy farms	34.5 (11.1)	2.7 (4.1)	0–23.5	88.0
Cattle/livestock raising	37.4 (12.4)	3.4 (5.1)	0–40.9	87.0
Cattle dealers	38.5 (13.1)	3.4 (5.1)	0–30.9	91.5
Agri-business				
Grain milling	39.4 (13.4)	4.9 (6.9)	0–39.9	90.7
Bean sorting/handling	36.5 (12.1)	4.1 (6.0)	0–28.2	73.8
Hay grain/feed dealers	40.9 (12.9)	4.1 (5.5)	0–28.2	92.5
Grain elevator operators	35.5 (12.9)	4.4 (6.9)	0–27.4	91.7
Overall	37.6 (0.23)	3.2 (0.09)	0–40.9	88.1

[a] sd, standard deviation.

Injury Incidence Rates by Occupation

Average annual injury claim incidence rates (claims/200,000 work hours) varied among the agriculture and agri-business sectors. Among agriculture sectors, annual injury claim incidence rates were highest for cattle dealers, followed by dairy farm workers and cattle or livestock raisers (Table V). Among agri-business sectors, grain milling workers had the highest claim rate followed by hay grain/feed dealers, bean sorting/handing workers, and grain elevator operation workers. More serious indemnity claim rates involving both medical and lost-time expenses were highest among cattle dealer operations, followed by cattle or livestock raising, hay grain/feed dealer operations and grain milling. Bean sorting/handling operators had the lowest indemnity claim rates. Of the less serious injuries involving medical expenses only, grain milling operations had the highest claim rate and hay grain/feed dealer operations had the lowest.

Injury Characteristic Frequencies

Injury source was defined as the origin of the energy that ultimately was transferred to the worker which resulted in his or her injury. Cattle dealers, cattle or livestock raisers, and dairy farmers had "animals" as the most frequent injury source (Table VI). Bean sorters/handlers, and hay grain feed dealers had "machinery" as the most frequent injury source. Grain millers and grain elevator operators had "tools" as the most frequent injury source.

TABLE IV. Distribution of Agriculture-Related Injury Claims by Quarter, 2000–2003

	January–March	April–June	July–September	October–December
	N (%)	N (%)	N (%)	N (%)
Agriculture				
Dairy farms	62 (17.9)	82 (23.6)	114 (32.9)	89 (25.6)
Cattle/livestock raising	125 (13.9)	287 (32.0)	258 (28.8)	227 (25.3)
Cattle dealers	115 (18.2)	161 (25.4)	189 (29.9)	168 (26.5)
Agri-business				
Grain milling	34 (13.0)	86 (32.8)	77 (29.4)	65 (24.8)
Bean sorting/handling	21 (14.5)	41 (28.3)	42 (29.0)	41 (28.3)
Hay grain/feed dealers	16 (11.4)	47 (33.6)	42 (30.0)	35 (25.0)
Grain elevator operators	12 (13.5)	27 (30.3)	32 (36.0)	18 (20.2)
All sectors	385 (15.3)	731 (29.1)	754 (30.0)	643 (25.6)

Injury cause was defined as the method of transfer of the energy that resulted in the worker being injured. Workers in all of the agri-business sectors had strain injuries as the most frequent injury cause (Table VII). Injuries classified as "environmental-animal" had the highest frequency among cattle dealers, cattle or livestock raisers, and dairy farmers.

Sprain/strain was the most frequent type of injury among bean sorters and handlers, grain elevator operators, grain millers, and hay grain feed dealers (Table VIII). Contusions were the most frequent type of injury among cattle dealers, cattle or livestock raisers, and dairy farmers. Lacerations, foreign bodies, and fractures were also more frequent injury types among all sectors.

The upper extremity was the most frequently injured body part among all sectors, with bean sorters and handlers having the highest frequency of upper extremity injuries (Table IX). Injuries to the lower extremity were the second most frequent injury location among cattle dealers, cattle or livestock raisers, and dairy farmers. Injuries to the trunk were the second most frequent injury location among bean sorters and handlers, grain elevator operators, grain millers, and hay grain feed dealers.

TABLE V. Estimated Annual Injury Claim Rates Among Colorado Agriculture Workers by Occupation, 2000–2004

	Injuries/200,000 work hours (95%CI)[a]		
	Overall	Medical	Indemnity
Agriculture			
Dairy farms	8.6 (7.8–9.4)	7.1 (6.3–7.8)	1.5 (1.2–1.9)
Cattle/livestock raising	8.1 (7.6–8.5)	6.0 (5.6–6.4)	2.1 (1.8–2.3)
Cattle dealers	10.7 (9.9–11.4)	8.3 (7.7–9.0)	2.3 (2.0–2.7)
Agri-business			
Grain milling	11.8 (10.5–13.1)	10.2 (9.0–11.4)	1.6 (1.1–2.1)
Bean sorting/handling	6.7 (5.7–7.8)	6.0 (5.0–6.9)	0.8 (0.4–1.1)
Hay grain/feed dealers	6.8 (5.8–7.9)	5.1 (4.2–6.0)	1.7 (1.2–2.3)
Grain elevator operators	6.2 (5.0–7.4)	5.4 (4.3–6.4)	0.9 (0.4–1.3)

[a]CI, confidence interval.

Economic Analysis

Injury costs were divided into medical and indemnity components, with their combination being the overall cost of injury. With all agriculture-related operations combined, the highest average injury costs by cause of injury were observed for vehicular and caught injuries (Table X). Caught injuries included situations where the worker was injured as a result of being caught in machinery or other equipment. The injury cause with lowest mean cost was strike injuries. Vehicular injuries had the highest mean medical and indemnity costs per injury.

The highest mean costs by type of injury were observed for dislocations and fractures (Table XI). Contusions had the lowest average cost per injury. Dislocations had the highest average medical and indemnity costs per injury. Contusions had the lowest mean medical and indemnity costs per injury.

The highest mean costs by location of injury were observed for spine/back and leg (Table XII). Facial injuries had the lowest mean costs. Leg injuries had the highest mean medical cost per injury, while spine/back injuries had the highest mean indemnity costs. Facial injuries had the lowest mean medical and indemnity costs per injury.

DISCUSSION

This study provided a unique opportunity to investigate the workers' compensation claims experience of specific agriculture and agri-business workers in Colorado. This investigation is the first to characterize Colorado's

TABLE VI. Most Frequent Injury Sources Among Colorado Agriculture and Agri-Business Workers by Percentage, 2000–2004

	Dairy farms (N = 451)	Cattle/livestock raising (N = 1,101)	Cattle dealers (N = 769)	Grain milling (N = 322)	Bean sorting/ handling (N = 168)	Hay grain/feed dealers (N = 173)	Grain elevator operators (N = 109)
Environment	6.4	8.7	8.1	8.7	6.5	12.7	6.4
Machine	5.1	7.6	6.9	11.5	12.5	16.1	12.8
Animals	28.9	23.6	24.2	2.5	0	1.2	0.9
Metal items	8.6	5.2	9.8	5.3	3.6	5.8	4.6
Tools	3.1	7.4	7.4	12.4	10.7	10.4	14.7

agriculture-related injuries using workers' compensation claims data and covered the time period from January 2000 to July 2004; the data provided a total of 3,093 injury claim events for analysis and calculation of claim rates. Average annual injury claim incidence rates were estimated using similar methodology as other investigations that utilized workers' compensation claims data [Dement and Lipscomb, 1999; Shah et al., 2003; Horwitz and McCall, 2004; Jones and Kumar, 2004].

There are a number of possible methods for conducting surveillance for work-related injuries based on health outcome: workers' compensation, sickness and accident insurance, OSHA 300 logs, plant medical records, physical examinations, self-administered questionnaires, and professional interviews. Hazard surveillance based on evaluation of job exposures to physical stressors by non-occupational health personnel is another approach [Silverstein et al., 1997]. The analysis of workers' compensation claims data to identify the causes, sources, types, and locations of occupational injuries, as well as their costs, is one approach for targeting primary prevention strategies to reduce musculoskeletal injuries. Research utilizing workers' compensation claims data has been reported in the literature in various industries such as sawmill operations, logging, health care, and construction [Dement and Lipscomb, 1999; Bell and Helmkamp, 2003; Shah et al., 2003; Horwitz and McCall, 2004; Jones and Kumar, 2004; Khuder et al., 1999]. Kaufman et al. [1998] used workers' compensation claims data to identify hazards related to skin disorders in various work environments in Washington State. Islam et al. [2001] analyzed workers' compensation claims data to investigate gender differences among reported injury claims in West Virginia.

A literature review produced limited research utilizing state-specific, workers' compensation claims data in the agriculture and agri-business industries. Demers and Rosenstock [1991] investigated occupational injuries among Washington State agriculture workers. The state workers compensation database was analyzed for the determination of the various types of injuries. The authors did not report their findings based on individual agriculture occupations.

The BLS reported a 2004 injury rate estimate of 5.6 injuries per 100 workers in crop production (NAICS 111), and 8.5 injuries per 100 workers in animal production (NAICS 112). The 2004 national injury rate for beef cattle ranching and farming (NAICS 11211) was 7.4 per 100 workers and the dairy cattle and milk production (NAICS 11212) injury rate was 6.7 per 100 workers [US Department of Labor, 2005]. Results from this study show that the injury rates among Colorado cattle dealers, cattle and livestock

TABLE VII. Most Frequent Injury Causes Among Colorado Agriculture and Agri-Business Workers by Percentage, 2000–2004

	Dairy farms (N = 451)	Cattle/livestock raising (N = 1,101)	Cattle dealers (N = 769)	Grain milling (N = 322)	Bean sorting/ handling (N = 168)	Hay grain/feed dealers (N = 173)	Grain elevator operators (N = 109)
Burn	1.8	1.3	1.8	1.9	1.2	4.6	5.5
Caught	5.3	3.2	6.6	4.0	9.5	6.9	2.8
Cumulative trauma	2.2	1.3	1.7	2.2	4.8	0.6	2.8
Cut	4.9	8.5	7.3	7.5	8.3	10.4	7.3
Environment-animal	29.0	19.8	23.7	3.7	1.2	0.0	1.8
Fall or slip	12.2	14.0	6.1	13.0	12.5	19.1	13.8
Miscellaneous	7.3	6.0	5.6	9.3	15.5	1.7	18.3
Other	2.0	5.0	4.0	3.1	2.4	1.7	4.6
Strain	13.7	19.4	13.0	35.1	29.8	24.3	21.1
Strike	10.0	11.0	9.5	3.7	6.0	7.5	6.4
Struck	8.9	5.6	10.1	4.0	3.6	8.1	8.3
Vehicle	0.7	2.8	2.1	1.9	0.6	4.6	0.9

TABLE VIII. Most Frequent Injury Types Among Colorado Agriculture and Agri-Business Workers by Percentage, 2000–2004

	Dairy farms (N = 451)	Cattle/livestock raising (N = 1,101)	Cattle dealers (N = 769)	Grain milling (N = 322)	Bean sorting/ handling (N = 168)	Hay grain/feed dealers (N = 173)	Grain elevator operators (N = 109)
Amputation	0.2	0.1	0.4	0.3	1.2	0.0	0.0
Burn	1.6	1.0	1.7	1.9	1.2	4.6	4.6
Carpal tunnel syndrome	0.0	0.0	0.1	0.0	1.2	0.0	0.0
Concussion	0.2	0.6	0.0	0.6	0.6	0.6	0.9
Contusion	46.8	30.1	42.1	23.6	20.8	24.9	24.8
Crushing	1.1	0.9	2.5	1.6	1.8	0.0	0.0
Dermatitis	0.2	0.5	0.1	0.0	1.2	0.0	0.0
Dislocation	0.4	1.5	0.3	0.3	0.0	0.6	0.0
Foreign Body	6.2	4.3	4.8	7.1	14.3	8.7	15.6
Fracture	4.0	8.7	5.3	3.4	1.2	7.5	1.8
Hernia	0.2	0.7	0.0	0.0	0.0	0.0	0.9
Infection	0.0	0.4	0.5	0.3	0.6	0.0	0.9
Inflammation	0.7	0.4	0.4	0.3	0.6	0.6	0.9
Laceration	6.7	11.2	9.6	8.7	8.3	13.3	11.9
Multiple physical injuries	0.0	0.2	0.0	0.0	0.6	0.0	0.0
Puncture	3.5	4.6	3.3	4.0	3.0	2.9	1.8
Respiratory disorders	0.2	0.4	0.3	0.6	0.6	0.6	2.8
Sprain/strain	23.9	28.4	21.8	42.5	39.3	31.8	28.4

raisers, and dairy farm workers were higher than national BLS estimates. Between 1984 and 1986, New York dairy farmers had an injury rate of 16.6 injuries per 100 workers [Pratt et al., 1992]. Eastern Ontario dairy farms had an injury rate of 4.7 injuries per 100 person-years in 1986 [Brison and Pickett, 1992] and Nordstrom et al. [1995] observed a risk rate of 3.5 per 100 person-years among dairy farm workers. Eastern Ontario beef operations had an injury rate of 10.5 injuries per 100 person-years in 1986 [Brison and Pickett, 1992].

TABLE IX. Most Frequent Injury Sources Among Colorado Agriculture and Agri-Business Workers by Percentage, 2000–2004

	Dairy farms (N = 451)	Cattle/livestock raising (N = 1,101)	Cattle dealers (N = 769)	Grain milling (N = 322)	Bean sorting/ handling (N = 168)	Hay grain/feed dealers (N = 173)	Grain elevator operators (N = 109)
Head							
Brain	0.2	0.4	0.3	0.3	0.0	0.0	0.0
Face	14.0	11.0	12.5	11.2	17.9	16.2	19.3
Neck	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Skull	1.8	2.3	2.0	3.4	1.2	1.2	0.9
Lower extremity							
Foot	11.3	9.4	11.3	11.5	6.5	8.7	2.8
Leg	12.9	16.8	16.8	9.9	8.3	12.7	13.8
Trunk							
Chest	5.3	3.5	6.1	3.4	2.4	2.9	1.8
Internal organs	0.2	1.5	1.4	1.2	1.2	0.0	3.7
Lower trunk	2.0	2.9	2.0	0.9	1.8	2.3	4.6
Neck	1.1	1.4	0.3	0.9	0.6	1.7	0.9
Spine/back	14.9	13.9	10.0	20.8	14.3	16.2	11.9
Upper extremity							
Arm	11.3	13.0	12.7	12.1	14.9	10.4	14.7
Hand	22.0	19.9	18.6	21.1	28.0	22.0	19.3

TABLE X. Mean Medical and Indemnity Costs* by Cause of Injury

	Medical	Indemnity	Total
	Average (sd)[a]	Average (sd)[a]	Average (sd)[a]
Vehicle	7,488 (1,982)	12,299 (4,590)	21,229 (6,122)
Caught	7,315 (2,604)	6,950 (2,817)	14,765 (5,305)
Fall or slip	4,262 (499)	4,826 (974)	9,511 (1,393)
Environment	4,321 (795)	3,565 (762)	8,266 (1,365)
Strain	3,162 (344)	3,963 (678)	7,517 (1,000)
Cumulative trauma	3,595 (1,068)	4,313 (1,585)	8,478 (2,582)
Strike	1,663 (281)	831 (225)	2,585 (463)

*U.S. dollars.
[a]sd, standard deviation.

TABLE XII. Mean Medical and Indemnity Costs* by Body Part

	Medical	Indemnity	Total
	Average (sd)[a]	Average (sd)[a]	Average (sd)[a]
Spine/back	3,211 (483)	6,239 (1,053)	10,096 (1,558)
Leg	5,394 (880)	3,785 (771)	9,530 (1,633)
Arm	5,167 (705)	3,515 (704)	9,072 (1,432)
Foot	2,392 (483)	3,358 (1,216)	6,079 (1,699)
Neck	2,090 (880)	2,352 (1,547)	4,634 (2,210)
Hand	1,506 (154)	903 (158)	2,519 (296)
Face	1,140 (425)	800 (468)	2,025 (865)

*U.S. dollars.
[a]sd, standard deviation.

According to the BLS [US Department of Labor, 2005], annual injury rates for agri-business operations such as grain and oilseed milling (NAICS 311200) and farm product wholesalers (NAICS 4245) were 5.6 and 5.7, respectively. The present study revealed higher claim rates for grain milling operations, hay grain/feed dealers, and grain elevator operations than BLS estimates. It also revealed a higher injury rate for bean sorting/handling operations than the 2004 BLS [US Department of Labor, 2005] injury rate for crop production (5.6).

BLS injury incidence rates are a commerce-driven reporting mechanism based on OSHA 200 injury logs. Industrial sectors in the BLS injury incidence rate reporting system are classified according to the 2002 NAICS, and its coding methodology makes it difficult to make direct comparisons to the agri-business operations that were included in this study. In addition, BLS injury rates did not include agriculture operations with 10 or fewer employees [US Department of Labor, 2005]. Roughly 95% of U.S. farms have less than 11 employees [Pratt et al., 1992]. Based on the 2002 Census of Agriculture, 74% of all farms do not hire any workers. Therefore only a small percentage of agriculture operations purchase any form of worker's compensation insurance [US Department of Agriculture, 2002]. Other than the workers' compensation provider insuring approximately 75% of agricultural businesses compensation policies in Colorado, information was not provided by the carrier concerning its representation of all agriculture operations of all sizes. Since single operator agriculture operations are not required to carry workers' compensation insurance, this dataset is not representative of smaller, one employee operations.

TABLE XI. Mean Medical and Indemnity Costs* by Type of Injury

	Medical	Indemnity	Total
	Average (sd)[a]	Average (sd)[a]	Average (sd)[a]
Dislocation	11,549 (2,885)	8,169 (2,863)	20,337 (5,240)
Fracture	8,416 (1,470)	6,289 (1,459)	15,275 (2,674)
Strain	3,330 (295)	4,145 (569)	7,879 (838)
Sprain	3,261 (768)	3,940 (1,723)	7,777 (2,606)
Laceration	3,269 (972)	1,692 (587)	5,171 (1,486)
Contusion	2,673 (396)	2,546 (499)	5,532 (799)

*U.S. dollars.
[a]sd, standard deviation.

The specific industries and occupations represented in this study is an ad hoc combination of agriculture and agri-business operations. A comparison to previous agriculture studies involving cattle and livestock raisers, dairy farmers and cattle dealers is appropriate. However, a direct comparison to prior agriculture studies cannot be made for the agri-business operations of grain milling, grain elevator operations, hay grain/feed dealers, and bean sorting/handling. These sectors involve different working environments, operations, tasks as well as tools and machinery.

Like previous agriculture studies, the findings from this investigation indicate higher injury rates are associated with certain farm environment characteristics, specifically the presence of animals or livestock. The finding of higher injury rates among farms with large animals has also been reported by Stallones [1990], and an excess injury risk associated with beef farms in Canada was reported by Pickett et al. [1995].

The farm work environment is characterized by a wide variety of tasks and hazards for injury. These risk hazards include machinery, work from heights, animals, water, poisonous gases and chemicals, and electricity [VonEssen and McCurdy, 1998; McCurdy and Carroll, 2000]. The present study involving cattle dealers, cattle and livestock raisers, and dairy farmers supports the findings of other researchers who found that animals/livestock, machinery, and falls are among the more common sources of agriculture-related injuries [Brison and Pickett, 1992; Browning et al., 1988; Crawford et al., 1998; Gerberich et al., 1998; Hoskin et al., 1988; Layde et al., 1995; Nordstrom et al., 1995].

Agriculture machinery is a necessity for farm production and represents a cause of injury accounting for 18%–35% of cases [Myers, 1990; Brison and Pickett, 1992; Zhou and Roseman, 1994; Cleary et al., 1961; Crawford et al., 1998; Gerberich et al., 1998; Harting et al., 1997; Hoskin et al., 1988; Layde et al., 1995; Lewis et al., 1998; Nordstrom et al., 1995; Pickett et al., 1995]. Tractors are among the most common farm machines and have been associated with the majority of farm machinery-related fatalities. Among Colorado machinery-related injury claims, the highest percentage was vehicular-related. Knives, non-powered hand tools, needles, hammers, sledges, mallets, and ladders were the most frequent injury sources among tool-related claims.

Working from heights is often a necessity while working on the farm. Falls represent up to one-quarter of injury cases on the farm [Brison and Pickett, 1992; Zhou and Roseman, 1994; Nordstrom et al., 1995; Pickett et al., 1995]. Among Colorado agriculture workers, the most frequent classification of fall or slip injuries were those that involved falling or slipping from a different level.

Animal/livestock injuries account for between 12% and 33% of injuries on the farm [Cleary et al., 1961; Cogbill et al., 1985; Hoskin et al., 1988; Myers, 1990; Brison and Pickett, 1992; Pratt et al., 1992; Zhou and Roseman, 1994; Layde et al., 1995; Nordstrom et al., 1995; Pickett et al., 1995; Gerberich et al., 1998; Lewis et al., 1998]. Animal-related injuries are common in settings were working with heavy and powerful animals is required. In comparison, the most frequent injury cause among Colorado agriculture workers involved animals or livestock, and these claims more frequently involved contusions to the leg, arm, and hand. Risk factors associated with animal-related injuries include work activities that increase exposure and proximity to farm animals. For example, Boyle et al. [1997] found that dairy cattle workers who spend more than 30 hr per week milking have up to 20-fold increased risk for injury; a fourfold increased risk was found to be associated with trimming or treating hooves. Abrasions/contusions and sprains/strains/torn ligaments represented more than one-quarter of all reported cases [VonEssen and Donham, 1999].

The present study is in agreement with previous agriculture studies that found the most frequent types of injuries are contusions, lacerations, fractures, and sprains/strains [Cleary et al., 1961; Browning et al., 1988; Demers and Rosenstock, 1991; Brison and Pickett, 1992; Zhou and Roseman, 1994, 1995; Pickett et al., 1995; Crawford et al., 1998; Lewis et al., 1998]. It also is in agreement that the most frequently injured body parts are hands, legs, spine/back, face, and feet. [Cleary et al., 1961; Browning et al., 1988; Brison and Pickett, 1992; Zhou and Roseman, 1994; Pickett et al., 1995].

The present study is the first to analyze and present injury claims data involving agri-business operation. Agri-business operations present different hazards and environments as compared to the traditional agriculture setting. In addition, these operations involve different tools and machinery that are different from those used in farming and ranching environments. Injury rates among bean sorting/handling workers, hay grain/feed dealers and grain elevator operators were all higher than their respective BLS estimates. These findings warrant further investigations that identify work hazards specific to these different industrial and occupational sectors. This could lead to the development of effective injury-reducing interventions and technologies.

Injury cost analysis revealed that vehicular injuries were the most costly. The National Safety Council [2003] reported motor-vehicular injuries as being the most costly injury among all industrial sectors ($22,222). More costly types of injuries in the present study also included dislocations and fractures. In comparison, the National Safety Council [2003] reported that fractures/crush/dislocations were the second most costly ($18,638) injuries behind amputations ($21,800) among all industrial sectors. In addition, the National Safety Council [2003] reported that the average cost of a leg injury was $15,759 and the average for a low back injury was $14,913. The National Safety Council [2003] also reported that injuries to the head ($21,523) and neck ($21,222) were the most costly injury body part locations.

Study Limitations

The use of workers' compensation claims data to analyze agriculture-related injuries presents inherent limitations to the study. The use of NCCI occupational coding for the analysis of agriculture-related tasks made it difficult to correlate with recognized reporting agency occupational classification codes. Despite playing a role in the agriculture industry in Colorado, grain milling, bean sorting and handling, hay grain and feed dealers, and grain elevator operations are not easily classified in the agriculture industry in any of the recognized industrial classification systems. This ad hoc combination of industries and occupations prevents the data from representing the agriculture industry as a whole. Despite this limitation, the authors believe that the analysis of specific Colorado agriculture-related sectors is vital to future injury prevention research efforts. This project shed light on the difficulty of combining workers' compensation and national injury surveillance data. A methodological limitation of this study is the use of BLS prevailing national wage estimates to estimate denominator hours at risk. The authors estimated occupational wages by correlating NCCI codes with prevailing national industry-specific SOC codes and their occupational wage estimates as reported by the BLS. An underestimation or overestimation of hourly wages could have resulted in an underestimation or overestimation of injury claim rates. Workers compensation data can be a powerful resource for injury surveillance. Therefore efforts should be taken to correlate national SOC, NAICS, and NCCI classification schemes.

A second limitation in the use of workers' compensation claims data for injury surveillance is the dependence on injury reporting. It was the policy of the insurance provider to emphasize early and comprehensive injury reporting to all policy holders and their employees. Workers' compensation data could potentially underreport the true number of injuries in agriculture because both a worker and physician must recognize that his or her condition is work-related. Many agriculture workers live on the farms that they operate and the differentiation between an occupational and non-occupational injury may be difficult. Also, smaller agriculture operations may deliberately underreport injuries for fear of policy premium escalation. In this study, the injury rate is a measure of incidence with claims as the numerator and hours of work as the denominator. If injuries were not reported to the workers' compensation insurer, the injury claim frequencies and incidence rates presented here would be underestimated. An underreporting of payroll data by policy holders for the purpose of cheaper premiums could have potentially resulted in an overestimation of injury rates. This practice would have needed to take place on a large scale among policy holders to have an influence on obtained injury rates.

The workers' compensation insurance company that supplied the injury claims data used in this investigation did provide coverage to the majority of agriculture operations in the State of Colorado; however, results of the present study cannot be used to represent all Colorado agriculture operations or the agriculture industry as a whole. The injury claims data is limited by the degree of accuracy of data entry at the time of injury. Since injury claims included in this study were not randomly selected, a threat to internal validity existed. Compensation records are known to be insensitive to the total extent of occupational disease, however, recent investigations have demonstrated the validity of compensation data based on internal analyses [Demers and Rosenstock, 1991]. The present study utilized BLS industry-specific occupational wage estimates for the estimation of risk hours and injury claim rates. This methodology has been utilized in other studies but more complete state-regulated employment figures could provide more accurate risk hazard denominator data [Dement and Lipscomb, 1999; Horwitz and McCall, 2004; Jones and Kumar, 2004]. The degree to which results from Colorado agriculture workers and operations apply to other states or jurisdictions is unknown, and should be approached with caution. Seasonal and commodity variations exist across states, and injury patterns may be influenced by these variances. This study utilized injury claims data from 2000 to 2004. An investigation that included a longer time period would be more representative of the specific occupational sector as well as provide for the revelation of injury trends. Despite these limitations, this study is the first of its kind to utilize workers' compensation injury claims data to investigate specific agriculture-related operations in the State of Colorado while providing vital injury characteristic information that can be used to develop effective injury prevention strategies.

CONCLUSION

In summary, Colorado agriculture workers (cattle dealers, cattle or livestock raisers, dairy farmers) and agri-business workers (grain milling workers, bean sorting/handling workers, hay grain/feed dealers, and grain elevator operators) have higher rates of injury claims. Understanding the occurrence of injuries among Colorado agriculture and agri-business workers is critical to implementing and evaluating effective intervention programs for specific agriculture-related occupations. Results of this study will direct attention to the development of safety interventions that address the worker–animal interface, fall protection systems, machinery usage, and overexertion prevention strategies.

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APPENDIX B

WORKERS' COMPENSATION

FIRST REPORT OF INJURY (FRI) FORM

PINNACOL
ASSURANCE

FIRST REPORT OF INJURY [redacted]
To report a claim call your service team:
Small Business Services Team at 303-361-4000 or 1-800-873-7242
Or Fax to 303-361-5000 or 1-888-329-2251
or www.pinnacol.com

Early reporting can save you money. Report all injuries immediately!
The information below allows Pinnacol Assurance's customer service representatives to quickly and accurately process your claim. Use the completed form as a guide when reporting by phone or online to save you time. Don't wait to report if you don't have all the answers.

A. Critical Data - *REQUIRED INFORMATION TO BEGIN PROCESSING YOUR CLAIM BY PHONE OR ONLINE.*

Policy Number: ____________ Company Name: ____________

Address or Location (if different than mailing address): ____________

Injured Worker's Social Security Number: ____ - ____ - ____ Date of Injury: ____ / ____ / ____

First Name: ____________ M.I. ____ Last Name: ____________

B. Injured Worker Information

Home Address: ____________ City ____ State ____ Zip ____ Phone: ( ) ____________

Date of Birth: ____ / ____ / ____ ❑ Male ❑ Female Marital Status: ____________

Language: ❑ English ❑ Spanish ❑ Other: ____________ Occupation: ____________

Date Hired: ____ / ____ / ____

Employee Status: ❑ Full-time ❑ Part-time ❑ Seasonal ❑ Volunteer ❑ Independent Contractor

Days worked per week: ____ and average weekly wage $ ____

OR

Hours worked per day: ____ and hourly pay rate $ ____ and hours worked per week: ____

C. Accident / Injury Information

Fatal Injury? ❑ Yes ❑ No **If fatal injury: Date of Death:** ____ / ____ / ____

Is this a lost-time claim? ❑ Yes ❑ No (Claim is lost time if there is a loss of more than three scheduled workdays due to the injury.)

Time of Injury: ____ ❑ a.m. ❑ p.m Time Work Began: ____ ❑ a.m. ❑ p.m. Last Work Date: ____ / ____ / ____

Full Pay on Date of Injury: ❑ Yes ❑ No

Accident Occurred on Employers Premises: ❑ Yes ❑ No Severe Injury: ❑ Yes ❑ No

Accident Location: ____________ If Applicable: Location Code: ____ Dept. Code: ____

Name of Employer Representative Notified: ____________ Date Notified: ____ / ____ / ____

How did Injury Occur: ____________ Attach additional pages if necessary

Specific Activity the Employee Was Engaged In: ____________ What Equipment Was Being Used? ____________

Body Part(s) Injured: ____________

Witnesses: ____________ Name(s) & Phone Number(s)

❑ Safety Equipment Provided ❑ Safety Equipment Used ❑ Possible Drug/Alcohol Involved ❑ Employer Questions Liability

D. Medical Provider Information; Where was your employee treated?

❑ No Medical Treatment ❑ Treated by Employer ❑ 911 Called ❑ Walk-In Clinic

❑ Emergency Room ❑ Hospitalized > 24 hrs / Overnight ❑ Possible Surgery

____
Medical Provider Name Street Address City State Zip Phone

E. Return to Work Information

Has injured worker returned to work? ❑ Yes ❑ No

Date Returned to Work: ____ / ____ / ____ Estimated Date of Return to Work: ____ / ____ / ____

Prepared By: ____________ (Please Print) Title: ____________

Email: ____________ Fax: ____________

Phone: ( ) ____________ Date: ____ / ____ / ____