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Risk Factors for Agricultural Injury: An Evaluation Using Systematic Review and Injury Surveillance

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RISK FACTORS FOR AGRICULTURAL INJURY: AN EVALUATION USING SYSTEMATIC REVIEW AND INJURY SURVEILLANCE

by

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Purpose- Agriculture is the most hazardous industry in the United States. The effectiveness of intervention programs for injury prevention can be improved by acquiring knowledge of risk factors for occupational injury in agricultural operators. The landscape of agriculture is changing in the U.S. Agricultural populations, environments and risk factors are changing as well with the changes in the structure of farms and ranches. The objective of this study was to identify significant risk factors for agricultural injury based on the literature and three years of injury surveillance data covering seven U.S. states. Methods- We conducted a systematic review of reported risk factors for agricultural injury. Studies that reported adjusted odds ratio or relative risk estimates were identified from *PubMed* and *Google Scholar*. Pooled risk factor estimates were calculated using meta-analysis. We also analyzed agricultural injury surveillance data to evaluate risk factors for severe injury. The Central States Center for Agricultural Safety and Health (CS-CASH), in collaboration with the National Agricultural Statistics Service (NASS), gathered these data from 6,953, 6,912 and 6,912 farms/ranches in 2011, 2012 and 2013, respectively, covering Iowa, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Kansas. Results- The systematic review identified 33 risk factors for agricultural injury and 25 of them were statistically significant in meta-analysis. Analysis of injury surveillance data led to the identification of 13 significant risk factors; three of them were not found in the systematic review. The risk factors were related to demographic characteristics, farm environments, behaviors and work practices.

Conclusion- A total of 25 identified factors significantly increased the risk of injury. Several factors are well-established in numerous studies while others need further exploration. The identified risk factors should be: a) considered when selecting high-risk populations for interventions, and b) considered as potential confounders in intervention studies.

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LIST OF ABBREVIATIONS

ATV	All-Terrain Vehicle
BLS	Bureau of Labor Statistics
CAIS	Childhood Agricultural Injury Survey
CI	Confidence Interval
CMA	Comprehensive Meta-analysis Software
CS-CASH	Central States Center for Agricultural Safety and Health
FSS	Farm Safety Survey
ISS	Injury Severity Scale
M-OISPA	Minority Farm Operator Occupational Injury Surveillance of Production Agriculture
NASS	National Agricultural Statistics Service
NAWS	National Agricultural Workers Survey
NIOSH	National Institutes for Occupational Safety and Health
NOS	Newcastle-Ottawa Scale
OISPA	Occupational Injury Surveillance of Production Agriculture
OR	Odds Ratio
ROPS	Roll Over Protective Structures
RR	Relative Risk
SAS	Statistical Analysis System

CHAPTER 1: INTRODUCTION

1.1 INJURY INCIDENCE

By the year 2020, injuries will cause more deaths, disabilities, and costs than those from all communicable disease combined (1). Since the beginning of the last decade of the 20th century, injuries to agricultural workers have been studied, particularly in the developed countries, and high rates of mortality and morbidity have been reported in agricultural workers. According to the United States Department of Labor's Bureau of Labor Statistics (BLS), the incidence of fatal injuries was 22.2 / 100,000 full-time equivalent (FTE) workers, and the non-fatal injury rate was 5.7 injuries / 100 FTE for hired farm workers in 2013 (2, 3). The fatality rate for all industries combined was less than one-eighth of the rate for agriculture in 2011 (4). In Australia, the annual fatality rate for agricultural workers was three to four times higher than that for all workers in 1989 – 1992 (5). The Canadian Census of Agriculture of 2001 reported the annual incidence of 3.5 injuries / 100 workers (6). A Finnish study based on the records from worker's compensation system reported that 20.2 % of the total of 78,679 farmers had one or more injuries in 2000 – 2004 (7). In Poland, the total of 28,033 agricultural injuries occurred that resulted in 211 deaths in 2004 – 2005 (8).

Outside Europe and North America, the knowledge of agricultural injuries and injury prevention is scarce. A study from Hubei, People's Republic of China reported that 33% of the total of 1,358 farmers selected from 14 villages had one or more injuries in 1995 – 1997 (9). A study based on records from South Korean worker's compensation system reported 11,931 injuries and 219 deaths in 2005 (10). The injury incidence rate was 1.66 injuries / 100 workers, lower than the rates reported in most studies in the West. Likewise, lower rates were reported in studies from India and Tanzania with 0.13

and 3.27 injuries / 100 workers, respectively (11, 12). The great variation in injury rates may be due to differences in working conditions, injury definitions, data collection methods, cultural differences, knowledge, attitudes, and other factors. While the rates vary, agriculture consistently ranks among the most hazardous industries in most countries and data sources.

Incidence rates can be used as an indication of the magnitude of the injury problem. The rates described above represent a hard pressing problem of unintentional occupational injury in modern agriculture. Further, the reported rates underestimate the actual incidence in most cases. For example, the BLS does not collect injury data from farms that employ less than 11 employees, but these farms represent 95% of all U.S. farms, leading to substantial underreporting of injuries (13-16). Underreporting occurs in hired workers as well. Half of the hired workers were not authorized to work in agriculture in the United States in 2001 – 2002 (17).

1.2 INJURY SOURCES

Injury sources are identified and reported in many injury data collection systems. They provide valuable information that helps design source-specific interventions. The most common sources of injury include machinery, animals, and falls. Farm equipment can pose unique hazards (18). Machinery-related injury sources include tractors, combines, harvesters, planters, power take-off drivelines, augers, and all-terrain vehicles (18-24). Tractors are commonly used in farming (18), and they account for a large proportion of machinery-related fatalities (22). The U.S. Occupational Safety and Health Administration require that roll over protective structures (ROPS) and seatbelts are provided by the employer for each tractor operated by an employee. However, this and other OSHA regulations are enforced only for farms with 11 employees or more which includes about 95% of farms (18). Animal-related injuries result from horses, boars, bulls, and other livestock (18, 21, 25-27). Cattle and horses account for the majority of animal-related injuries because greater exposure and proximity to these large and powerful animals increases the risk of injury (18). Some occupational tasks include working at heights such as harvesting tree fruit and other tasks that require the use of ladders. Fall-related injuries account for 25% of total injuries on the farm (16, 28-30). Fall-related injuries on the same level occur due to tripping, slipping, and sliding on working surfaces (30, 31). Other sources include water, poisonous gases, electricity, transportation vehicles, and objects (struck by, struck against) (11, 18, 20, 32). A Tanzanian study reported that 33% of the total of 206 injuries occurred during farm-related transportation work (11). In the U.S., it is likely that the high-speed limits (55 miles per hour or higher) on rural highways and relatively slow speeds of farm vehicles can lead to rear-end crashes (18). More studies are needed to address injuries that occur during the transportation of farm-related goods that occur on roads with varying speed limits. Studies should also address specific issues such as design flaws, compromised safety features, and unsafe behaviors of workers. In the summary, multiple factors typically contribute to injury incidents, providing alternative options for prevention.

1.3 INJURY CHARACTERISTICS

Injury characteristics can shed light on the nature of the problem. This information can help in the development of strategies for prevention. The characteristics include physical nature: sprain, strain, fracture, laceration etc. (19, 20, 30, 32); work activity: lifting, operating machinery, handling livestock, etc. (16, 22, 33); worker situation: working alone, accompanied by others (34); location: home, road, field, pasture, building, etc. (16, 22, 35); and time: day, week, month, season (16, 22, 33). Injury severity is defined by the level of medical treatment: no care, out-patient care, hospitalization (21, 25, 26); economic loss: disability duration (lost time) and cost of medical care (16, 36, 37), and prognosis: complete recovery, impairment (16). Extremities were the most common body part involved during injury (15, 34, 38, 39). According to the National Safety Council, injuries most commonly occurred to the back in 2011 (4). Working long hours in the fields or working with animals demand bending frequently, and this practice can increase the pressure on the back. By the end of the work day, farmers get exhausted, and the fatigue resulted from exhaustion can lead to increased risk of injury. Automation can help reduce injuries. For example, milking parlors are designed to reduce exposure from stooping and bending as well as injuries from contact with animals (30). While these technologies reduce hazardous exposures, smaller farms may not be able to afford them. Therefore, educational and other measures for injury prevention can be more suitable for low-income farmers than engineering controls.

The most common location for injury was farm field according to some sources (14-16). Workers on crop farms conduct the majority of their tasks in the fields. Many injuries resulted in out-patient care while only a few resulted in hospitalization (26). Injuries can lead to heavy economic loss, work productivity loss, and physical and psychosocial disability. Many injuries are not treated at healthcare facilities. Particularly minor injuries remain unreported leading to underestimation of minor as well as severe but not life-threatening injuries (8, 26). The magnitude of underreporting of injuries relies on the type of health care and insurance systems available in different counties. For example, in Finland, worker’s compensation is compulsory for all self-employed farmers and employees. The system compensates health care, lost time, rehabilitation and other losses. Claims and policy data from this system have been used for numerous research studies (7, 37, 40). Worker’s compensation systems differ by state but self-employed farmers are generally not covered in the United States. While coverage differences exist, workers compensation data are generally available for employees on larger farms (37, 40).

1.4 INJURY RISK FACTORS

This dissertation focuses on injury risk factors. According to the World Health Organization, a risk factor is any attribute, characteristic or exposure of an individual that increases the likelihood of developing a disease or injury (41). According to Heldon and Baker's model for injury prevention (42), a three-tier system of risk factors contributes to injury outcome. The system includes the agent – sources of injury such as machinery, animal, falls and other; the host – farm worker characteristics such as migrant status, language skills, training, access to healthcare services, and perceived vulnerabilities; and the environment – work setting, tasks, conditions, hazards, time pressure and dispersed or variable physical environment. The model suggested preventive measures to target the three layers of risk factors such as improvement of ergonomic designs of machinery, education and training of farm workers, proper maintenance of protective gear, and improvement in regulatory environment such as limiting the access of children to dangerous farm machinery. Most preventive measures target primary prevention – preventing the contact between the host and the agent – the energy source. These measures include improved engineering controls, protective clothing, and protective guards. Most primary preventive measures for host population tend to be educational (18). These measures help reduce inconsistencies in implementing safety-enhancing behaviors.

Prior research has identified many risk factors for agricultural injury. The results for risk factors vary in individual studies. In some cases, conflicting results have been reported for different health conditions. For instance, arthritis increased the risk of injury

(27) while high blood pressure reduced the risk (43). Living on the farm has been reported as a risk factor (37), but also a protective factor (19). Therefore, considering all available studies is necessary for evidence-based (44) evaluation of risk factors for a better understanding of risk factors, compared to relying on information from single or a few reports. To date, no such synthesis of risk factors conducted from multiple studies is available.

1.5 INTERVENTIONS FOR PREVENTION OF INJURY

The increased prevalence of using ROPS on tractors has resulted in the significant reduction of fatalities from tractor overturns. In one data linkage study, the fatalities in the United States from tractor overturns decreased by 28.5% between 1992-2007 (24), and this decline in fatalities was attributed to the increased use of ROPS. The association was adjusted for the age, region, relation to the farm, and farm group. Providing ROPS and seatbelts on tractors has been a successful intervention for the primary prevention of fatal injury. Intervention efforts for the prevention of non-fatal injury are on-going, but there is little evidence of their success (45, 46). Some intervention studies have evaluated educational measures in certain farm populations such as principal operators and farm children and youth. Others have evaluated engineering controls prescribed by safety expert recommendations (45). However, demonstrating the efficiency of these interventions has been challenging (45). Intervention studies could be improved by implementing rigorous study designs and improving program evaluation measures. The efficiency of interventions can also be improved by acquiring detailed information of the agent, host and environment-based risk factors and directing interventions at appropriate populations. Many contributing factors, sources, and characteristics of injury have been identified in different agricultural settings and this information can be used for designing specific prevention measures. Better understanding of risk factors for injury is an essential step in developing well-tailored intervention programs.

1.6 CHANGING FARMING PRACTICES IN THE UNITED STATES

Farms in the United States are diverse. The farm types range from residential and lifestyle farms to large enterprises with commodity sales in millions annually. The U.S. farm structure and organization is changing. Small-scale family farms constituted 90.1% of all U.S. farms while large-scale family and nonfamily farms and midsize family farms comprised only 9.9 % (47). However, only 26% share of the production was attributed to small family farms, and the bulk of production was attributed to midsize family farms and large farms (48). The marginalization of small farms is increasing while large farms continue to perform better. This polarization of net income has resulted in small farm owner/operators engaging in off-farm work besides their farm business (48). Also, fluctuations in certain commodity prices (49) result in the increase of anxiety in small farm owners, and this uncertainty of earnings from farm business lead to even greater reliance on off-farm employment. Many families continue to maintain their farms for residential or lifestyle purpose and not as their primary business. Only 47% of the total U.S. principal operators reported farming as their primary occupation in 2012 (50).

Challenging economic conditions have forced small family farm operators to increase farm size and production, or to work part-time on the farm and keep off-farm employment, preferably full-time, to meet economic needs. Both trends may contribute to adverse outcomes. Increases in farm size increases farm work hours and related risks among full-time farmers. Working long hours off the farm can cause fatigue and less attention to safety during farm work. With changes in farm structure and economics, modifications in farm practices and organization have become inevitable, and this process is ongoing. Therefore, injuries and risk factors should be studied in the context of these changes.

1.7 INJURY SURVEILLANCE

In the United States, the Centers for Disease Control and Prevention’s National Institutes for Occupational Safety and Health (NIOSH) has administered four injury surveillance mechanisms. The Childhood Agricultural Injury Survey (CAIS) for children and youth of less than 20 years old (51), the Minority Farm Operator Occupational Injury Surveillance of Production Agriculture (M-OISPA) for farms operated by minority populations (52), the Occupational Injury Surveillance of Production Agriculture (OISPA) for working adults and other adults of 20 years old and older (53), and the National Agricultural Workers Survey (NAWS) for hired workers (54). Also, the Farm Safety Survey (FSS) conducts surveillance of known hazards that occur on farms involving manure pits, all-terrain vehicles (ATVs), tractors, animals, silos and grain bins, pesticides, and noise (55). The NIOSH surveys provide useful information on population demographics and injury outcomes. These surveys have been conducted periodically, but NIOSH has announced a decision to discontinue these surveys in the future. To capture changes in injury rates, patterns and risk factors in farm operators and workers over time and by region, annual surveillance is needed. The BLS conducts annual injury surveillance of hired workers covering all industries, including agriculture, forestry and fishing. BLS data show injury frequencies, rates and other descriptive characteristics by industry and occupation. However, BLS surveys do not cover self-employed farmers and hired workers on farms with less than 11 employees, which represent 95% of all U.S. farms (13, 15, 16). No annual injury surveillance system exists for this important segment of the agricultural workforce. Also, data from these U.S. government surveys have not been used for analytical studies, evaluating risk factors for injury. The Central

States Center for Agricultural Safety and Health (CS-CASH), funded by NIOSH, initiated an annual injury surveillance system in collaboration with U.S. Department of Agriculture's National Agricultural Statistics Service (NASS). This surveillance covers seven states in the central U.S.

1.8 OBJECTIVES OF THE DISSERTATION RESEARCH

The objectives of this dissertation research were to evaluate common and emerging risk factors for injury by conducting a systematic review of the available literature, and by conducting logistic regression analysis of a three-year annual injury surveillance data from the CS-CASH surveillance system.

CHAPTER 2: SYSTEMATIC REVIEW AND META-ANALYSIS OF RISK FACTORS FOR AGRICULTURAL INJURY- PART I

2.1 ABSTRACT

Purpose- The objective of this study was to identify significant risk factors for agricultural injury based on the literature. Methods- We conducted a systematic review of commonly reported risk factors. Studies that reported adjusted odds ratio (OR) or relative risk (RR) estimates for the selected risk factors were identified from *PubMed* and *Google Scholar*. Pooled risk factor estimates were calculated using meta-analysis. Results- A total of 441 (*PubMed*) and 285 (*Google Scholar*) studies were found in the initial searches; of these, 132 and 78 studies, respectively, met the selection criteria for injury outcomes, and 32 of these reported adjusted OR or RR estimates. One study was excluded as it did not meet the set Newcastle-Ottawa Scale quality criteria. Finally, 31 studies were used for meta-analysis. The pooled ORs for the risk factors were as follows: male gender (vs. female) 1.68, full-time farmer (vs. part-time) 2.17, owner/operator (vs. family member or hired worker) 1.64, regular medication use (vs. no regular medication use) 1.57, prior injury (vs. no prior injury) 1.75, health problems (vs. no health problems) 1.21, stress or depression (vs. no stress or depression) 1.86, and hearing loss (vs. no hearing loss) 2.01. Conclusion- All selected factors except health problems significantly increased the risk of injury, and they should be: a) considered when selecting high-risk populations for interventions, and b) considered as potential confounders in intervention studies.

2.2 INTRODUCTION

With a growing body of literature, it is common that the point estimates for risk factors vary from study to study. For example, some studies have identified health problems as a risk factor for injury (27, 56), but other studies reported them as a protective factor (43, 57). Systematic review and meta-analysis provide the weight of evidence from all available findings, leading to a more precise estimation of the effect of a risk factor, compared to the one using individual studies (58).

Systematic reviews of the current literature can improve the understanding of risk factors and how they contribute to injury events. Changes occur in farm populations, practices, and environments over time in different regions, and therefore, such reviews should be repeated periodically.

The risk factors can be classified as either individual-level or farm-level (59).Individual-level risk factors include demographic groups or personal characteristics. Examples of the commonly addressed demographic groups include male farmers, female farmers, older farmers, younger farmers, full-time farmers, and part-time farmers. Examples of the reported personal characteristics of farm workers include history of injury in the past, used medication regularly, have hearing loss, and have health ailments. Farm-level risk factors include factor related to the farm environment and safety-related factors.

The objective of this study was to evaluate individual-level risk factors for agricultural injury using the systematic review and meta-analysis process. We conducted the first systematic review risk factors from the literature from the 1990s to the 2010s. We evaluated the weight of evidence for male gender, full-time farming, farm owner/operator status, regular medication use, history of prior injury, and having health problems, stress/depression and hearing loss as risk factors for agricultural injury.

2.3 METHODS

We used a common systematic review process, which includes defining the question, preparation, systematic research of the literature, selection of studies, quality assessment of studies, analysis and synthesis of the data, and interpretation of the results (45, 46, 60). In this systematic review process, we found point estimates for 34 different injury risk factors. In this chapter, we report on eight risk factors. These risk factors were chosen because they had the following characteristics: 1) reported multiple times in the literature, 2) evaluated in multivariable regression models adjusting for potential confounders, 3) proximal to farmers regardless of the geographic location or type of farming, and 4) classified in a way that enabled their inclusion in meta-analysis. Factors that did not meet one or more of these conditions will be discussed in Chapter 3.

2.3.1 Definitions

Definitions for agricultural injury differ. In this review, studies of farmers, ranchers, and workers raising crops and animals were considered 'agricultural'. Forestry, fishing, hunting, and trapping were excluded. The following was used as a guideline to define 'injury': unintentional, sudden (vs. long-term exposure), forceful event, with an external cause, resulting in body tissue damage or unconsciousness, resulting in possible medical care and/or lost work time, occurring to a person engaged in agricultural work activity at the time of injury incident. The terms accident and incident are used in some studies instead of injury with similar intent.

The selected risk factors were defined and prepared for meta-analysis. Following is a list of risk factors, levels and definitions used in the analyses:

Table 2.1 Definitions used for risk factors (Part I).

Risk factor	Levels	Definitions
Gender	Male vs. female	
Work time	Full-time vs. part time	Full time defined as 5-7 days weekly or 40 or more hours weekly.
Worker status	Owner/operator vs. other	Other defined as family member or hired worker. Some studies included only one principal (primary) operator. Other studies considered both spouses equally as farmers or primary operators. Children were excluded.
Regular medication use	Yes vs. no	Taken regularly or taken in combination with another medication vs. not taken. Definitions for regular included: once per week over thirty days, once per week during most weeks over three months.
Prior injury	Yes vs. no	One or more injuries prior to the study period vs. none.
Health problems	Yes vs. no	Self-reported or diagnosed by a physician including musculoskeletal conditions, heart disease, high blood pressure, diabetes, and chronic respiratory conditions such as bronchitis and asthma.
Stress or depression	Yes vs. no	Self-reported or identified using validated instruments such as Center for Epidemiologic Studies Depression Scale.
Hearing loss	Yes vs. no	Self-reported or diagnosed difficulty in hearing, deafness or use of a hearing aid in one or both ears.

2.3.2 Identification of studies

We searched *PubMed* and *Google Scholar* databases to identify studies. The first author (RJ) completed the searches and identified studies while the last author (RR) provided supervision in the selection process. Multiple rounds of searches were conducted, and the final round was completed in October 2014. In *PubMed*, 441 studies were identified using keywords ‘risk factor* agricultur* injur*’ (anywhere in the paper). Using the same search input, *Google Scholar* identified 18,700 studies. After using keywords ‘agricultural injuries’ or ‘agricultural injury’ (anywhere in the title of the paper), 163 and 122 relevant studies were identified, respectively.

After scanning the titles and abstracts, and removing duplicates, 132 *(PubMed)* and 78 *(Google Scholar)* studies were found that focused on injury outcomes. Others were excluded because they focused on agricultural diseases, road safety, farm practices, safety education, tractor roll-over protection, interventions, pesticides, farm animals, farm ergonomics, and farm vehicle/equipment accidents. Data elements needed in quality assessment and meta-analysis were extracted from the identified studies and entered into a database.

In the next step, studies were examined to find adjusted odds ratio (OR) or relative risk (RR) estimates for at least one of the selected risk factors. A total of 32 of the *PubMed* studies reported such estimates. The rest were excluded because they were narrative reviews, interventions, non-agricultural studies, studies of injury to children and youth, studies of causes or characteristics of injury, or studies that did not report adjusted OR or RR estimates. A similar process was repeated for the *Google Scholar* studies. Nine eligible studies were found, but all of them were already included in those found from *PubMed*.

As the final step, references cited in the selected studies were checked to identify additional studies but no further eligible studies were found for the review. The steps for selection of studies are illustrated in Figure 2.1.

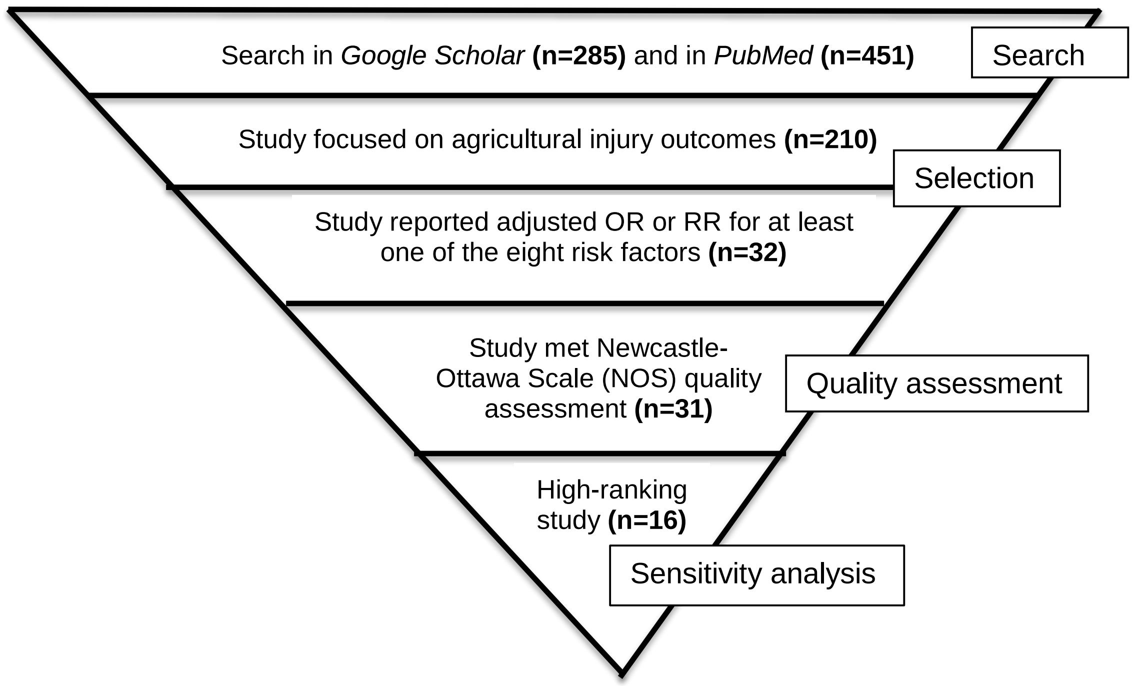

Figure 2.1 Schematic for identifying studies for systematic review and meta-analysis with measures taken during each stage (Part I).

2.3.3 Quality assessment

The quality of the 32 selected studies was assessed by employing the Newcastle-Ottawa Scale (NOS) checklist, which is designed for assessing the quality of evidence of non-randomized studies (61, 62). The NOS considers selection of study participants, comparability of study groups, and the ascertainment of exposure and outcome data, and it generates a score for study quality (62). We used commonly applied cut-off scores (63, 64) for eligibility; score of 6 out of 9 for case-control, 6 out of

10 for cross-sectional, and 5 out of 9 for cohort studies. One of the 32 selected studies did not pass NOS quality criteria, leaving 31 studies to be included in the meta-analysis.

2.3.4 Sensitivity analysis

Of the 31 included studies, 16 scored at least one point higher than the set cut-off points. These were termed as ‘high-ranking’ studies and the rest were ‘low-ranking.’ Among the 16 high-ranking studies, 14 were cross-sectional, one was case-control, and one was a cohort study. We conducted sensitivity analysis of the pooled OR for each of the eight risk factors to examine the stability of the measured associations. These sensitivity analysis were conducted by calculating the pooled ORs (see data analysis) and confidence intervals (CI), first with, and then without low-ranking studies. For risk factors where all studies were either high-ranking or low-ranking, pooled estimates were calculated with and without studies that reported point estimates with statistically non-significant confidence limits ($p>0.05$).

2.3.5 Data analysis

The systematic review included studies with adjusted OR or RR estimates. For simplicity, all RR estimates were converted into approximate OR estimates using the following formula:

OR = (1-Po) x RR / (1- Po x RR) where Po is the incidence of agricultural injury in the non-exposed individuals (without the risk factor) (65).

Po varies in workers without risk factors from study to study. It also varies within a study depending on comparison populations used to assess a specific risk factor. It is not possible to construct the exact Po for each conversion from research reports. Hence, we set Po at 0.05 or 5 injuries per 100 workers for all conversions, which is a fairly representative injury rate across agricultural injury studies and statistics. Point estimates were converted for studies that used opposite referent groups by using the reciprocal of the point estimate and confidence limits. In studies where authors reported point estimates for more than two levels of the risk factor, the categories were dichotomized, and then compared in case and control or comparison groups separately. For instance, in one study the authors reported ORs for three categories of regular medication use (medication not taken regularly, medication taken alone, taken in combination) (66). In this case, the two categories ‘medication taken alone’ and ‘medication taken in combination’ were combined, and compared against the category ‘medication not taken regularly.’ The meta-analysis was conducted using the Comprehensive Meta-analysis Software (CMA) program (67). Pooled ORs and 95% confidence intervals (CI) were calculated using the inverse variance method for each of the eight risk factors. We utilized both fixed and random effects for the meta-analysis depending on the anticipated heterogeneity among the studies. The studies were also balanced by weighting using the CMA software. Weighting is vital for obtaining an unbiased estimated pooled OR. Variances within-studies (V_r) and/or between-studies (T^2) were used to obtain the weight of a study (W_i). For the fixed effects model, the weight of a study was calculated by taking the inverse of variance within studies/between studies.

$W_i = \frac{1}{V_r}$; Where W_i = weight of a study and V_r = variance within-studies.

For the random effects model, the weight was calculated by adding variance within-studies to variance between-studies.

$W_i = V_r + T^2$; Where W_i = weight of a study and T^2 = variance between-studies.

The pooled OR was calculated by dividing the summation of the product of the weights of the studies and the natural log of given odds ratios by summation of the weights of the studies. The results were considered statistically significant at $p \le 0.05$ level.

$M = \frac{\sum_{i=1}^{k} W_i Y_i}{\sum_{i=1}^{k} W_i}$; Where M = pooled odds ratio, W_i = weight of the i^{th} study, and Y_i = natural log of the odds ratio of the i^{th} study (67).

2.4 RESULTS

2.4.1 Characteristics of studies included in the systematic review and meta-analysis

2.4.1.1 Location and sample size: The majority of the selected studies (n=20) represented agricultural populations in the United States. Others (n=11) represented populations from Australia, China, Poland, Finland, and Canada. The sample sizes varied from 113 in the smallest to 274,797 in the largest study. Eleven studies had less than 1000 participants, twelve had 1,000 – 3,999 participants, and seven had 4,000 – 99,000 participants. The study details (study, location, design, sample size, target population, injury type, significant risk factors found, and confounders adjusted in multivariable model) for the included studies is available in the Appendix.

2.4.1.2 Population: The proportion of participants drawn from the source populations varied with the sampling scheme used. In four studies, the researchers used records of all participants in their defined population. Insurance records were used in two of these studies. In other studies, samples were derived from their corresponding populations by employing random or non-random sampling. Agricultural census records were used to identify participants in the majority of the studies (n=12) that used random sampling. Among studies where random sampling was not used, six studies used stratified sampling (equal probability or systematic), two studies used hospital records, and three studies had insufficient information on the sampling strategy. The populations were engaged in agricultural production work, similar to what is described in the North

American Industrial Classification System; codes 111 (Crop production) and 112 (Animal production), including subcategories under these codes (68). The participants were defined as principal owners/operators, regular or seasonal workers, full-time farmers, part-time farmers, male farmers, female farmers, farmers who were young, middle and older age, and farmers who had their principal source of income from farming. The vast majority of participants were white in all but two studies. Studies of children and youth were excluded as their injuries and preventive strategies differ in many respects from working adults.

2.4.1.3 Injury outcome: Self-reporting was used for data collection in most studies. The injury outcome was mostly assessed by asking farmers if they had an injury (or injuries) in the past 12 months. Further definitions included ‘injury that required medical care (other than first aid) and/or lost work for half a day or more’. In two studies, administrative insurance records were used. In two studies (8, 57), the severity of the injury was assessed by the Injury Severity Scale (ISS), which scores the outcome by medical characteristics of the injury. One study presented risk factors separately for serious and non-serious injuries, based on the amount of compensation in insurance claims (serious = €2,000 and more) (37). Most studies provided information on injury characteristics. Common sources/causes included machinery, animals, and falls. Injury locations included fields and animal facilities. Work tasks included transport of agricultural goods, operation and repair of machinery, mounting and dismounting of tractors, tractor overturns, fieldwork, and animal-related tasks such as feeding, milking, herding, moving and riding animals.

2.4.2 Estimated effect of risk factors on agricultural injury

Pooled risk estimates were calculated in eight separate meta-analyses for the selected eight risk factors using adjusted point estimates in the source studies. Different studies adjusted for a different set of confounders. The most common confounders included in the multivariable models were age (n=17), education (n=15), gender (n=13), work hours (n=12), marital status (n=9), health and safety-related factors (n=18), and farm-related factors (n=18). The results for the eight risk factors are illustrated in Table 2.2. The short descriptions are as following.

2.4.2.1 Male gender: We used OR estimates from ten studies where point estimates of injury for males (vs. females) were reported. The probability of injury was higher in males in nine studies and nearly equal in one study. The RR estimates from four studies were approximated to OR estimates. The pooled OR estimate for male gender was 1.68 (95% CI: 1.63 – 1.73).

2.4.2.2 Full-time farming: There were seven studies with point estimates of injury for full-time farming (vs. part-time). The RR estimates from two studies were approximated to OR estimates. We used the random effects model to obtain the result of the meta-analysis. In six studies, the probability of injury in full-time farmers (vs. part-time) was higher, and in one study it was lower. The pooled OR estimate for full-time farming was 2.17 (95% CI: 1.12 – 4.21).

2.4.2.3 Farm owner/operator status: In five studies, the OR estimates of injury were reported for owners/operators vs. family members or hired workers working on the farm. In four studies, the probability of injury was higher in owners/operators while in one study, a protective effect was reported. The pooled OR estimate for owner/operator status was 1.64 (95% CI: 1.13 – 2.38).

2.4.2.4 Regular medication use: We used four studies where OR estimates of injury for regular medication use (vs. no regular medication use) was reported. In four studies, the authors reported a higher probability of injury to farmers who used medication regularly. The pooled OR estimate for regular medication use was 1.57 (95% CI: 1.23 – 2.00).

2.4.2.5 History of prior injury: In six studies, point estimates for history of prior injury (vs. no prior injury) were reported. Two studies had RR estimates that were approximated to OR estimates. In five studies, the probability of injury was higher in farmers who had a past injury while in one study the results were opposite. The pooled OR estimate for a history of prior injury was 1.75 (95% CI: 1.58 – 1.94).

2.4.3.6 Health problems: Five studies with OR estimates of injury for farmers with health problems (vs. without) were used for the meta-analysis. In three studies, the authors reported an increased risk of injury from health problems. In two studies, they reported that having health problems was protective. The pooled OR estimate for health problems was 1.21 (95% CI: 0.96 – 1.53). The difference was not significant (p=0.09).

2.4.3.7 Stress/depression: OR estimates of injury for farmers who reported depression symptoms or increased stress level (vs. those who did not) were reported in seven studies. The RR estimates from two studies were approximated to OR estimates. In seven studies, individuals who had symptoms of depression or had a high stress level had a higher probability of injury. The pooled OR estimate for stress/depression was 1.86 (95% CI: 1.60 – 2.16).

2.4.3.8 Hearing loss: In seven studies, OR estimates of injury were reported in farmers who suffered from hearing loss or wore hearing aid devices compared to farmers who did not have conditions pertaining to hearing. In seven studies, the probability of injury was higher in individuals with hearing impairment or those that used hearing aid devices. The pooled OR for hearing loss was 2.01 (95% CI: 1.57 – 2.57).

Table 2.2 Results of the meta-analyses for selected risk factors (Part I).

Risk factor (papers)	Studies	OR (95% CI)	Pooled OR (95% CI)
Male gender (vs. female) (n=10)	Erkal et al., 2008	1.90 (1.64 – 2.20)	1.68 (1.63 – 1.73)
	Nogalski et al., 2007	1.27 (1.06 – 1.51)	
	Rautiainen et al., 2009	1.77 (1.65 – 1.88)	
	Erkal et al., 2009	1.10 (0.70 – 1.60)	
	Tiesman et al., 2006	1.34 (1.10 – 1.63)	
	Karttunen & Rautiainen, 2013	1.75 (1.68 – 1.82)	
	Moshiro et al., 2005	1.75 (1.46 – 2.12)	
	Maltais, 2007	1.44 (1.33 – 1.56)	
	Gerberich et al., 1998	4.44 (1.89 – 12.45)	
	Taattola et al., 2012	1.43 (1.00 – 2.12)	
Full time farming (vs. part time) (n=7)	Carruth et al., 2002	3.10 (1.52 – 6.30)	2.17 (1.12 – 4.21)
	Pickett et al., 1996	1.68 (0.95 – 2.96)	
	Sprince et al., 2002	2.02 (1.38 – 2.94)	
	Zhou & Roseman, 1994	5.25 (1.24 – 22.18)	
	Lee et al., 1996	6.56 (3.60 – 11.94)	
	Crawford et al., 1998	2.01 (1.00 – 4.05)	
	McGwin et al., 2000	0.48 (0.38 – 0.79)	
Owner/operator (vs. family member/hired worker/other) (n=5)	Broucke & Colemont., 2011	1.96 (0.14 – 27.73)	1.64 (1.13 – 2.38)
	Zhou and Roseman, 1994	3.36 (1.00 – 11.34)	
	Pickett et al., 1996	0.58 (0.28 – 3.33)	
	Xiang et al., 1999	1.63 (0.61 – 4.35)	
	Hwang et al., 2001	1.60 (1.03 – 2.50)	
Regular medication use (vs. no regular medication) (n=4)	Pickett et al., 1996	1.51 (0.81 – 2.80)	1.57 (1.23 – 2.00)
	Xiang et al., 1999[b]	3.02 (1.05 – 8.64)	
	Sprince et al., 2003[b]	1.80 (1.01 – 3.17)	
	Sprince et al., 2003	1.44 (1.04 – 1.96)	
History of prior injury (vs. no prior injury) (n=6)	Zhou and Roseman, 1994	3.71 (1.83 – 7.52)	1.75 (1.58 – 1.94)
	Erkal et al., 2009	3.80 (2.36 – 6.20)	
	Day et al., 2009	0.54 (0.33 – 0.91)	
	Erkal et al., 2008	3.20 (2.61 – 3.91)	
	McGwin et al., 2000	1.54 (1.00 – 2.22)	

	Tiesman et al., 2006	1.36 (1.19 – 1.56)	
Having health problems (vs. no health problems) (n=5)	Sprince et al., 2003 (Arthritis)[c]	3.00 (1.71 – 5.24)	1.21 (0.96 – 1.53)[a]
	Day et al., 2009 (Chronic medical condition)[c]	0.65 (0.45 – 0.92)	
	Xiang et al., 1999 (High BP)[b, c]	0.20 (0.06 – 0.69)	
	Xiang et al., 1999 (Heart disease)[b, c]	0.47 (0.15 – 1.49)	
	Hwang et al., 2001 (Arthritis)[c]	2.56 (1.52 – 4.32)	
	Carruth et al., 2002 (Back pain)[c]	2.05 (1.11– 3.80)	
Having stress/depression (vs. no stress/depression) (n=8)	Xiang et al., 1999	4.91 (1.93 – 12.6)	
	Park et al., 2001	3.22 (1.04 – 9.99)	1.86 (1.60 – 2.16)
	Simpson et al., 2004	1.27 (0.93 – 1.71)	
	Thu et al., 1997	1.70 (1.17 – 2.34)	
	Tiesman et al., 2006	1.44 (1.10 – 1.87)	
	Taattola et al., 2012	2.06 (1.41 – 3.00)	
	Xiang et al., 2000	6.28 (4.05 – 9.75)	
	Crawford et al., 1998	1.90 (0.82 – 4.40)	2.01 (1.57 – 2.57)
Having hearing loss (vs. no hearing loss) (n=6)	Xiang et al., 1999[b]	1.88 (0.67 – 5.26)	
	Hwang et al., 2001	1.86 (1.22 – 2.83)	
	Sprince et al., 2007	1.98 (1.02 – 3.80)	
	Sprince et al., 2002	4.37 (1.55 – 12.25)	
	Sprince et al., 2003	2.36 (1.07 – 5.20)	
	Sprince et al., 2003[b]	1.82 (1.07 – 3.08)	

a. Pooled estimate not significant ($p>0.05$).
b. Different study with same first author and year of publication.
c. Specific health condition addressed.

2.4.3 Sensitivity analysis of measured associations

As illustrated in Table 2.3, all measured associations remained relatively stable after the implementation of the sensitivity analysis. The change in the strength of associations (OR) was minimal, i.e. within the range of 0.01 – 0.52. There was no change in the direction of the association in all but one case; for health problems, the pooled OR estimate changed from 1.21 to 0.86, but both pooled estimates were statistically insignificant.

Table 2.3 Sensitivity analysis results; pooled risk factor estimates for agricultural injury calculated from all studies and high-ranking studies (Part I).

Risk factor	Pooled OR, all studies (95% CI)	P-value*	Pooled OR (95% CI) high-ranking studies	P-value*
Male gender (vs. female)	1.68 (1.63 – 1.73)	0.00	1.67 (1.62 – 1.72)	0.00
Full time farming (vs. part time)	2.17 (1.12 – 4.21)	0.02	2.69 (1.68 – 4.31)	0.00
Owner/operators (vs. others/family members)	1.64 (1.13 – 2.38)	0.00	2.15 (1.03 – 4.48)	0.04
Regular medication use (vs. no regular medication)	1.57 (1.23 – 2.00)	0.00	1.58 (1.21 – 2.06)[a]	0.00
History of prior injury (vs. no prior injury)	1.75 (1.58 – 1.94)	0.00	1.42 (1.25 – 1.60)	0.00
Having health problems (vs. no health problems)	1.21 (0.96 – 1.53)	0.09	0.86 (0.63 – 1.17)	0.34
Having stress/depression (vs. no stress/depression)	1.86 (1.60 – 2.16)	0.00	1.87 (1.59 – 2.20)	0.00
Having hearing loss (vs. no hearing loss)	2.01 (1.57 – 2.57)	0.00	2.03 (1.55 – 2.65)[a]	0.00

*- P-value of 0.00 reflected very small, undetermined value, a- Only low-ranking studies were available for the meta-analysis. Pooled estimate was calculated without studies that had a non-significant confidence interval for this risk factor (p>0.05).

2.5 DISCUSSION

2.5.1 Reported reasons for risk differences

This study presents findings for commonly reported risk factors for agricultural injury based on the evidence from all studies identified in a systematic review of the literature. To our knowledge, no similar review studies have been conducted to date. Seven of the eight evaluated risk factors were associated with an increased risk of injury, pooled odds ratios ranging from 1.57 to 2.17. Based on the p-value of the pooled OR estimates, full-time farming is significant ($p<0.05$), and history of prior injury, male gender, hearing loss, regular medication use, stress/depression, and farm owner/operator status are very significant ($p<0.01$) risk factors for injury. These risk factors can be used for targeting interventions. While information on populations with elevated risk is important in itself, understanding reasons behind the elevated risk may point to specific interventions for the target populations at risk. Some explanations were offered in the source studies and they are discussed briefly in the following for each of the identified risk factors.

2.5.1.1 Male gender: Males have a higher risk of agricultural injury compared to females. Rather than gender itself, the difference may be based on the division of work tasks between the genders. This is reflected in findings where males have a higher risk of injury from machinery while females have a higher risk of animal-related injuries (69). In contrast, Erkal et al. (25, 26) found a higher risk of animal-related injuries in males, but the difference was reduced after controlling for working hours in associated tasks. Also contrary to common findings, males had a lower risk of injury than females in crop production work after controlling for task-based exposure (59). Further, in a Tanzanian study, the risk of transportation-related injuries was 1.75 times greater in males but transportation-related work was also more frequent in males (11). One study reported a higher risk of hospital admissions due to farm injury in males regardless of the amount of hours spent on farm work (8). The differences in the duration and ways by which men and women are exposed during agricultural activities are not well-known. Although such data are difficult to obtain, future research should explore task-based working hours and differences in work exposures and injuries by gender. Overall, our results showed that male farmers had 1.68 times greater odds of agricultural injury compared to female farmers.

2.5.1.2 Full-time farming: The risk of injury increases with the amount of hours spent in farm-related tasks such as machinery, animal handling, and transportation (20, 21). Machinery-related injuries largely occur during busy spring planting and fall harvesting seasons (21). Carruth et al. (56) showed that women who worked full-time had three times greater risk of injury than women who worked part-time on the farm. However, in two studies, part-time farmers had a higher risk compared to full-time farmers. This could be due to part-time farmers with off-farm employment being tired when performing farm-related tasks during evenings and weekends (70). Further, Mongin et al. (71) suggested that full-time farmers may avoid injuries based on their greater experience in farm work. In some cases, full-time farmers may also have hired workers to perform hazardous tasks (70). However, in summary, working full-time on the farm was a risk factor increasing the odds of injury by 2.17 times compared to working part-time.

2.5.1.3 Farm owner/operator status: Social and economic pressures to enhance productivity can make farm owners/operators perform dangerous tasks and put themselves at risk in spite of their knowledge of safety (16). Hwang et al. (14) suggested a similar effect from psychological stress, social pressure, and financial constraints, which can increase work exposure time and risk of injuries. The responsibility that comes with owning the farm, making it more productive, and passing it to the next generation may make owners/operators perform more demanding and risky tasks in comparison to family members and hired workers (14). Van De Broucke and Colemont (72) also reported a higher risk of injury in owners/operators compared to other workers. However, when stratified by tasks, the differences in safety behavior scores (Likert 1 – 5 scale) became insignificant reflecting different risk levels in different tasks. Overall, the odds of injury were 1.64 times higher in owners/operators compared to non-owners/operators.

2.5.1.4 Regular medication use: Certain common medications such as narcotic analgesics, tranquilizers, sleeping pills, and antidepressant drugs can sedate the central nervous system. This can cause changes in farmers' behavior, which may result in an increased risk of injury. Side effects of medication can affect the alertness and compromise judgment, which is required to perform complex farm-related tasks (66). The lack of alertness may lead to failure in maintaining an upright posture, which can result in fall-related injuries (31). The likelihood of regular medication use for adverse health conditions increases with age (66). Xiang et al. (43) reported increased odds of injury from medication use in older (60 years and older) farmers. Overall, regular use of medication is a risk factor for injury, and farmers who used medications regularly had 1.57 times higher odds of injury compared those who did not use medication regularly.

2.5.1.5 History of prior injury: Zhou and Roseman (16) reported a three-fold risk of injury in farmers who had residual injury (history of injury in a lifetime prior to the reporting period). Erkal et al. (25, 26) reported similar findings for the risk of animal-related injury. McGwin et al. (70) suggested that the residual health effects of prior injuries can contribute to the occurrence of subsequent injuries. In addition, farmers with prior injury may work in more hazardous environments, take more risks, and be less conscious of safety (70). A possible synergistic effect from history of prior injury and regular medication use for depression was also reported. In contrast, Day et al. (57)

reported a protective effect of prior injury.They suggested that farmers who had serious injury in the past may be more proactive in developing safety measures compared to farmers with no history of serious injury.Overall, the result of the meta-analysis shows that farmers with history of prior injury have 1.75 times higher odds of injury in comparison to farmers with no prior injury.

2.5.1.6 Health problems: According to Hwang et al (14)., the risk of injury was higher in farmers who had joint trouble of the shoulder, wrist, knee or spine at the lower back. Sprince et al. (27) reported increased odds of injury from animals for farmers who had arthritis. They explained that arthritis limits the movements of upper and lower extremities and this situation can result in diminished ability to control large animals, resulting in loss of ability to maintain proper balance on the ground, which may lead to fall-related injury (31). Marcum et al. (59) reported increased odds of injury in farmers with bronchitis and emphysema. These chronic respiratory conditions can affect breathing, and that can result in increased fatigue which may contribute to the risk of injury at work (59). In contrast, Day et al. (57) reported reduced odds of injury in farmers with back pain and chronic medical conditions. Also, Xiang et al. (43) reported lower odds of injury in older farmers with high blood pressure. It is possible that farmers who had chronic medical conditions such as high blood pressure or a chronic respiratory condition may restrict their tasks and exposures to farm-related activities (57). The risk of injury can vary with the health problems experienced. Future studies should look at different health problems separately. In summary, the result of the meta-analysis showed that farmers with health problems had 1.21 times higher probability of injury compared to farmers without health problems, but this difference was not statistically significant.

2.5.1.7 Stress or depression: Depression and the side effects of depression medication can cause inattention and cognitive changes, which can put farmers at a risk of injury (33). Xiang et al. (73) reported four times greater risk of injury in women with depression compared to women without depression. Work overload as well as under load can cause depression symptoms. Work overload commonly occurs when the help is limited during busy times of the year. Work underload occurs when performing repetitive tasks while working in solitude. Low decision latitudes (limited decision-making) during overload situations can lead to increased mental strain (74). Thu et al. (75) concluded that the risk of injury was higher in farmers who reported having high level of stress (vs. no high level of stress). From most studies, it is not possible to determine to what extent stress and depression are risk factors for injury or consequences of injury. Prospective studies can help explain the temporality of depression/stress and injury. Tiesman et al. (35) and Park et al. (33) showed prospectively that depression is a risk factor for injury, and that injury can also be followed by depression or stress. The overall result of the meta-analysis showed that farmers with stress or depression had 1.86 times higher probability of injury than farmers who did not experience depression or stress.

2.5.1.8 Hearing loss: The diminishing hearing capability can make farmers insensitive to warning signals from machinery, animals, and other exposures. One might think that hearing aid devices may overcome poor hearing. However, Sprince et al. (76) reported increased odds of injury in farmers who had difficulty in hearing even when they wore hearing aid devices. According to Choi et al (77)., hearing aid devices alter the hearing sensation and using an inadequate device may not improve hearing adequately. They also showed that hearing loss and hearing asymmetry were significantly associated with farm injury. The farm environment usually has many noise sources such as machinery, equipment, and animals. Working in such an environment with compromised hearing can contribute to the risk of injury (77). Overall, our results showed that the odds of injury increased two-fold in farmers who had hearing loss or who wore hearing aid devices compared to farmers with normal hearing.

2.5.2 Strengths

A growing number of studies have reported on risk factors for agricultural injury. In many cases, these studies show similar results, but some results are inconsistent or contradictory. Systematic review brings together all available studies and quantifies the evidence from all studies in meta-analysis. In the agricultural safety and health field, systematic reviews have been done to evaluate the effectiveness of interventions to reduce injury (45, 46, 60, 78). Other reviews have provided descriptive information on agricultural injury rates, characteristics, sources, risk factors, and vulnerable populations (18, 79-81). To our knowledge, no systematic reviews have been done to evaluate risk factors for agricultural injury. With the relatively large number of existing studies, this review is timely, and has the capability to produce relatively stable estimates based on multiple studies.

The reviewed studies represented diverse geographic locations, study designs, sampling schemes, and methods of data collection. The majority (19) was cross-sectional, although prospective cohort (4) and case-control studies (8) were also included. The studies used various data sources such as mail surveys, interviews, and insurance records.

Several methods can be used for assessing the quality of research studies including Critical Appraisal Skills Program (82), Strobe (83), and the Downs and Black Checklist (84). The NOS (62) was used in this review. It is suitable for quality assessment of non-randomized studies, and it produces a score that can be used for study selection. None of the studies received a full score on NOS. All studies failed to explain the characteristics of non-respondents. Many studies interviewed non-respondents and enrolled them into the study as respondents. All selected studies used multivariate modeling for adjustment of confounders, which were selected from the univariate analyses in most cases. Overall, all but one of the selected studies met the pre-determined quality score, and were used to estimate risk factors.

Sensitivity analysis showed that the estimates of injury risk factors were relatively stable when considering all 31 studies, or just the 16 high-ranking studies. For example, the pooled OR estimate for prior injury (vs. no prior injury) reduced by 0.33 (from 1.75 to 1.42) after two low-ranking studies were removed. The sensitivity analysis confirmed that all 31 studies can be used for calculating the final risk estimates.

2.5.3 Limitations

The study had several limitations. The strengths and limitations of systematic reviews have been discussed in numerous textbooks and studies. The limitations include reliance on the quality of source studies. Measures are taken in the systematic review process to select high quality studies and reducing biases. However, publication bias in particular is difficult to overcome. Studies with negative or non-significant findings are more difficult to publish than studies with positive findings (85). This applies to intervention studies, but could affect risk factor studies as well.

Although some studies used secondary data such as hospital or insurance records, many studies used self-reporting. This can introduce a recall bias. For instance, Mongin et al. (71) suggested that farmers who had injuries in the past may remember their injuries better than those without injuries in the past. Further, participants with severe injury may remember the exposures better than those with non-severe injury. In some instances, participants may not be able to interpret the survey questions, which can result in information bias. The studies selected for this systematic review employed measures to control recall and information bias, such as using insurance data, structured questionnaires, and computer-assisted interviews for data collection. Therefore, the recall and information bias may not have a large effect on our results.

None of the studies had similar response rates in case and control/comparison groups, or they failed to provide sufficient information on responses in each group. The differential response rate between case and control/comparison groups may have introduced a selection bias. Non-differential responses among cases and controls can lead to over or underestimation of the association between the exposure and the outcome. However, studies used a range of data sources such as random or stratified sampling, regional government survey records, sampling of all individuals from a defined population, or using total population-based administrative (insurance) records. These measures may have reduced the effects of selection bias.

None of the studies provided estimates for interaction effects between risk factor variables, which can distort results. For example, without controlling for tasks, the risk of injury was higher in males, but after controlling for tasks, the effect of gender greatly diminished (59). Controlling for tasks is therefore important, but calculating interaction terms for task and gender could reveal further information on specific tasks that are particularly hazardous for one gender of the other. Future research should explore interactions among covariates for agricultural injury.

We approximated RR estimates to OR prior to conducting the meta-analysis. Also, for some studies, the point estimates for risk factor were constructed from the original data where we dichotomized multiple categories, or reversed the referent group. Although these modified estimates provide only approximations of the point estimates, we believe that the summary measures were not significantly affected by these processes. These measures enabled combining the studies (cohort, case-control, and cross-sectional) in meta-analysis, which increased the overall stability and precision of the pooled estimates.

CHAPTER 3: SYSTEMATIC REVIEW AND META-ANALYSIS OF RISK FACTORS FOR AGRICULTURAL INJURY- PART II

3.1 ABSTRACT

Introduction- Agricultural injury is a significant public health problem globally. Extensive research has addressed this problem, and a growing number of risk factors has been reported. Our objective was to identify reported risk factors for agricultural injury and calculate pooled estimates for factors that were assessed in two or more studies. Methods- A total of 441 (Pubmed) and 285 (Google Scholar) studies were identified focusing on occupational injuries in agriculture. From these, 39 studies reported point estimates of risk factors for injury; 38 of them passed the Newcastle-Ottawa criteria for quality, and were selected for the systematic review and meta-analysis. Results- Several risk factors were significantly associated with injury in the meta-analysis. These included older age (vs. younger), education up to high school or higher (vs. lower), non-Caucasian race (vs. Caucasian), Finnish language (vs. Swedish), residence on-farm (vs. off-farm), sleeping less than 7 – 7.5 hours (vs. more), high perceived injury risk (vs. low), challenging social conditions (vs. normal), greater farm size (vs. smaller), animal production (vs. other production), higher sales (vs. lower), greater income (vs. less), greater number of workers employed on farm (vs. less), unsafe practices conducted (vs. not), computer use for farm management (vs. not), accidental exposure to pesticides and/or chemicals to the skin (vs. not), high cooperation between farms (vs. not), and machinery condition fair/poor (vs. excellent/good). Conclusion- Several risk factors for agricultural injury have been reported repeatedly in the literature while others are emerging from a few reports. The identified risk factors should be considered when designing interventions and selecting affected populations.

3.2 INTRODUCTION

Current research has addressed many risk factors for agricultural injury. However, the results vary from study to study, and are contradictory in some cases. To enhance the success of intervention efforts for injury prevention, evidence-based evaluation of risk factors is essential to understand the risk of injury in different agricultural worker populations (7).

The risk factors for injury can be either individual-level or farm-level (59). Many individual-level or farm-level risk factors have been reported repeatedly while some risk factors have been reported only in a few reports. Individual-level risk factors can be either demographic or personal characteristics. Example of the reported individual-level factors include age, education, retirement status, race, marital status, native language, farming experience, on farm residence, off-farm employment, and primary occupation. Farm-level risk factors can be further classified into farm environment-related and safety-related risk factors. Some examples of reported environment-related factors include farm size, use of tractors of different sizes, field crops harvested, farm sales, farm income, animal production, number of hired workers, and cooperation between farms. Examples of safety and behavior-related factors include unsafe practices, maintenance of farm machinery, receipt of safety training, use of computers for farm management, accidental exposure to pesticides and/or chemicals to the skin, alcohol use, smoking, sleep quantity and quality, perceived injury risks, and social conditions. To control injuries cost-effectively, gaining a better understanding all possible risk factors is an essential step. The objective of this study was to evaluate the weight of evidence for reported demographic, environment, safety, and behavior-related risk factors from the available literature using a systematic review and meta-analysis. This comprehensive review will contribute to our evidence-based understanding of common as well as emerging risk factors for agricultural injury using a structured, systematic, independent and transparent process (44).

3.3 METHODS

We conducted a systematic review and meta-analysis of risk factors for agricultural injury. The methods used in this review were similar to our earlier report (86) in Chapter 2 with some modifications in the inclusion criteria and analysis. In this review we expanded the inclusion criteria and accepted studies with unadjusted as well as adjusted OR or RR estimates for agricultural injury. This enabled us to include both well-established and emerging risk factors. We used unadjusted estimates for meta-analysis when adjusted estimates were unavailable. In some cases, we calculated crude OR estimates using descriptive data reported in the studies. Based on our experience with the earlier review (86), we learned that different studies used very different combinations of confounders in their adjusted models. Therefore adjusted estimates may not be robust as different studies controlled for different sets of risk factors. In almost all cases, the risk factors found in adjusted models excluded hours spent in farm work, and different tasks conducted on the farm. This may lead to residual confounding effects, even when the risk factor variable was highly significant in adjusted analyses. For example, male gender is commonly found as a strong risk factor, but it may in fact merely reflect the division of work tasks and exposure durations in hazardous tasks. Typically those risk factor variables with the strongest association with injury were found in both unadjusted and adjusted models. In some cases, it is possible that, adjusting for certain variables may also eliminate important risk factor variables from adjusted models. Further, knowledge of risk factors, confounded or not, can be beneficial for selecting target audiences for interventions. Therefore, in this review, we accepted unadjusted as well as adjusted estimates to describe the association of risk factors and agricultural injury.

3.3.1 Definitions

There is no universally accepted definition of agricultural injury. The definitions vary from study to study. We included studies that used definitions relatively close to the following: an unintentional, sudden (vs. long-term exposure), forceful event with an external cause resulting in body tissue damage or unconsciousness (and possible medical care and/or lost work time), occurring to a person engaged in agricultural work activity at the time of injury. In some studies, the terms accident or incident are used instead of injury with the same meaning. The definitions for the risk factors were as follows:

Table 3.1 Definitions used for risk factors (Part II).

Risk factor	Levels	Definitions
Education	High school or more vs. less	More than high school was defined as college, technical, professional or graduate school.
Age	Various age categories	We compared injury odds in younger vs. older farmers
Marital status	Married, divorced, non-married, separated, other	We compared farm workers who were married to those with other marital statuses.
Race	Caucasian, African-American, Hispanic, other	We compared injury odds in Caucasian vs. non-Caucasian farmers.
Native language	Finnish vs. Swedish	Studies from Finland described native language as a risk factor. We compared injury odds in Finnish speaking Finnish farmers to those speaking Swedish.
On-farm residence	On-farm vs. off-farm	Farm operators or workers who live on the farm (at the residences located on the farm) were considered as on-farm residents and others as off-farm.
Off-farm work	Yes vs. no	Some farm workers work in other occupations besides farm work. Off-farm work was considered as non-agricultural work activities.
Alcohol use	High CAGE score vs. low, drinking vs. no drinking	We included studies that evaluated the use of alcohol using the score on self-reported CAGE questionnaire, and questions about the amount of alcohol consumed
Smoking	Ever-smoker or current smoker vs. non-smoker	Self-reported history of smoking was evaluated.
Sleep	Less than seven hours, seven to eight hours, and more than eight hours	Sleep was evaluated by the amount of sleep received every night.
Perceived injury risk	High vs. low	Self-reported risk was used.

Social conditions	Tensions in relationships with neighbors yes vs. no, challenging social situations yes vs. no	Social conditions were defined as challenges in social life or difficult personal situations with family or others.
Farm-related factors	Higher vs. lower land acreage, sales, income, and number of people working on farm, and type of commodities produced as livestock vs. crop, mixed or other	We compared injury odds in farmers who worked on greater land areas, earned high sales and income from farming to those who worked on smaller lands, earned less in sales and income, respectively. Comparisons were also made by the type of commodity produced, number of workers employed on farm and cooperation between farms.
Safety-related factors	Unsafe practices yes vs. no, machinery condition fair/poor vs. excellent/good, safety training attended yes vs. no, computer use for farm management yes vs. no, and accidental exposure to pesticides and/or chemicals to the skin yes vs. no	Some safety-related risk factors were evaluated. Unsafe practices were defined as failure to perform safe practices during farm-related activities, for example, no frequent seat belt use during transport of agricultural goods, failure to turn off machinery frequently, hurrying more often during work, unsafe lifting of heavy objects, and exposure to harmful acids/alkalis on the skin.

3.3.2 Identification of studies

We determined the following criteria for a study to be eligible for the systematic review:

1) The study must focus on agricultural outcomes and report one of the indices of injury occurrences such as incidence rate, prevalence rate, cumulative incidence, or annual incidence—calculated using defined denominator populations.

AND

2) The study must report adjusted or unadjusted point estimates such as odds ratios, risk ratios, relative risks, rate ratios, hazard ratios, incidence risk ratios, and prevalence ratios.

We searched studies in *PubMed* and *Google Scholar* databases, published up to 2014. We identified 441 studies in *PubMed* and 285 studies in *Google Scholar* using the search process described in Chapter 2.

We then scanned titles and abstracts, removed duplicates, and shortlisted 210 studies that met our first eligibility criterion. Others were excluded because they focused on one of the following: agricultural diseases, non-occupational injuries, road safety, farm practices, safety education to farmers, tractor roll-over protection, interventions, pesticide use and its effect on farmer's health, farm animals, ergonomic issues in farm workers, and farm-vehicle/equipment accidents.

After evaluating the 210 studies, we identified 37 studies that met our second eligibility criterion. We excluded the remaining studies because they provided narrative reviews, reviews of interventions, covered non-agricultural activities, focused on causes or characteristics of injury, described risk factors already evaluated in Chapter 2, or did not report adjusted or unadjusted point estimates for risk factors. After checking references of the 37 identified studies, we added two more studies that met our eligibility criteria resulting in the inclusion of a total of 39 studies for the systematic review and meta-analysis. The included studies reported point estimates of injury for one or more risk factors. A total of 25 risk factors were described in the studies. The individual steps for selection of studies are illustrated in Figure 3.1.

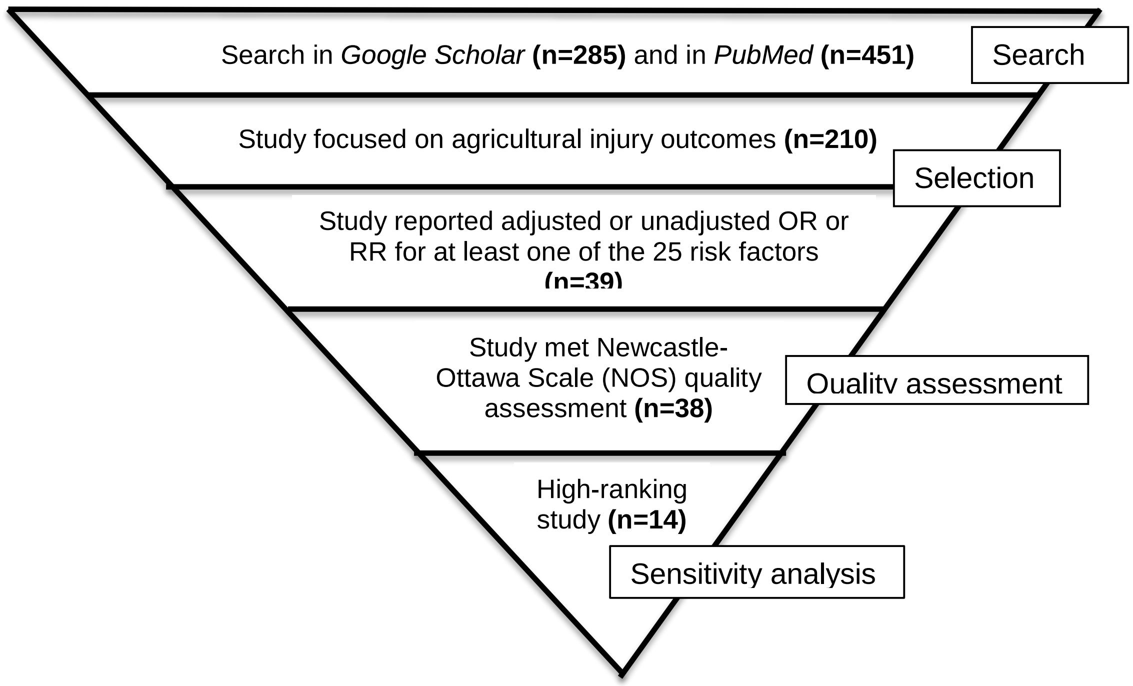

Figure 3.1 Schematic for identifying studies for systematic review and meta-analysis with measures taken during each stage (Part II).

3.3.3 Quality assessment

We evaluated the quality of the 39 selected studies using the NOS checklist. We used commonly used cut-offs (63, 64); the scores of 6 out of 9 for case-control, 6 out of 10 for cross-sectional, and 5 out of 9 for cohort studies. One study from the total of 39 studies failed the quality assessment resulting in the inclusion of 38 studies for the systematic review and meta-analysis. We calculated pooled estimates in the meta-analysis for the 21 risk factors from these 38 studies. Point estimates for three risk factors were reported in single studies. Estimates for age were evaluated differently (explained elsewhere).

3.3.4 Sensitivity analysis

To determine the stability of measured associations of each of the 21 risk factors to injury outcomes, we performed sensitivity analysis of the measured associations. For this task, we ranked all 38 studies based on their scores on the NOS (described in Chapter 2). Studies that scored at least one point higher than the cut-offs (7/9, 7/10 and 6/9 or higher) were considered as 'high-ranking,' and the rest as 'low-ranking.' We determined that 14 of the total of 38 studies were high-ranking. Among these 14 studies, four were case-control, four were cohort, and six were cross-sectional studies. We then excluded the low ranking studies and repeated the meta-analysis for all risk factors. For risk factors with either all high-ranking or all low-ranking studies, studies with statistically non-significance ($p > 0.05$) CI were dropped. The difference in the pooled estimate from the two rounds of meta-analysis (meta-analysis with, and then without studies with low-rank/ non-significant CI) reflected the strength of association. The pooled estimates with the high risk difference in sensitivity analysis were considered less stable than the others.

3.3.5 Data analysis

The 38 identified studies reported adjusted or unadjusted point estimates for at least one of the 25 risk factors. Age categories differed with different intervals, referent groups, and numbers of levels in different source studies. Therefore, we conducted the evaluation of age differently from the other 24 risk factors. To facilitate harmonization of differences in age categories, we assigned the reported point estimates for each age category to the mid-point of the interval of each age category. For example, for the age category 50 – 60 years, OR of 2.16 was reported in one of the selected studies (87). We assumed that this OR was associated with the mid-point of the category—55 years. This measure has been applied successfully, previously (88). All non-OR point estimates were converted into ORs (explained in Chapter 2). We plotted age category midpoints on the X axis and corresponding ORs on the Y axis in a scatter plot. Each reported OR was weighted by the corresponding study size. We quantified the correlation between age and injury risk using Pearson's r-square. Statistical significance was considered at $p \leq 0.05$. The trend of the correlation was visualized by drawing a regression line in the scatter plot using Statistical Analysis System (SAS) (89).

The evaluation of the other 21 risk factors was conducted as follows: prior to the initiation of meta-analysis, all non-OR estimates for the 21 risk factors from the studies were converted into OR using the method of conversion described in Chapter 2. Required adjustments to the point estimates for some risk factors were made prior to conducting meta-analysis. The adjustments included inversion of the reference group for studies with opposite reference groups, and dichotomization of categories for studies that reported point estimates for more than two levels of the risk factor.

We used CMA program (67) for meta-analysis. All ORs were entered in the software program and pooled OR and pooled CI were generated using the inverse variance method for each of the 21 risk factors. The meta-analysis process is described in detail in Chapter 2.

3.4 RESULTS

3.4.1 Characteristics of studies included in the systematic review and meta-analysis

3.4.1.1 Location and sample size: The selected studies represented agricultural populations from the United States (n=27) as well was from other countries (n=11) including Australia, Belgium, Canada, China, and Finland. The sample size of the studies ranged from 113 to 274,797. Many studies selected samples of less than 1,000 participants (n=17), some selected 1,000 – 3,999 (n=12), and others (n=9) selected 4,000 – 99,000 participants. The study details (study, location, design, sample size, target population, injury type, significant risk factors found, and confounders adjusted in multivariable model) for the included studies is available in the Appendix.

3.4.1.2 Population: The identified studies used different populations drawn from national census (n=1), insurance records (n=3), hospital records (n=1), and used different data collection methods including random sampling (n=22), stratified sampling (n=8), and other measures (n=3). The populations were engaged in agricultural production work that is classified as codes 111 (Crop production) and 112 (Animal production) in the North American Industrial Classification System, and subcategories under these codes (68). The subpopulations included principal owners/operators, regular or seasonal workers, migrant workers, farm residents, farm non-residents, full-time farmers, part-time farmers, male farmers, female farmers, farmers with young, middle and older ages, farmers who had farming as their only income source, and farmers who worked off-farm. Most participants were Caucasian. We included studies that were primarily focused on adults. Children and youth were not included because their injury characteristics, sources, and preventive strategies differ from those in adults.

3.4.1.3 Injury outcome: The vast majority of studies used self-reporting as a measure of data collection where the injury outcome was evaluated by asking farmers if they had an injury (or injuries) in the past 12 months. Other definitions included injury that required medical care (other than first aid) and/or lost work for half a day or more. Injury severity was measured by evaluating medical characteristics using ISS (57), and the amount of compensation in insurance claims (37). Injuries occurred in fields and animal facilities. Work tasks included transport of agricultural goods, operation and repair of machinery, mounting and dismounting of tractors, fieldwork, and animal-related tasks such as feeding, milking, herding, moving and riding animals. Injuries resulted in lost work time, and medical care such as out-patient level-care and hospitalization. Common injury sources/causes included machinery, animals, and falls.

3.4.2 Estimated effect of risk factors on agricultural injury

The results of the correlation between age and injury are illustrated in a weighted scatter plot in Figure 3.2. Also, a bubble plot with the weights of point estimates based on the sizes of corresponding studies is depicted in Figure 3.3. The regression line reflected an increasing trend in injury risk by age. The correlation between the risk of injury and age was relatively weak but statistically significant (Pearson's correlation p-value=0.03, r-square=0.21).

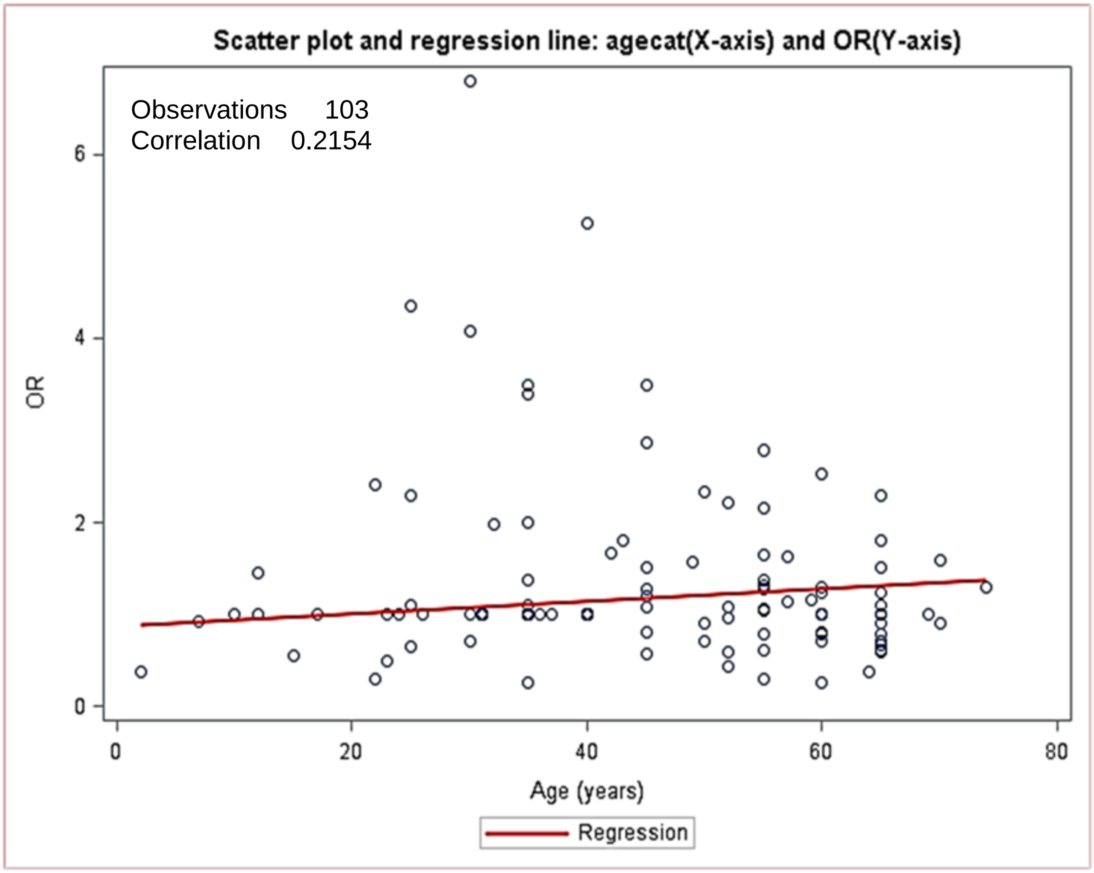

Figure 3.2 Scatter plot with reported risk estimates of agricultural injury for age.

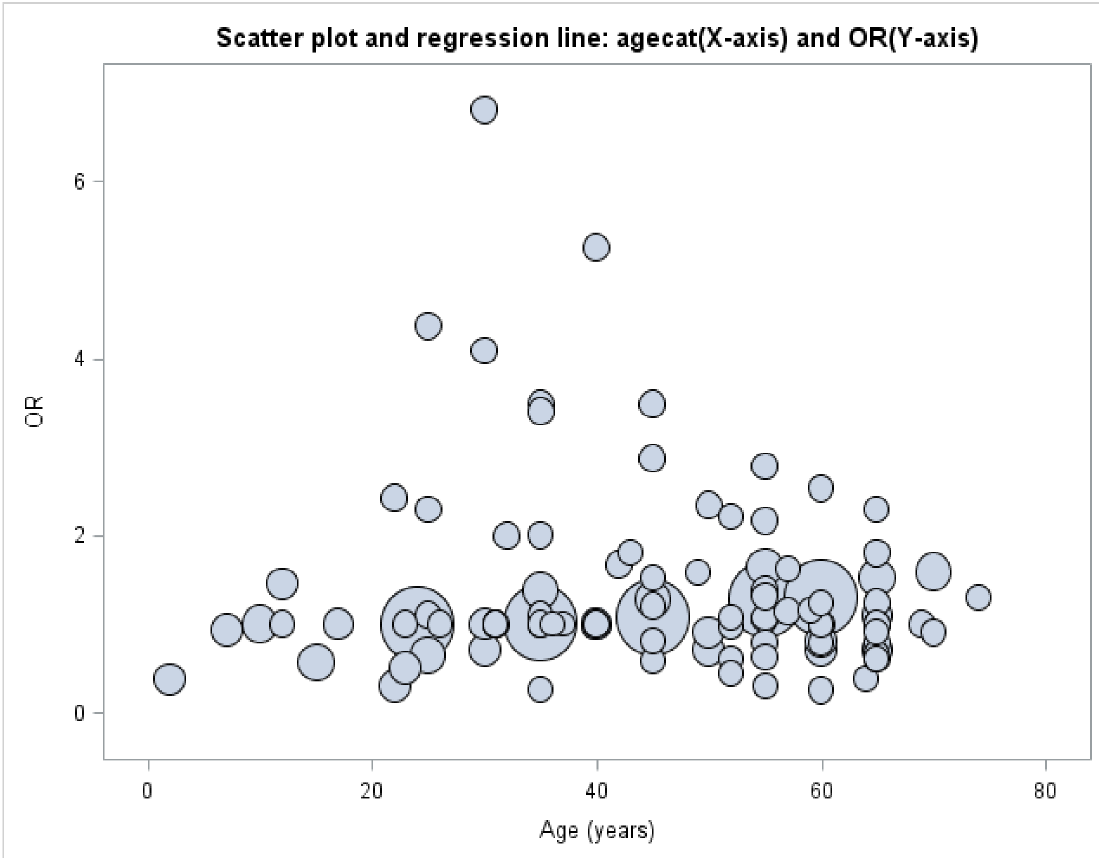

Figure 3.3 Bubble plot with reported risk estimates of agricultural injury for age.

Pooled risk estimates were calculated in the remaining 21 separate meta-analyses using two or more studies. Different studies adjusted for different sets of confounders. The most common confounders included in the multivariate models were age (n=29), work hours (n=17), education (n=14), gender (n=14), marital status (n=10), health and safety-related factors (n=23), and farm-related factors (n=23). The results for the 24 risk factors are illustrated in Table 3.2. The short descriptions are as follows:

3.4.2.1 Demographic risk factors:

Pooled estimate calculated from eight studies showed that high school-level education or more (vs. less) increased the odds of injury (OR: 1.39; 95% CI: 1.21 – 1.59). Three studies reported married (vs. other) status as a risk factor while five studies reported it as protective. The overall effect of marital status was inconclusive ($p > 0.05$). Four studies reported lower odds of injury for Caucasian farmers while one study reported the opposite. The pooled estimates showed that the risk of injury was 0.76 times lower in Caucasian farm workers compared to those of other races (95% CI: 0.61 – 0.95). The pooled estimates for Finnish language (vs. Swedish) calculated from three Finnish studies showed that the odds of injury was 1.21 times higher in Finnish speaking farmers compared to those who spoke Swedish as their native language (95% CI: 1.14 – 1.29). Experience in farming less than 20 – 25 years (vs. more experience) was protective in three studies and a risk factor in one study. The meta-analysis was inconclusive. Four studies reported higher odds of injury for those who lived on the farm compared to those who lived off the farm. Two studies reported the opposite. The summary effect indicated that the odds of injury were 1.18 times higher for those who lived on the farm (95% CI: 1.08 – 1.29). Three studies concluded that the odds of injury were higher for those who worked off-farm than those who did not. One study showed contradictory results. The meta-analysis was inconclusive for off-farm work.

3.4.2.2 Personal or behavioral risk factors:

High CAGE score or excessive drinking was reported as harmful in six studies while one study reported a protective effect of excessive drinking. The meta-analysis was inconclusive. Two studies reported that current smoking was protective for injury. Smoking in the past was reported as harmful in one study and protective in two studies. The overall result was inconclusive. The pooled estimates calculated from two studies for sleep showed that sleeping less than seven to seven and half hours (vs. more) contributed to increase the risk of injury by 1.32 times (95% CI: 1.12 – 1.56). Pooled estimate from two studies showed that the odds of injury were 1.66 times higher in individuals who perceived high injury risk than those who perceived low risk (95% CI: 1.28 – 2.15). Two studies showed a very high risk of injury in those who had challenging social conditions such as tensions with neighbors or stress due to social situations; pooled estimate indicating 3.49 times greater injury risk (95% CI: 1.81 – 6.75).

3.4.2.3 Farm-related risk factors:

The pooled estimates for farm size calculated from six studies indicated that greater farm size (vs. small) increased the odds of injury by 1.14 times (95% CI: 1.11 – 1.17). Three studies reported higher odds of injury in farmers who produced livestock compared to those who produced other commodities. One study reported the opposite. The overall effect reflected 1.71 times higher odds of injury in livestock farmers (95% CI: 1.04 – 2.79). The summary effect for gross sales calculated from two studies showed that the odds of injury were 1.33 times higher in those with greater sales vs. those with smaller sales (95% CI: 1.28 – 1.39). The pooled estimates of injury for higher income earned from farming (vs. lower income) reflected 2.33 times higher risk of injury among higher income farmers (95% CI: 2.22 – 2.44). The meta-analysis conducted using three reports for the number of workers employed on the farm showed that the odds of injury were 1.92 times higher when higher numbers of workers were employed on the farm (vs. lower) (95% CI: 1.32 – 2.79).

3.4.2.4 Safety-related risk factors:

Four studies reported higher odds of injury in farmers who employed unsafe practices such as not turning off machinery regularly, accidental exposure to alkalis/acids on the skin, frequently hurrying during farming, and unsafe lifting of heavy objects. The overall results showed that the odds of injury were 1.67 times higher in farmers who exhibited these behaviors compared to those who did not (95% CI: 1.34 –

2.09). Not attending safety training or quality management courses or instructions was reported as harmful in three studies while it was reported as protective in one study. The meta-analysis was inconclusive for attending safety training courses or instructions. The pooled estimate calculated from two studies for computer use for farm management indicated 1.35 times higher odds of injury for computer using farmers (95% CI: 1.10 – 1.65). Overall effect of accidental exposure to pesticides and/or chemicals to the skin obtained from three studies showed that the odds of injury were 1.71 times higher in those who had accidental exposure to pesticides and/or chemicals to the skin than those who did not (95% CI: 1.35 – 2.16).

Table 3.2 Results of the meta-analysis for selected risk factors (Part II).

Risk factor (papers)	Comparison categories	Study	Study OR and CI	Pooled OR and CI
		DEMOGRAPHIC		
Education (n=8)	More than high school vs. less	Sprince et al., 2007	2.12 (1.13 – 3.90)	1.39 (1.21 – 1.59)
	More than high school vs. less	Sprince et al., 2003	1.61 (1.21 – 2.12)	
	More than high school vs. less	Sprince et al., 2003[b1]	1.79 (1.12 – 2.84)	
	More vs. less	Lewis et al., 1998	2.13 (1.24 – 3.62)	
	More than high school vs. less	Sprince et al., 2008	1.51 (0.74 – 3.08)	
	More than high school vs. equal or less	Tiesman et al., 2006	1.07 (0.86 – 1.33)	
	Technical, high school or more vs. less	Lee et al., 1996	1.14 (0.57 – 2.25)	
	More than High school vs. less	Sprince et al., 2003[b2]	1.39 (0.86 – 2.24)	
Marital status (n=8)	Married vs. non-married	Tiesman et al., 2006	0.75 (0.58 – 0.96)	1.02 (0.73 – 1.48)*
	Married vs. non-married	Marcum et al., 2011	1.15 (0.75 – 1.76)	
	Married/ ≥ 16 years vs. < 16 years/never married	Gerberich et al., 1998	2.19 (1.16 – 4.28)	
	Married vs. non-married	Sprince et al., 2008	0.56 (0.22 – 1.43)	
	Married vs. non-married	Lee et al., 1996	1.72 (0.87 – 3.41)	
	Married vs. non-married	Sprince et al., 2003[b2]	0.70 (0.34 – 1.44)	
	Married vs. other	Xiang et al., 1999	0.99 (0.26 – 3.87)	
	Married vs. never married	Wang et al., 2010	1.03 (0.62 – 1.70)	
Race (n=5)	White vs. non-White	Erkal et al., 2009	0.28 (0.08 – 0.90)	0.76 (0.61 – 0.95)
	White vs. non-White	Erkal et al., 2008	0.52 (0.26 – 1.11)	
	White vs. African-American	Marcum et al., 2011	0.96 (0.68 – 1.33)	
	White vs. other	Marcum et al., 2011[c]	0.60 (0.30 – 1.23)	
	White vs. non-White	McCurdy et al., 2004	3.19 (1.38 – 7.36)	
	White owners vs. African-American owners	McGwin et al., 2000	0.75 (0.43 – 1.45)	

	White owners vs. African-American workers	McGwin et al., 2000[c]	0.27 (0.14 – 0.53)	
Native language (n=3)	Finnish vs. Swedish	Karttunen & Rautiainen, 2013	1.12 (1.03 – 1.23)	1.21 (1.14 – 1.29)
	Finnish vs. Swedish	Virtanen et al., 2003	1.28 (1.16 – 1.43)	
	Finnish vs. Swedish	Rautiainen et al., 2009	1.30 (1.15 – 1.46)	
Experience (n=4)	25 years or less vs. more	Sprince et al., 2002	1.79 (1.14 – 2.79)	0.91 (0.74 – 1.11)*
	25 years or less vs. more	Sprince et al., 2008	0.37 (0.13 – 1.06)	
	25 years or less vs. more	Sprince et al., 2003[b2]	0.70 (0.37 – 1.32)	
	20 years or less vs. more	Wang et al, 2010	0.84 (0.64 – 1.09)	
On-farm residence (n=6)	Farm vs. off-farm	Rautiainen et al., 2009	1.47 (1.19 – 1.81)	1.18 (1.08 – 1.29)
	Yes vs. no	Carruth et al., 2002	2.34 (0.92 – 5.93)	
	Yes vs. no	Layde et al., 1995	0.43 (0.19 – 0.93)	
	Yes vs. no	Nordstrom et al., 1996	0.40 (0.16 – 1.00)	
	Farm vs. off-farm	Karttunen & Rautiainen, 2013	1.15 (1.04 – 1.28)	
	Yes vs. no	Sprince et al., 2003[b2]	1.07 (0.46 – 2.47)	
Off-farm work (n=4)	Yes vs. no	Sprince et al., 2003[b1]	0.59 (0.36 – 0.97)	0.95 (0.76 – 1.18)*
	Yes vs. no	Carruth et al., 2002	1.20 (0.71 – 2.14)	
	Yes vs. no	Rautiainen et al., 2004	1.01 (0.76 – 1.34)	
	More than 50 days vs. less	Xiang et al., 1999	1.84 (0.57 – 5.93)	
Principal occupation (n=1)	Agriculture vs. non-agriculture	Park et al., 2001	1.23 (0.30 – 3.44)	1.23 (0.30 – 3.44)*
		PERSONAL/BEHAVIORAL		
Alcohol use (n=7)	High CAGE score vs. low	Tiesman et al., 2006	1.26 (0.93 – 1.74)	1.09 0.94 – 1.27)*
	High CAGE score vs. low	Sprince et al., 2003	2.10 (1.01 – 4.40)	
	High CAGE score vs. low	Sprince et al., 2002	2.49 (1.00 – 6.19)	
	High CAGE score vs. low	Sprince et al., 2003[b2]	2.30 (0.71 – 7.40)	
	Alcohol drinking yes vs. no	Zhou & Roseman, 1994	1.99 (1.05 – 3.94)	

	Current drinker vs. abstainer	Wang et al., 2010	1.77 (1.27 – 2.47)	
	Former drinker vs. abstainer	Wang et al., 2010[c]	0.96 (0.42 – 2.17)	
	Three drinks per week vs. none	Rautiainen et al., 2004	0.68 (0.48 – 0.97)	
	1 – 2 drinks per week vs. none	Rautiainen et al., 2004[c]	0.80 (0.60 – 1.05)	
Smoking (n=3)	Ever smoked yes vs. no	Crawford et al., 1998	0.62 (0.29 – 1.31)	0.90 (0.57 – 1.43)*
	Ex-smoker yes vs. no	Sprince et al., 2003[b2]	1.70 (1.02 – 2.82)	
	Current smoker yes vs. no	Sprince et al., 2003[b2 c]	0.85 (0.37 – 1.95)	
	Former smoker vs. never	Park et al., 2001	0.87 (0.54 – 1.43)	
	Current smoker vs. never	Park et al., 2001[c]	0.34 (0.08 – 1.48)	
Sleep (n=2)	Less than 7 hours of sleep vs. more than 7 hours of sleep	Tiesman et al., 2006	1.24 (1.00 – 1.56)	1.32 (1.12 – 1.56)
	Less than 7.5 hours of sleep vs. 7.5 hours of sleep or more	Choi et al., 2005	1.43 (1.13 – 1.82)	
Perceived injury risk (n=2)	High vs. low	Taattola et al., 2012	1.70 (1.22 – 2.39)	1.66 (1.28 – 2.15)
	High vs. low	Leppala et al., 2013	1.61 (1.07 – 2.42)	
Social conditions (n=2)	Tensions in relationships with neighbors yes vs. no	Xiang et al., 2000	3.67 (1.52 – 8.89)	3.49 (1.81 – 6.75)
	Stress due to social situations yes vs. no	Thu et al., 1997	3.30 (1.20 – 8.80)	
		ENVIORNMENT-RELATED		
Farm size (n=6)	10 –19 hectares vs. < 10 hectares	Rautiainen et al., 2009	1.01 (0.89 – 1.15)	1.14 1.11 – 1.17)
	20 – 29 hectares vs. < 10 hectares	Rautiainen et al., 2009[c]	1.16 (1.01 – 1.33)	
	30 – 39 hectares vs. < 10 hectares	Rautiainen et al., 2009[c]	1.19 (1.03 – 1.37)	
	≥ 40 hectares vs. < 10 hectares	Rautiainen et al., 2009[c]	1.37 (1.19 – 1.57)	
	10 – 19 hectares vs. < 10 hectares	Karttunen & Rautiainen, 2013	1.00 (0.93 – 1.06)	
	20 – 29 hectares vs. < 10 hectares	Karttunen & Rautiainen, 2013[c]	1.13 (1.06 – 1.22)	
	30 – 39 hectares vs. < 10 hectares	Karttunen & Rautiainen, 2013[c]	1.18 (1.09 – 1.27)	

	≥ 40 hectares vs. < 10 hectares	Karttunen & Rautiainen, 2013[c]	1.35 (1.25 – 1.45)	
	1 – 4 hectares vs. 10 – 19 hectares	Virtanen et al., 2003	0.71 (0.56 – 0.91)	
	5 – 9 hectares vs. 10 –19 hectares	Virtanen et al., 2003[c]	0.84 (0.75 – 0.94)	
	20 – 29 hectares vs. 10 – 19 hectares	Virtanen et al., 2003[c]	1.06 (0.11 – 1.18)	
	30 – 49 hectares vs. 10 –19 hectares	Virtanen et al., 2003[c]	1.21 (1.12 – 1.29)	
	50 – 99 hectares vs. 10 – 19 hectares	Virtanen et al., 2003[c]	1.26 (1.15 – 1.39)	
	100 hectares or more vs.10 – 19 hectares	Virtanen et al., 2003[c]	1.41 (1.15 – 1.73)	
	100 – 199 acres vs. < 100 acres	Pickett et al., 1996	1.10 (0.61 – 2.00)	
	200 – 299 acres vs. < 100 acres	Pickett et al., 1996[c]	1.85 (0.98 – 3.47)	
	> 299 acres vs. < 100 acres	Pickett et al., 1996[c]	2.09 (1.16 – 3.76)	
	≥ 40 hectares vs. < 40 hectares	Leppala et al., 2013	3.84 (1.25 – 11.11)	
	100 – 300 acres vs. < 100 acres	Zhou & Roseman, 1994	2.11 (1.05 – 4.45)	
	> 300 acres vs. < 100 acres	Zhou & Roseman, 1994[c]	1.46 (0.66 – 3.36)	
Type of commodity produced (n=4)	Livestock/large animal vs. other/crop/mixed	Carruth et al., 2002	7.84 (1.42 – 43.08)	1.71 (1.04 – 2.79)
	Livestock vs. other	McGwin et al., 2000	3.35 (1.65 – 7.76)	
	Livestock vs. other	Broucke & Colemont, 2011	0.53 (0.23 – 1.23)	
	Livestock vs. crop	Park et al., 2001	2.04 (0.75 – 5.54)	
Farm sales (n=2)	Sales more than $10,000 vs. less	Hwang et al., 2001	1.24 (1.00 – 1.54)	1.33 (1.28 – 1.39)
	Farm receipts more than $50,000 CAD vs. less	Maltais, 2007	1.34 (1.29 – 1.40)	
Farm income (n=3)	€ 5,000 – € 9,999 vs. < € 5,000	Rautiainen et al., 2009	2.05 (1.74 – 2.43)	2.33 (2.22 – 2.44)
	€ 10,000 – € 14,999 vs. < € 5,000	Rautiainen et al., 2009[c]	2.71 (2.28 – 3.20)	
	≥ € 15,000 vs. < € 5,000	Rautiainen et al., 2009[c]	3.26 (2.74 – 3.88)	

	€ 5000 – € 9,999 vs. < € 5,000	Karttunen & Rautiainen, 2013	1.85 (1.69 – 2.02)	
	€ 10,000 – € 14,999 vs. < € 5,000	Karttunen & Rautiainen, 2013[c]	2.43 (2.21 – 2.66)	
	≥ € 15,000 vs. < € 5,000	Karttunen & Rautiainen, 2013[c]	2.97 (2.70 – 3.28)	
	> $ 20,000 vs. < $ 20,000	Tiesman et al., 2006	0.73 (0.53 – 1.00)	
Number of workers on farm (n=3)	Two vs. one	Zhou & Roseman, 1994	2.52 (1.16 – 5.91)	1.92 (1.32 – 2.79)
	Three to ten vs. one	Zhou & Roseman, 1994[c]	2.86 (1.30 – 6.92)	
	Ten or more vs. one	Zhou & Roseman, 1994[c]	4.37 (1.13 – 30.47)	
	Three vs. two or less	Crawford et al., 1998	1.51 (0.62 – 3.69)	
	Four vs. two or less	Crawford et al., 1998[c]	0.97 (0.35 – 2.65)	
	Five or more vs. two or less	Crawford et al., 1998[c]	1.90 (0.77 – 4.71)	
	Two or more vs. one	Broucke & Colemont, 2011	1.74 (0.59 – 5.17)	
Cooperation between farms (n=1)	Yes vs. no	Taattola et al., 2012	1.61 (1.19 – 2.22)	1.61 (1.19 – 2.22)
		SAFETY-RELATED		
Unsafe practices (n=4)	Turn off machinery never vs. always/sometimes	McGwin et al., 2000	3.22 (1.32 – 9.35)	1.67 (1.34 – 2.09)
	Exposure to acids/alkalis yes vs. no	Lewis et al., 1998	2.60 (1.15 – 5.91)	
	Hurry when farming frequently vs. sometimes/rarely	McGwin et al., 2000[c]	1.21 (0.79 – 1.76)	
	Heavy lifting yes vs. no	Rautiainen et al., 2004	1.68 (1.21 – 2.36)	
Poor maintenance (n=1)	Machinery condition fair/poor vs. excellent/good	McGwin et al., 2000	1.87 (1.21 – 1.96)	1.87 (1.21 – 2.96)
Safety training (n=5)	Safety training courses attended no vs. yes	Day et al., 2009	0.99 (0.68 – 1.44)	1.03 (0.74 – 1.43)*
	Safety training no vs. yes	McGwin et al., 2000	1.43 (1.00 – 2.11)	
	Safety training no vs. yes	Broucke & Colemont, 2011	1.55 (0.26 – 9.06)	
	Safety training no vs. yes	Park et al., 2001	1.29 (0.56 – 2.94)	

	Quality management training no vs. yes	Leppala et al., 2013	0.68 (0.47 – 1.00)	
Computer use for farm manageme nt (n=2)	Yes vs. no	Taattola et al., 2012	1.13 (0.86 – 1.61)	1.35 (1.10 – 1.65)
	Yes vs. no	Leppala et al., 2013	1.76 (1.01 – 3.06)	
Accidental exposure to pesticides and/or chemicals to the skin (n=3)	Yes vs. no	Carruth et al., 2002	1.54 (0.77 – 3.05)	1.71 (1.35 – 2.16)
	Yes vs. no	Rautiainen et al., 2004	1.83 (1.41 – 2.37)	
	Get pesticides on the skin yes vs. no	Park et al., 2001	1.02 (0.44 – 2.35)	

a. Pooled estimate not significant (p > 0.05).
b. Different study with same first author and year of publication.
c. Different categories used in the same study.

3.4.3 Sensitivity analysis

All measured associations remained stable during sensitivity analysis. The change in the strength of association was minimal and ranged from 0.00 to 0.43. A change in the direction of the association was observed in only two cases -- smoking and off-farm work. However, the pooled estimates for these risk factors were not significant. The results of sensitivity analysis are illustrated in Table 3.3.

Table 3.3 Sensitivity analysis results; pooled risk factor estimates for agricultural injury calculated from all studies and high-ranking studies (Part II).

Risk Factor	Pooled OR, all studies (95% CI)	P-value	Pooled OR (95% CI), high-ranking studies	P-value*
Education (high school or more vs. less)	1.39 (1.21 – 1.59)	0.000	1.38 (1.19 – 1.60)	0.000
Marital status (married vs. non-married/other)	1.02 (0.73 – 1.48)	0.810	1.12 (0.74 – 1.71)	0.570
Race (White vs. non-White)	0.76 (0.61 – 0.95)	0.019	0.82 (0.65 – 1.05)	0.120
Native language (Finnish vs. Swedish)	1.21 (1.14 – 1.29)	0.000	1.18 (1.10 – 1.27)	0.000
Experience (25/20 years or less vs. more)	0.91 (0.74 – 1.11)	0.360	0.97 (0.79 – 1.20)	0.830
On-farm residence (vs. no)	1.18 (1.08 – 1.29)	0.000	1.17 (1.07 – 1.29)	0.000
Off-farm work (vs. no)	0.95 (0.76 – 1.18)	0.660	1.04 (0.81 – 1.32)	0.740
Alcohol use (CAGE score high vs. low, or alcohol drinking or amount yes vs. no**)**	1.09 (0.94 – 1.27))	0.210	1.03 (0.88 – 1.20)	0.710
Smoking (ever smoker, ex-smoker or current smoker vs. non-smoker)	0.90 (0.57 – 1.43)	0.660	1.14 (0.78 – 1.66)	0.470
Sleep (7 or 7.5 hours or less vs. more)	1.32 (1.12 – 1.56)	0.001	1.24 (0.98 – 1.56)	0.060
Perceived injury risk (high vs. low)	1.66 (1.28 – 2.15)	0.000	1.70 (1.20 – 2.39)	0.002
Social conditions (yes vs. no)	3.49 (1.81 – 6.75)	0.000	3.67 (1.51 – 8.89)	0.004
Farm size (greater vs. smaller)	1.14 (1.11 – 1.17)	0.000	1.14 (1.11 – 1.16)	0.000
Type of commodity produced (livestock vs. other)	1.71 (1.04 – 2.79)	0.031	1.33 (0.73 – 2.42)	0.340
Farm sales (high vs. low)	1.33 (1.28 – 1.39)	0.000	1.28 (1.13 – 1.44)	0.000
Farm income (high vs. low)	2.33 (2.22 – 2.44)	0.000	2.39 (2.28 – 2.50)	0.000
Number of workers on farm (greater vs. smaller)	1.92 (1.32 – 2.79)	0.001	1.49 (0.92 – 2.42)	0.102
Unsafe practices (vs. not)	1.67 (1.34 – 2.09))	0.000	1.85 (1.37 – 2.51)	0.000
No safety training (vs. yes)	1.03 (0.74 – 1.43)	0.840	0.83 (0.61 – 1.13)	0.260
Computer use for farm management (vs. not)	1.35 (1.10 – 1.65)	0.003	1.13 (0.86 – 1.61)	0.016

Accidental exposure to pesticides and/or chemicals to the skin (vs. not)	1.71 (1.35 – 2.16)	0.000	1.73 (1.35 – 2.22)	0.000

*- P-value of 0.000 reflected very small, undetermined value.

3.5 DISCUSSION

3.5.1 Reported reasons for risk differences

In the current study, we have reported risk estimates for a range of well-established and emerging risk factors, based on the evidence found in the current literature. To our knowledge, the current study was the first to measure pooled estimates for agricultural injury risk factors. Of the 25 risk factors that we evaluated, seventeen increased the risk of injury while one decreased the risk. Three out of the 18 significant risk factors were derived from single reports. The pooled estimates ranged from 0.76 to 3.49. Significant factors included age, education, native language, race, on-farm residence, sleep, perceived injury risk, social conditions, farm size, sales, income, livestock production, number of workers employed, cooperation between farms, unsafe practices, poor maintenance, computer and/or internet use, and accidental exposure to pesticides or chemicals. Injury was not significantly associated with marital status, experience, principal occupation, alcohol use, smoking, and safety training.

Intervention programs should consider targeting populations with elevated risk of injury. The pooled estimates calculated in the meta-analysis indicate the magnitude and direction of the association. The source studies suggested causal mechanisms relating to elevated risk of injury from these factors. The risk factors are as follows:

3.5.1.1 Demographic risk factors:

The current study showed that higher education was a risk factor. Farmers who had education up to high school or more had the higher risk of injury compared to those who were educated less. Studies suggested that farmers with higher education may be able to recall injuries better than those with less education, leading to the overrepresentation of injured farmers with higher education (27, 32, 76). Research suggests that higher education and the knowledge of safety in the context of farm work and farm environment are two different things. Therefore, higher education does not help reduce the risk of injury which is contrary to workers from most other industries; less educated workers from most other industries workers tend to have high risk of injury (90).

Marital status is yet to be fully explored in injury risk research. Gerberich et al. (21) reported that those who were married had the higher risk of injury than those who were less than16 years old and were never married. The researchers suggested that age might have confounded the association between marital status and injury. Married couples with higher age have higher risk of injury as they have greater exposure to farm work compared to the exposure to younger farmers. Other studies found marital status as a significant risk factor for injury in their univariate analyses but failed to achieve significance in multivariate analyses (35, 91). Our meta-analysis was inconclusive for marital status as a risk factor.

McCurdy et al. (92) showed that race was an independent risk factor for injury, and that Caucasian farmers were at higher risk of injury than other races. However, they recommended that the result should be interpreted with caution because of the small count of non- Caucasian farmers with injury compared to the number of injured Caucasian farmers (6 vs. 129) in the study. Also, they suggested that educational programs on safety should be applied to workers from all ethnicities (92). McGwin et al. (70) on the other hand reported a greater risk of injury in non-Caucasian (African-American workers, in particular), compared to that in Caucasian workers. They stated that African-American workers have greater risk of having persistent injuries which result in work loss. However, the risk of injury in African-American owner/operators was similar to that in their Caucasian counterparts. These results imply that the effect of race on injury was confounded with the operator status. The meta-analysis showed that the Caucasian race was protective for injury risk.

Finnish language (vs. Swedish) was a risk factor among farmers in Finland. Language may reflect differences in culture, farming practices, and insurance utilization that could not be controlled for with available variables in the studies (7, 37). However, Swedish speaking farmers may under-report their injuries; they filed fewer claims for minor injuries while the rate of serious injury claims was similar in both groups (7, 40). Also, it is possible that Swedish speaking farmers have safer farms and take fewer risks than Finnish speaking farmers (40). More efforts are needed to understand the risk differences among farmers speaking different languages as their mother tongue.

Injury risk tends to be lower in farmers with longer farming experience. This may be due to adopting safer work practices compared to those with less experience (20). Also, the effect of experience on injury may (19, 21), or may not (91) be confounded with age, and may depending on the body part injured (eye, back, knee etc.) and other factors. In this review, the overall effect of experience on injury was not significant. More research is needed to understand the effect of experience and its interaction with age.

Residence on the farm was a risk factor. Farmers who live on the farm have a greater exposure to farm work and farm environment leading to increased probability of injury (7). On the contrary, two studies (19, 30) reported higher risk of injury in farmers who lived off the farm compared to those who lived on the farm. This result was adjusted for possible confounders. However, caution should be taken when considering injuries in off-farm residents. Often, it is difficult to understand the occupational nature of injuries that occur in off-farm residents (30). Nonetheless, farm residents generally have a higher risk of occupational injury.

The meta-analysis was inconclusive for off-farm work. According to Sprince et al. (27), farmers who hold off-farm employment spend fewer hours on the farm than those who work on the farm, exclusively, indicating higher exposure to farm work and underlying risks to farmers. On the contrary, Xiang et al. (43) suggested that farmers who work off-farm, experience more stress which in turn increases their risk of injury. More research should explore the effect of off-farm work on injury.

Having farming (vs. other) as primary occupation was reported in one study but the result was inconclusive. Farming is one of the most hazardous industries (18), and those who are employed primarily in agriculture should have higher risk of injury. On the other hand, individuals who consider farming as a secondary business may pay better attention to safety due to lack of confidence and experience in agriculture (72). The meta-analysis was inconclusive for primary occupation. More studies should explore principal occupation as a risk factor.

3.5.1.2 Personal or behavioral risk factors:

Excessive use of alcohol was associated with high risk of injury (16, 93). However, Rautiainen et al. (94) reported that use of alcohol was protective compared to non-use. Alcohol use was evaluated differently across studies. The studies used CAGE questionnaire for the determination of the hazardous level of alcohol use or reported the amount of alcohol consumed in a day, week, month or year. The meta-analysis was inconclusive for alcohol as a risk factor. More research is needed to examine the association between alcohol use and injury.

Crawford et al. (87) suggested that the stimulant effect of tobacco can induce alertness that can result in decreased risk of injury. The meta-analysis was inconclusive for smoking as a risk factor. The effect of smoking warrants further exploration.

Meta-analysis showed that inadequate sleeping (less than 7 – 7.5 hours) was associated with injury. Choi et al. (77) explained that adequate sleeping is required to maintain alertness to remain productive on the job. Sleeping more than 8.5 hours also elevated the risk of injury that could be indicative of underlying diseases (77). Additionally, alcohol can cause changing sleeping patterns, daytime drowsiness and loss of alertness (35). Modification of the effect of inadequate sleep on injury by alcohol use should be explored further.

High perceived injury risk was a risk factor**.** Self-awareness of the risk of injury can increase the level of alertness towards imminent hazards, and should result in a decrease of the actual risk of injury. However, the issue may arise from the existence of known hazards or taking risks, knowingly. In one example, active safety and security monitoring reduced the risk of injury (95). Further studies should explore how high perceived risk of injury could result in safety-enhancing behaviors among farmers.

Challenging social conditions was a risk factor. Studies reported high risk of injury in those with compromised inter-personal relationships or social situations (9, 75). Difficult social and economic conditions pose a barrier for promoting safety behaviors (75). Programs to overcome these challenges could have health benefits, including reducing the risk of injuries.

3.5.1.3 Farm-related risk factors:

Larger farm size was a risk factor for injury. Larger farms manage greater tillable areas, which requires longer exposure hours to farm work and accompanying risks (29, 38). Larger farms may also have livestock operations that involve high workload year-round and added economic pressure (8). However, long work hours may not explain the high rates of injury as most of the manual work may be done by hired employees on larger farms. They may also need to comply with safety regulations, which should improve their injury risk. The meta-analysis result may be influenced by having a high proportion of very small part-time farm operations in the small farm category. More research is required to understand injury patterns on large farms that produce different commodities.

Animal (vs. crop) production was associated with high risk of injury (39), particularly in women farmers (56, 96). According to a Belgian study (72), crop farming involves less variety of tasks than mixed farming, which may reduce their injury risk. McGwin et al. (70) showed the association between animal production and injury while adjusting for work hours.

Higher farm income was a risk factor. High farm income commonly implies higher exposure to farm work as well (7, 37). However, some studies reported high injury rates for low-income farmers (35, 97). Low income, along with debt (35, 97), stress and depression (35) may increase the risk of injury. More efforts are needed to evaluate income in greater detail.

Higher farm sales can be an indicator of greater exposure to farm work, similar to income and farm size mentioned above (14). A Canadian agricultural census-based study (6) found the opposite. They explained that farmers who accumulated high sales tend to know prevention of injury better than those with less sales (6). More studies are needed to understand the risk taking behaviors in farmers relative to sales, income, and farm size.

Greater cooperation between farms (vs. low) was a risk factor. The high risk may be due to borrowing malfunctioning machinery from other farmers without the knowledge of its condition, and such machinery could pose a high risk of injury (69). More research could reveal further mechanisms for high risk of injury resulting from cooperation between farms.

Larger number of employed workers on the farm was a risk factor. Zhou and Roseman (16) reported that the risk of injury increased with the number of hired workers on the farm. Crawford et al. (87) suggested that the ability to employ workers indicates larger farm size and greater exposure time. On the other hand, lack of hired help can also lead to a higher risk of injury, if owners/operators overextend their working capacity (72).

3.5.1.4 Safety-related risk factors:

Reporting unsafe behaviors was a risk factor. The risky behaviors included unsafe lifting of heavy objects, frequently hurrying when performing tasks, less frequency of turning off machinery, and accidental exposure to acids/alkalis. Some behaviors considered unsafe may be unintentional due to lack of awareness, or intentional in many cases. Safe behaviors, such as using seatbelts frequently have shown to reduce transportation-related injuries among farmers (13). Unsafe practices such as lifting of heavy weights could be reduced by mechanization, management or organization of work (94).

Safety training courses and material were found inconclusive in the meta-analysis. Training in one study included safety information embedded into chemical handling, animal husbandry, pasture management, machinery and equipment operation, and wool classing course components (57). It is likely that agricultural training courses do not have enough safety-related content to make an impact on injuries (95). The evaluation of farm safety training warrants further research.

Computer use for farm management was a risk factor. A high percentage of farms in the United States had computer (70%) and internet (67%) access in 2013 (98). Taattola et al. (69) explained that operators on modern farms may work longer hours, thereby having a greater exposure to farm-related activities. Farmers with advanced equipment may have higher levels of stress and urgency to get jobs done in spite of the availability of better management tools. More research is required to understand the association of injury and use of advanced technologies, and the effect of confounding factors such as farm size, number of workers employed, income, age, race, and native language of workers.

Accidental pesticides/or chemicals exposure to the skin was a risk factor. High doses of pesticides or chemicals can be hazardous to health. However, this exposure may be an indicator for the general level of safety precautions on the farm, rather than an independent risk factor due to toxicity of the chemical. Further research is needed to understand these mechanisms.

Poor maintenance of machinery was a risk factor. Poorly maintained machinery tends to be unreliable and also requires frequent repairs compared to adequately maintained machinery (70). Injuries often result from situations where the normal process of work is disrupted by malfunction. Machinery maintenance may also be an indicator of general attention to safety on the farm.

3.5.1.5 Age as a risk factor:

One of the unique aspects of the current study was the assessment of the effect of age on injury using a correlation metric, adjusted for study sizes. The source studies used different categorizations for age. It was not possible to dichotomize or re-classify age categories uniformly between studies. Instead we constructed a dataset assigning each reported risk estimate (OR) to the corresponding midpoint year of each age category. This dataset enabled calculating the correlation between OR and age in years, and showing the result graphically in a weighted scatter plot with a regression line. We found that older farmers were at high risk of injury compared to their younger counterparts. The risk of injury increased with age only slightly, and the correlation was weak (r-square=0.21). When the ORs were not weighted by study size, the association was reversed; older farmers had fewer injuries. However, the majority of the studies in fact showed higher risk of injury in younger farmers.

Many explanations have been offered in support of younger farmers having a higher injury risk. Younger farmers tend to be less experienced in farming, and tend to engage more in risk-taking behaviors compared to older farmers (14, 16, 27, 32, 72, 92). Also, younger farmers may remember their injuries better compared to older farmers (27, 32, 87). Younger farmers may have high stress from increasing production and expanding the business (69). Work long hours, on and off the farm can lead to high frequency of risk-taking behaviors.

Other explanations were offered as to why older farms may have a higher injury risk (43, 59). Older farmers continue working on the farm because there is no set retirement age in farming in many countries. Although they may reduce their farming activity (59) possibly due to health ailments, medication use, and other issues, they still participate in farm work by helping other operators such as a son, daughter or other relative (43).

We base our conclusion that older age is a risk factor for injury on the analysis where the sizes of the studies were considered, giving more weight on findings from largest studies. However, this conclusion should be interpreted with caution as the majority of (smaller) studies show the opposite. Several confounding factors may also play a role such as hours spent on individual tasks, commodities produced, operator status, gender, race, farm size, income, availability of assistance for work, medication use, health issues, hearing loss, and others.

3.5.2 Strengths

Risk factors for agricultural injury have been studied fairly extensively. Many studies were consistent, showing similar effects of risk factors. However, there were also contradictory findings. The evidence from all available studies can be analyzed in a systematic review, and a quantitative summary can be generated using meta-analysis. This method allows creating a common understanding of risk factors from individual studies that may not show similar results. Similar systematic reviews have been done frequently for evaluating the effectiveness of interventions to reduce injury (45, 46, 60, 78, 99). To our knowledge this is the first systematic review of risk factors for agricultural injury.

Numerous studies have addressed common risk factors such as gender, age, education, health problems, medication use, hearing loss, farm size, and type of commodity produced. Other risk factors have been reported less frequently. For instance, computer and/or internet use, language, social conditions, and cooperation between farms have been identified in small numbers of studies. Therefore, this review is timely and provides useful insights into well-established as well as emerging risk factors from available studies, published to date.

The effect of age on injury has been investigated in many studies. Age is one of the most commonly used variables for adjustment in multivariate models as well. The effect of age is challenging to summarize from different studies. Different categorizations are used for age to fit the population, study design, data source and sample size. We developed a method correlating mid points of age categories with injury risk estimates for those categories. This is a unique contribution from this study.

The selected studies were diverse in terms of geographic locations, study designs, sample sizes, sampling schemes, populations, methods of data collection, and factors used for adjustment of multivariate models. Our review included cross-sectional (n=20), prospective cohort (n=7) and case-control (n=11) studies. The studies used various data sources such as mail surveys, interviews, and insurance or hospital records.

Of some of the methods available for quality assessment of research studies, such as Critical Appraisal Skills Program (82), Strobe (83), and the Downs and Black Checklist (84), we used the NOS (62) for the current study. The NOS is an appropriate tool for assessing the quality of non-randomized studies with the capability of generating numerical scores. These scores can be used for determining the eligibility for inclusion of the studies for the systematic review. Although we used adjusted risk estimates for risk factors from most studies, we also used unadjusted risk estimates when adjusted estimates were not available. In some cases we also calculated crude ORs using reported frequencies. We included unadjusted estimates because adjustment of confounders varies with studies, and this observation resulted in waiving the requirement of adjustment for confounders. Only one study did not meet our pre-determined NOS score for quality. Sensitivity analysis showed that eliminating the low-ranking studies did not make much impact on the pooled estimates calculated in the meta-analysis; the pooled estimates for risk factors were stable even with 14 high-ranking studies used for the meta-analysis.

3.5.3 Limitations

The study had some limitations. The overall quality of systematic reviews depends on the quality of source studies. We selected studies of high quality using the predetermined quality criteria, and this measure might have helped overcome this limitation. As with all reviews, our study is subject to publication bias. Studies with non-significant findings are difficult to get published (85). We addressed this issue by allowing inclusion of non-significant point estimates of injury for risk factors from published studies. However, often the non-significant associations are not mentioned, or if they are, usable non-significant estimates are not included in the reports.

Self-reporting was used in many source studies, and this can introduce recall biases. It is possible that farmers with any or severe injuries remembered more about exposures than those with no injury or non-severe injury. Also, insurance claims may include some under-reporting due to high requirements for accepting claims. On the other hand insurance systems create a ‘moral hazard’ (94) where claims are filed fraudulently for economic gain (37, 40). In one insurance system, both over- and under-reporting were relatively low (39). Information bias could have also resulted due to failure to interpret survey questions correctly. The selected studies used data sources such as administrative records, and data collection methods such as structured questionnaires, and computer-assisted interviews. These measures help reduce the possibility of recall bias up to a certain extent.

All case-control studies had differential response rates between case and control/comparison groups, and that could have led to selection bias. Selection bias results in over or underrepresentation of one or both groups (cases, controls/comparison group). However, studies sampled their populations using random sampling, stratified sampling, regional government survey records, sampling of all individuals from a defined population, or using total population-based administrative records (hospital or insurance). These measures may have reduced the effects of selection bias.

Although some studies reported adjusted risk estimates, they did not adjust the association between risk factor and injury for individual tasks. Adjustment for tasks could have revealed actual risk differences among populations.

We modified some of the risk estimates reported in the source studies to maintain consistency among studies for the type of risk estimate (OR or non-OR estimates), referent group, and number of categories used. The modified risk estimates may not be absolute estimates. However, modification of risk estimates many not have affected the overall summary effect. On the contrary, the modified estimates may have increased the stability and precision of measured associations.

CHAPTER 4: RISK FACTORS FOR SEVERE INJURIES TO FARM AND RANCH OPERATORS IN CENTRAL STATES

4.1 ABSTRACT

Introduction- This study focuses on severe injuries in farm and ranch operators in the central United States. Methods- The Central States Center for Agricultural Safety and Health (CS-CASH), in collaboration with the National Agricultural Statistics Service (NASS), gathered survey data from 6,953, 6,912 and 6,912 farms/ranches in 2011, 2012 and 2013, respectively, covering seven U.S. states (IA, MN, MO, NE, ND, SD, and KS). Severe injury was defined as an injury that resulted in a loss of one day of work or more, receipt of professional medical care (clinic visit or hospitalization), and expenditures of $1,000 USD or more. Results- The response rate ranged from 33.0% – 37.2%. The average annual incidence (injuries / 100 workers) was 6.91 for all injuries and 2.40 for severe injuries. Univariate logistic regression showed that operator status, gender, age, primary occupation, work hours, income, retirement status, type of agricultural operation, internet connection, field crops harvest, use of 100 hp tractor and larger, land area used for agriculture, and the amount of sales—were risk factors for severe injury. Adjusted analysis showed a greater risk of severe injury for operators of age 45 – 54 years (vs. 65 and higher), those who worked 75% – 99% of their time on the farm/ranch (vs. less hours), and those who operated larger land areas (vs. smaller). Conclusion- The identified operator demographics and production characteristics should be taken into account when planning injury prevention programs.

4.2 INTRODUCTION

While agricultural injury surveys and studies commonly report frequencies of injuries, their severity is often overlooked. Severe injuries require multi-faceted medical care, possibly care in intensive care units, and continued out-patient clinic sessions at physiotherapy, psychotherapy and rehabilitation facilities (100). The incidence rate, trends and characteristics for severe injuries may differ from those for all injuries (101). With better knowledge of the frequency and type of severe injuries, prevention and care can be organized more efficiently, thereby reducing costs (100).

Few studies have focused on the characteristics of severe injuries. Two studies were hospital-based, and the characteristics of injuries and injured operators were reported using medical records (8, 102). One study evaluated incidence and risk factors for severe injury in New York farmers using the cross-sectional study design (14). A Finnish study investigated sources and risk factors for serious injury using insurance claims (37). These studies contribute to the understanding of severe injury, but further studies are needed since the characteristics of injury and risk factors may differ by region and over time.

The Central States Center for Agricultural Safety and Health (CS-CASH), funded by NIOSH, initiated an annual injury surveillance system in collaboration with U.S. Department of Agriculture’s National Agricultural Statistics Service (NASS). This surveillance covers seven states in the central U.S.

The objective of this study was to evaluate the risk factors for severe injury by conducting univariate and multivariate logistic regression analysis of a three-year injury surveillance dataset (2011-2013) from the CS-CASH surveillance system.

4.3 METHODS

The CS-CASH research team conducts surveillance of non-fatal agricultural injury among farm and ranch operators in seven states, namely Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota and South Dakota. The NASS administered the annual surveys in 2011, 2012, and 2013, respectively, and CS-CASH team (co-authors) analyzed the data. The surveys were sent out in March/April each year and gathered data on injuries that occurred in the previous calendar year.

The survey was first pilot-tested in two states (IA, MO) in 2010 to determine feasibility prior to its implementation in the seven-state region (103). Pilot response rate was 41% (n=857 responses). Farms that responded included 1,287 principal operators, 500 workers and 360 children (aged less than 20 years). The one-year incidence of injury was 7.8%, 4.8% and 5.3% among principal operators, hired workers, and children and youth, respectively. This pilot study demonstrated the feasibility of the method and we expanded the survey to the CS-CASH service region (seven central states) with minor modifications.

4.3.1 Data collection

The base population for the injury surveys was those farm and ranch operators in the seven-state region that responded to the Census of Agriculture surveys in 2007 (used in 2011 and 2012 injury surveys) and 2012 (2013 injury survey). In 2007, the Census of Agriculture reported 458,055 farm and ranch operations and 664,509 farm operators in this region, which was approximately 20.8% of the total U.S. agricultural operations (n=2,204,792), and 21.3% of U.S. agricultural operators (n=3,115,172).

NASS administered the annual injury surveys by mail to random samples of 6,953, 6,912 and 6,912 farms/ranches (approximately 1,000 farms/ranches in each state), annually from 2011 – 2013, respectively. One reminder to complete the injury survey was sent to the non-respondents. The survey included questions about injuries to principal operators, and up to two other operators on each farm or ranch. The survey also had questions about other household members, children, and hired workers.

Following the data collection, NASS linked injury survey data with selected variables on farm characteristics from their existing Census database. NASS then created a de-identified dataset for secondary analyses by the CS-CASH research team. This measure enabled the evaluation of both individual and farm-level attributes of injury. We report on a subset of the results in this chapter, focusing on characteristics and risk factors for severe injury.

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4.3.1.1 Dependent variables:

The research dataset included 22 questions addressing basic demographics of up to three operators and specific questions about injuries to each operator. We defined agricultural injury as follows: "Injury" is the result of a sudden, unexpected, forceful event, which has an external cause, and which results in bodily damage or loss of consciousness. This definition was used earlier in the Iowa Certified Safe Farm study (94) and it is similar to definitions used in workers' compensation systems (7, 37). The following question was used to report injuries to each operator: "How many farm-related injuries occurred to each operator during [calendar year]?" The response options were 0

(None), 1 (One), 2 (Two) and 3 (Three or more) injuries. "Farm-related" includes work and leisure activities on the operation, in addition to commuting, transport, and business trips for the operation.

The consequences of the most serious injury (self-reported) to each operator were evaluated by asking questions about: a) the type of medical care received (no care, out-patient level care and hospitalization); b) lost work time due to injury (no lost time, less than half day, half to one day, 2 – 6 days, 7 – 29 days and 30 days or more); and c) estimated costs from the injury, both out-of-pocket costs and those paid by insurance.

The outcome of interest for this study was severe injury. We defined severe injury as an injury that resulted in at least half-day of lost work-time, professional medical care (out-patient or hospitalization), and paid expenses of $1,000 USD or greater with out-of-pocket and insurance costs, combined. Using these three criteria, we created a dichotomous outcome variable for each operator if they had ‘severe injury’ (yes, no). Those with only minor injuries or no injuries were coded as ‘no’ severe injury.

<u>4.3.1.2 Independent variables</u>:

Individual-level independent variables included operator sex (male, female), status (principal, 2nd, 3rd), age, primary occupation (farm/ranch, other), percent of time worked on farm/ranch (100%, 75% – 99%, 50% – 74%, 25% – 49%, 0% – 24%), principal operator’s total household income (less than $20,000, $20,000 – $29,999, $30,000 – $39,999, $40,000 – $49,999, $50,000 USD or more), percent of the total household income that came from agricultural operation, off-farm work days (none, 1 – 49 days, 50 – 99 days, 100 – 199 days, 200 days or more), and retirement status (yes, no).

Farm-level independent variables included the type of operation (farm, ranch), total acres, harvest or cutting of field crops (yes, no), hay/forage (yes, no) and woodland crops (yes, no), acres in Conservation Reserve Program, total cattle, hogs, poultry, sheep/lambs, horses/ponies, presence of other animals (yes, no), number of tractors by horsepower (40, 40 – 99 and 100 or more), internet access (yes, no), number of households living on operation, and type of organization (family or individual, partnership, incorporated under state law etc.).

4.3.2 Data analysis

We calculated the injury rate for each year as the number of injuries divided by the number of operators multiplied by 100. Some operators reported up to three injuries in one year, and all reported injuries were included in the total count of injuries. The average annual incidence (injury rate) was calculated by dividing the total number of injuries reported in three years by the total number of operators listed in responses multiplied by 100. We also calculated injury rates at the sub-population level; incidence rate for each level of all categorical variables was calculated by dividing the number of injuries within the variable level by the total responses reported for that level.

We calculated the incidence of severe injuries in the same manner. Using 'if-then' statements in SAS (89), we created the severe injury outcome variable from four injury variables: number of injuries reported, type of medical care received, lost work days, and costs (out-of-pocket and paid by insurance). Descriptive statistics were calculated using appropriate measures. The difference between severe injury and minor injury for the sources and characteristics of injury were evaluated by conducting cross-tabulations between the characteristics and the severe injury variable. We used Fisher's Exact tests for statistical significance ($p < 0.05$).

Risk factors for severe injury were evaluated using logistic regression. We conducted unadjusted analyses on all explanatory variables, individually, using $p < 0.05$ to indicate statistical significance. To control for potential confounding, an adjusted model was constructed with the backward stepwise selection procedure, starting with all statistically significant explanatory variables found in unadjusted analyses.

We converted continuous variables into categorical variables. The predictors of severe injury were measured by OR and their 95% CI. The model-fit was evaluated by Hosmer-Lameshow test where Chi Square p-value of < 0.05 would indicate the lack of fit in the model.

We conducted unadjusted and adjusted logistic regression analyses for evaluation of risk factors for all injuries, and then compared the magnitude of associations between risk factors and any injury to that between risk factors and severe injury.

The effect of missing values was taken into consideration. The proportion of missing values was 12.8% and 44.6% for the operator and farm-level independent variables, among the ones selected for the final multivariate model. However, the power of study was high (> 0.95), irrespective of the presence of missing data, indicating that the sample size was adequate, and the reported non-response may not have much effect on our findings.

4.4 RESULTS

4.4.1 Response rate

The average 3-year response rate of the survey was 35% (n=7,264 responses). The response rate was highest in 2013 (37.3%) and lowest in 2011 (33%). Most operations were identified as farms (82%), the remainder (18%) as ranches. Among the seven states, Minnesota had the highest 3-year average response rate of 39.1%, and North Dakota had the lowest rate of 24.3%.

4.4.2 Operator characteristics

A total of 9,707 operators were identified on 6,945 responding farms and ranches; 71.5% were principal operators, 23.5% second operators and 5% third operators. The majority of principal operators were male (93.6%), second operators were female (56.5%), and third operators were male (80.5%). The average age was 59.7 years for principal operators, 52.4 years for second operators and 42.2 years for third operators.

4.4.3 Injury incidence

A total of 560 operators had 671 injuries from 2011 – 2013 (n=9,707 total operators), which resulted in an average annual incidence of 6.91 injuries/100 workers. Because some operators had more than one injury (n=111 operators), the average annual incidence by total injured persons was lower (5.76 injury cases/100 workers). Of all injuries, 34.7% were severe, and the average annual incidence of severe injuries was 2.40/100 workers. The vast majority of operators did not have injuries or the injuries were minor (97.5%).

4.4.4 Injury outcomes

For the most serious injuries (self-reported), injury outcomes were measured in terms of the type of medical care received for injury, day/s of work lost due to injury, and the expenses paid out-of-pocket or by insurance. Missing observations were found for questions about outcomes for serious injury among operators with injury. Thirty percent of injured operators did not respond to questions about the type of care. This significant underreporting could have occurred because they may have perceived their injury as not 'serious'. A similar situation may have occurred for other outcome variables where no response was reported for the out-of-pocket amount paid (21.3%), amount paid by insurance (40.8%) and lost work time (6.3%). Most injured operators received out-patient level care (57.7%) and very few were hospitalized (3.2%). Many operators did not lose work time (29%). Among operators who lost work-time, the proportion of operators by work-time was almost evenly distributed across all levels and ranged from 8.4 –16.8%. Most operators spent less than $100 for treatment of injury using their insurance (21.4%) and own financial resources (31.6%). The proportion of operators who paid a high amount ($10,000 or more) was small; 8.2% reported coverage by insurance and 3% had out-of-pocket expenses.

4.4.5 Multiple injuries

Many operators had single injuries (n=449). Among operators who responded questions related to different serious injury outcomes, many of them had single injuries in most cases.

4.4.6 Effect of severe injury

Many operators had severe injuries among those who responded to questions related to the location where injury occurred in all cases (Fisher's Exact $p = 0.05$). The locations included home/office, farm building, barn/yard, field/pasture, and road/odd-farm. Likewise, many operators had severe injuries among those who responded to questions related to sources or external causes of injury (Fisher's Exact $p < 0.05$). The sources of all injuries included tractors, all-terrain-vehicles, machinery, livestock, power tools, hand tools, water, chemicals/pesticides, working surface, truck/automobile, and other vehicle (Figure 4.1).

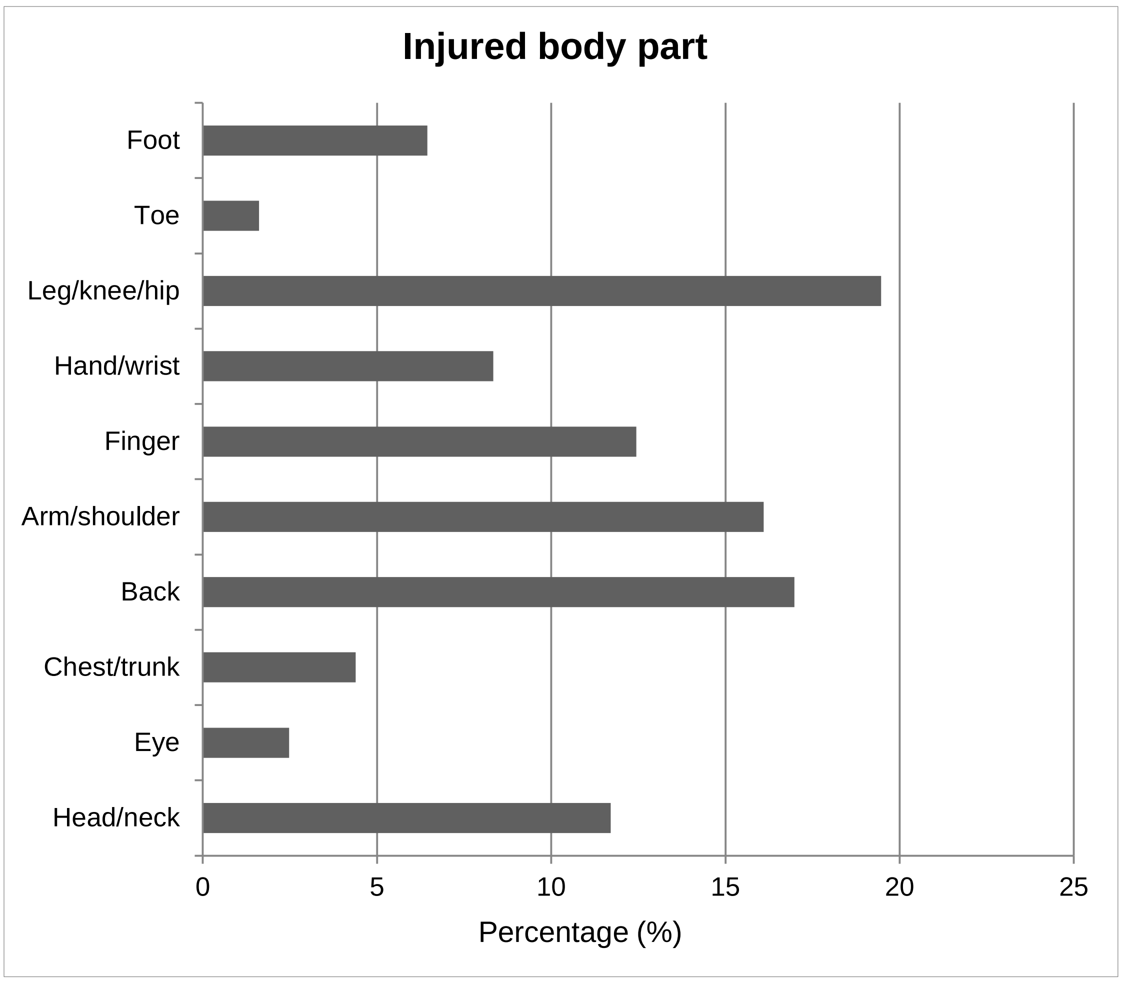

Figure 4.1 Bar graph with body parts involved in most serious injury: Central states injury surveillance 2011 – 2013.

Frequencies of operators with any injury and severe injury by different injury sources are shown in Table 4.1.

Table 4.1 Severe and minor injury frequencies attributed to individual source: Central states injury surveillance 2011 – 2013.

Injury source	**All reported serious injuries**	**Severe injury**	**Percentage (%)**	**Minor injury**	**Percentage (%)**
Tractor	25	18	9.6	7	13.2
ATV	12	9	4.8	3	5.7
Machinery	21	19	10.1	2	3.8
Livestock	92	72	38.3	20	37.7
Hand tool	22	13	6.9	9	17.0
Power tool	15	8	4.3	7	13.2
Chemical/pesticide	1	1	0.5	0	0
Working surface	32	30	15.9	2	3.8
Truck/automobile	14	12	6.4	2	3.8
Other vehicle	4	4	2.1	0	0
Water	3	2	1.1	1	1.8
Total	241	188	100	53	100

Also, among operators who responded to questions related to body parts involved in injury, many had severe injuries (Fisher's Exact $p < 0.05$).The body parts involved in all injuries included head/neck, eye, back, arm/shoulder, finger, hand/wrist, leg/knee/hip, toe, and foot (Figure 4.2).

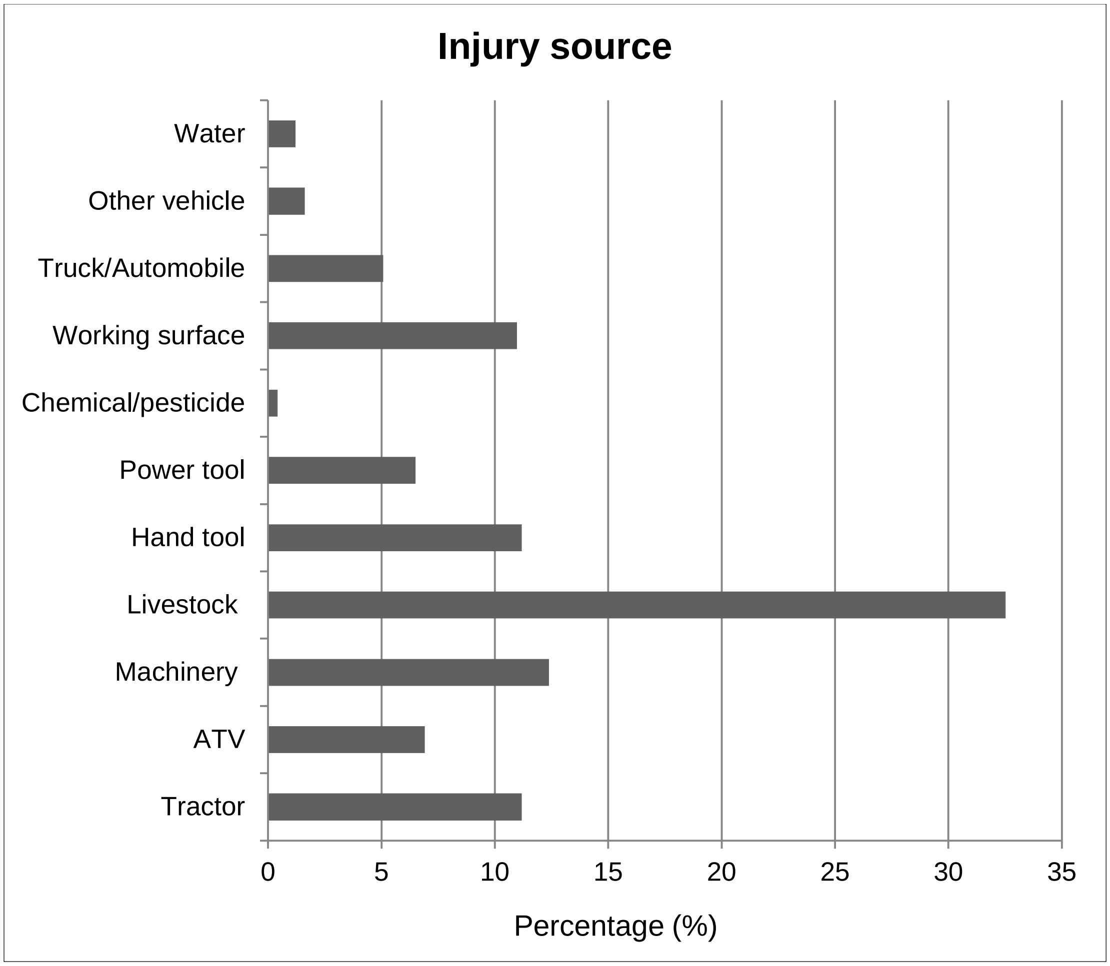

Figure 4.2 Bar graph with sources for most serious injury: Central states injury surveillance 2011 – 2013.

Frequencies of operators with any injury and severe injury by different body parts involved are shown in Table 4.2.

Table 4.2 Severe and minor injury frequencies by individual body part: Central states injury surveillance 2011 – 2013.

Body part involved in injury	All reported serious injuries	Severe injury	Percentage (%)	Minor injury	Percentage (%)
Head/neck	23	19	8.6	4	6.2
Eye	8	7	3.2	1	1.7
Chest/trunk	8	5	2.3	3	4.7
Back	49	39	17.7	10	15.6
Arm/shoulder	42	34	15.4	8	12.5
Finger	41	25	11.3	16	25.0
Hand/wrist	20	12	5.4	8	12.5
Leg/knee/hip	65	55	24.9	10	15.6
Toe	3	1	0.4	2	3.1
Foot	26	24	10.8	2	3.1
Total	285	221	100	64	100

4.4.7 Risk factors for severe injury

Several individual and farm-level determinants of injury were found in unadjusted logistic regression analyses. As illustrated in Table 4.3, statistically significant individual-level determinants included: operator age, status, gender, primary occupation, work time on agricultural operation, principal operator’s retirement status and percentage of income from farming/ranching. The farm-level determinants included the type of agricultural operation, internet access status, growing field crops, 100hp and larger tractors in use, amount in farm sales, and total acres in operation.

Operators 65 years of age or higher had the lowest incidence of severe injury (injury rate of 1.69 severe injuries/100 workers), compared to all other age categories. Operators in the middle age group (45 – 54 years) had the highest risk of severe injury (OR: 2.19; confidence intervals in Table 4.3), compared to operators 65 years or older.

Operators of other age groups also had the higher risk. For example, operators in age groups 20 – 44 years and 55 – 64 years had ORs of 1.65 and 1.58, respectively.

Male operators had 1.55 higher odds of severe injury compared to female operators. Operators who spent the majority of their time on farming/ranching had 2.44 times higher odds compared to part-time operators. Operators who spent 75% – 99% of their time on agricultural operations had 4.75 times greater odds, in comparison to operators who worked 0% – 24% of their time in farming/ranching.

Principal operators who earned 50% or more of their income from agriculture had twice the odds of severe injury compared to those who earned a lesser proportion of their income from agriculture. Principal operators who were retired had 0.37 times lower odds of severe injury than those who were not retired.

The odds of severe injury were 1.27 times higher in operators who operated ranches, compared to those operating farms. Access to the internet increased the odds of severe injury (OR: 1.64). Growing field crops increased the odds as well (OR: 1.88). Having large tractors (100 hp or more) increased the odds of severe injury (OR: 2.26). The odds of severe injury increased with the size of the operation (in acres and sales).

Table 4.3 Risk factors for severe injury: Injury rates and unadjusted risk estimates: Central states injury surveillance 2011 – 2013.

Risk factors	Severe injury		Risk estimate		
	Yes	**No**	**Rate**	**OR**	**95% CI**
OPERATOR-LEVEL					
Operator status					
Principal	186	6466	2.79	1.54	1.11 – 2.13
Operator 2 and 3	47	2527	1.85	1	-
Operator age (years)					
20 – 44	44	1541	2.77	1.65	1.09 – 2.51
45 – 54	67	1772	3.64	2.19	1.50 – 3.20
55 – 64	75	2752	2.65	1.58	1.09 – 2.28
65 or higher	47	2730	1.69	1	-
Gender					
Male	202	7206	2.72	1.55	1.05 – 2.28
Female	30	1659	1.77	1	-
Primary occupation					
Farming	174	4839	3.47	2.44	1.81 – 3.28
Other	59	4003	1.45	1	-
Work-time on operation (%)					
100	84	2276	3.55	3.89	2.44 – 6.19
75 – 99	56	1243	4.31	4.75	2.91 – 7.75
50 – 74	28	1121	2.43	2.63	1.51 – 4.59
25 – 49	41	1742	2.29	2.48	1.48 – 4.15
0 – 24	23	2426	0.93	1	-
Principal operator by percent income (%)					
Up to 49	85	4048	2.05	0.50	0.37 – 0.67
50 and up	101	2418	4.00	1	-
Principal operator by retirement status					
Retired	17	1365	1.23	0.37	0.22 – 0.62
Active	169	5101	3.20	1	-
Internet access					
Yes	145	4417	3.17	1.64	1.15 – 2.33
No	41	2049	1.98	1	-
FARM –LEVEL					
Agricultural operation					
Ranch	35	1030	3.28	1.27	0.87 – 1.86*
Farm	141	5308	2.58	1	-
Field crops harvested					
Yes	106	2813	3.63	1.88	1.35 – 2.61
No	55	2748	1.96	1	-
Tractor of 100hp in use					
Yes	121	3174	3.71	2.26	1.59 – 3.20
No	44	2608	1.65	1	-
Land in use (acres)					
1 – 100	38	1950	1.91	0.17	0.05 – 0.60

101 – 1,000	89	3372	2.57	0.23	0.07 – 0.79
1,001 – 3,000	44	830	5.03	0.47	0.13 – 1.63*
3,001 – 10,000	12	287	4.01	0.37	0.10 – 1.41*
10,000 and up	3	27	10.00	1	-
Total sales (USD)					
1 – 100	15	1159	1.27	0.37	0.21 – 0.63
101 – 1,000	5	188	2.59	0.76	0.31 – 1.89*
1,001 – 3,000	10	434	2.22	0.66	0.34 – 1.26*
3,001 – 10,000	17	685	2.42	0.71	0.42 – 1.18*
10,000 and up	139	4000	3.35	1	-

*= Statistically not significant ($p \geq 0.05$).

The determinants of all injuries were similar to those of severe injuries except the risk factor use of 40–99 hp tractors (Table 4.4). Unadjusted analysis showed that use of these type of tractors increased the risk of injury by 1.28 times in those who used them in comparison to those who did not (95% CI: 1.05 – 1.56). Land acreage under conservation programs was significant for any injury in unadjusted analysis, but was not significant after converting the format of this variable from numerical to categorical. Conversion of the format was conducted because 65% of farms/ranches did not have land under cultivation.

Table 4.4 Injury rates and unadjusted or crude risk estimates for predictors of severe injury: Central states injury surveillance 2011 – 2013.

	All Injuries		Severe injury	
Risk Factors	**OR**	**95% CI**	**OR**	**95% CI**
Operator status				
Principal	1.34	1.10 – 1.65	1.54	1.11 – 2.13
Operator 2 and 3	1	-	1	-
Operator age (years)				
20 – 44	1.63	1.25 – 2.13	1.65	1.09 – 2.51
45 – 54	1.73	1.35 – 2.23	2.19	1.50 – 3.20
55 – 64	1.51	1.19 – 1.91	1.58	1.09 – 2.28
65 or higher	1	-	1	-
Gender				
Male	1.46	1.14 – 1.87	1.55	1.05 – 2.28
Female	1	-	1	-
Primary occupation				
Farming	2.03	1.68 – 2.46	2.44	1.81 – 3.28
Other	1	-	1	-
Work time on operation (%)				
100	2.56	1.95 – 3.36	3.89	2.44 – 6.19
75 – 99	3.19	2.38 – 4.28	4.75	2.91 – 7.75
50 – 74	1.88	1.34 – 2.63	2.63	1.51 – 4.59
25 – 49	1.76	1.29 – 2.38	2.48	1.48 – 4.15
0 – 24	1	-	1	-
Principal operator by percent income (%)				
Up to 49	0.64	0.53 – 0.78	0.50	0.37 – 0.67
50 and up	1	-	1	-
Principal operator by retirement status				
Retired	0.55	0.41 – 0.73	0.37	0.22 – 0.62
Active	1	-	1	-
Internet access				
Yes	1.27	1.04 – 1.54	1.64	1.15 – 2.33
No	1	-	1	-
Agricultural operation				
Ranch	1.40	1.14 – 1.75	1.27	0.87 – 1.86*
Farm	1	-	1	-
Field crops harvested				
Yes	1.38	1.14 – 1.67	1.88	1.35 – 2.61
No	1	-	1	-
Tractor of 100hp in use				
Yes	1.79	1.47 – 2.17	2.26	1.59 – 3.20
No	1	-	1	-
Tractor of 40 – 99hp in use				
Yes	1.28	1.05 – 1.56	-	-
No	1	-	-	-
Land in use (acres)				

1 – 100	0.24	0.12 – 0.47	0.17	0.05 – 0.60
101 – 1,000	0.28	0.14 – 0.55	0.23	0.07 – 0.79
1,001 – 3,000	0.46	0.23 – 0.90	0.47	0.13 – 1.63*
3,001 – 10,000	0.28	0.13 – 0.60	0.37	0.10 – 1.41*
10,000 and up	1	-	1	-
Total sales (USD)				
1 – 100	0.48	0.36 – 0.65	0.37	0.21 – 0.63
101 – 1,000	1.17	0.75 – 1.81*	0.76	0.31 – 1.89*
1,001 – 3,000	0.60	0.40 – 0.89	0.66	0.34 – 1.26*
3,001 – 10,000	0.54	0.39 – 0.76	0.71	0.42 – 1.18*
10,000 and up	1	-	1	-

*= Statistically not significant ($p \geq 0.05$).

Three determinants of severe injury were found significant in adjusted logistic regression analysis. As shown in Table 4.5, these were operator age, work hours and size of land in use. In adjusted analyses for evaluation of risk factors for any injury, three factors were found significant. As illustrated in Table 4.5, these were operator age, principal occupation, and type of agricultural operation.

Table 4.5 Adjusted risk estimates for predictors of injury: Central states injury surveillance 2011 – 2013.

	All Injuries		Severe injury	
Risk Factors	**OR**	**95% CI**	**OR**	**95% CI**
Operator age (years)				
20 – 44	2.20	1.48 – 3.28	1.98	1.08 – 3.62
45 – 54	2.55	1.82 – 3.57	3.05	1.88 – 4.97
55 – 64	2.12	1.56 – 2.88	1.82	1.13 – 2.93
65 or higher	1	-	1	-
Primary occupation				
Farming	2.26	1.74 – 2.93	-	-
Ranching	1	-	-	-
Agricultural operation				
Ranch	1.42	1.07 – 1.88	-	-
Farm	1	-	-	-
Work-time on operation (%)				
100	-	-	4.22	1.97 – 9.05
75 – 99	-	-	5.62	2.59 – 12.19
50 – 74	-	-	4.38	1.94 – 9.88
25 – 49	-	-	2.74	1.24 – 6.07
0 – 24			1	-
Land in use (acres)				
1 – 100	-	-	0.22	0.06 – 0.84
101 – 1,000	-	-	0.22	0.06 – 0.78
1,001 – 3,000	-	-	0.40	0.11 – 1.43*
3,001 – 10,000	-	-	0.25	0.06 – 1.03*
10,000 and up	-	-	1	-

*= Statistically not significant ($p \geq 0.05$).

4.5 DISCUSSION

4.5.1 Injury Incidence

The injury incidence was 6.91 injuries / 100 self-employed farmers/ranchers in the current study. The BLS reported similar incidence rate of 5.70 injuries / 100 workers for hired workers in agriculture (includes forestry and fishing) in 2013 (3). Our incidence rate was within the range of 4.10 – 16.60 injuries / 100 workers reported by others (15, 16, 28, 37, 70, 87). Our incidence rate of 2.40 severe injuries / 100 workers was between two reported incidence rates of 1.25 and 9.00 severe injuries / 100 workers (14, 37). Both of these studies used definitions of severe injury that were somewhat similar to our study.

4.5.2 Effect of severe injury

In our study, the direction of the association between risk factors for any injury and for severe injury was similar. However, a stronger association was observed for risk factors for severe injury than that for any injury, which is similar to findings reported in a Finnish study (37). Frequency distributions for injury characteristics were similar for all injuries and severe injuries with few exceptions. Severe injuries represented a large proportion of all reported injuries. However, results indicate that the probability of a life-threatening injury that results in extended hospital stay, or injury of very serious nature, remains rare. Others have reported similar results for injuries that are very serious (26, 37, 94). Nonetheless, severe injuries require greater care than minor injuries, and can result in more significant work loss and a greater duration of temporary disability. Individual risk factors for severe injury are described below.

4.5.3 Risk factors for severe injury

4.5.3.1 Age: Middle age (45 – 54) was a significant risk factor for severe injury and for any injury (Table 9) found in adjusted analyses. Oldest operators (aged 65 years or more) had lower risk of injury compared to younger ones. Others have reported similar results (10, 14, 16, 27, 87, 104). Marcum et al. (59) suggested that as farmers age, they take fewer risks and tend to restrain themselves from performing dangerous activities. This study also suggested that their experience helps when performing hazardous activities. Other studies suggest that younger farmers lack experience which can put them at greater risk of injury (14, 16). Our results indicate that older operators had higher work exposure time but were at lower risk of severe injury compared to younger operators. This result is consistent with experience being an important factor in reducing injuries. Others have suggested a recall bias; the injury risk appears higher among younger farmers because they may recall injuries more readily than older farmers (16, 27). Further, older farmers may be more likely to recall severe injuries compared to minor injuries while younger farmers may recall all injuries, including severe injuries (87).

4.5.3.2 Gender: Univariate analyses showed a greater risk of severe injury in males. This result is in line with a vast majority of studies (6, 8, 11, 21, 25, 26, 37, 69). Traditionally, males have performed more crop production and machinery-related tasks, while females have performed more animal husbandry and domestic tasks (69). Also, females may have lower exposure to hazardous farm work, which may explain their lower rate of injuries (28). For example, higher risk of transportation-related injury to male farmers could be due to higher exposure to transportation tasks (11).The effect of age was reported on the association between gender and injury; the risk was similar for participants of both genders aged less than 20 years, but was higher in the males of older age (26). We did not find a similar effect of age on gender. To determine risk differences between the genders, exposure times dedicated to specific tasks should be considered. However, this information is rarely available as it is difficult and costly to measure.

4.5.3.3 Work time: Our univariate and multivariate analyses showed that the risk of severe injury was greater in operators who worked full-time, especially those who worked 74% – 99% of their time on the farm or ranch. Others have reported similar results (16, 20, 22, 29, 71, 87). Full-time farmers tend to have a greater exposure to potentially dangerous farm-related tasks such as operating machinery, handling animals and transporting goods. The risk of injury increases with the amount of hours worked (28). For instance, injuries mostly occur in spring and fall that are the busy season for cultivation and harvest (21). In contrast, two studies reported a higher risk of injury to part-time farmers (16, 70). Working off-farm may result in extended workdays and fatigue when performing farm-related tasks (70). Full-time farmers may have hired workers to perform tasks for them and this may decrease their exposure to farm work, and related injuries (70). In addition, full-time farmers may be able to prevent injuries using their experience and expertise (71).

4.5.3.4 Primary occupation: In the current study, principal occupation as farming did not emerge as a risk factor for severe injury, but it was found significant for any injury in the adjusted analysis. Operators who worked the majority of their time on farming or ranching had a higher risk of (any) injury than those who worked mostly in other occupations. Because farming/ranching is one of the most hazardous occupations (2, 3, 6, 18, 22, 24, 37, 69, 92, 105, 106), this result is expected. Also, it is possible that those who do farming as a primary activity for living may become accustomed to risks and not pay attention to safety as consistently as they should. However, those who do farming as a hobby or for other secondary purposes may pay better attention to safety due to their lack of familiarity in farming (72). Further research is needed to explore risks and suitable safety-enhancing interventions among farmers who do farming or ranching as their primary business and in those who do so for other purposes.

4.5.3.5 Income from farming: Our univariate analyses showed that principal operators who earned more than 50% of their income from farming/ranching had a higher risk of severe injury. Others have found that the risk of injury increases with farm income (39). High income from farming could be an indicator of higher exposure time and injury risk on the farm (103). Income and work time variables in our study had a similar trend. For example, principal operators who worked more than 50% of their time and earned more than 50% of their income from farming/ranching had a greater risk of severe injury compared to those who worked less and earned less from farming/ranching.

4.5.3.6 Internet access: Our univariate results showed that operators with internet access had a higher risk of severe injury compared to those with no internet. Taattola et al. (69) reported similar results. They discussed that farms using computers and internet access should have a more systematic approach to farm management and safety. However, operators on modern farms also work long hours and thereby have greater exposure to farm-related activities. In addition, they may have higher levels of stress and urgency to get jobs done in spite of the availability of better management tools (69). These circumstances can result in an increased risk of injury. However, internet access was not significant in their as well as our multivariate analyses. The association was confounded by other factors. For instance, among operators who had access to the internet, the injury odds were higher in operators who operated smaller land or were from older age group (65 years and higher).

4.5.3.7 Retirement status: We found that operators who reported being retired had a lower risk of severe injury compared to those who were not. Retired farmers likely have less exposure to farm work, which should decrease the risk of severe injury. This association was not found in the multivariate model as it was confounded by work hours, land acreage, and principal operator's percent of income from farming.

4.5.3.8 Type of agricultural operation: The severe injury rate was higher for operators on ranches compared to those on farms (3.28 vs. 2.58 severe injuries / 100 workers). Further, operators on ranches had 1.42 times greater risk of any injury than operators on farms, after controlling for confounders. These results indicate that ranches likely have more hazardous environment than that of farms. This type of comparison of injury rates among agricultural operations (farms vs. ranches) may be the first of its kind although many studies have found that raising livestock increases the risk of injury (16, 19, 25, 26, 33). In one study of 7,420 households, 20.1% of injuries were attributed to animals (n=1,016 injuries from animals, n=5,045 total injuries) (25). Animal-related injuries are common and severe (25), and therefore working on ranches could be more hazardous than working on crop farms. Further efforts should explore the mechanisms by which injuries occur at ranches.

4.5.3.9 Field crops harvest: The current study showed that operators who harvested field crops such as soybeans, wheat and corn, had a higher risk of severe injury compared to those who did not harvest field crops. However, Belgian researchers have reported that crop growing farmers operate machinery safely compared to farmers who work on mixed farms, leading to decreased risk of injury (72). In the current study, half of the responding farms that harvested field crops also produced animals. Hence, it is difficult to compare the risk by farm type because crop farms and dairy or beef farms have different predominant sources of injury—machinery vs. animals. Both of these sources of injury are common, and mixed farms can have both. In addition, there is a range of machinery used on mixed and animal farms, compared to that used on crop farms. Also, we did not find field crop harvest as a significant risk factor in our adjusted analyses and as a result, our finding based on the univariate analysis may not be well-justified. The association between field crops harvest and severe injury was confounded by operator age, land in use, and principal operator's income from agricultural operation. To characterize the risk of injury from individual sources, future research should explore risk differences across different types of farms.

4.5.3.10 Tractors of 100 horsepower: Univariate analyses showed that having larger tractors (100 hp and over) increased the risk of severe injury and any injury while having 40 – 99 hp tractors increased the risk of any injury. Crop farming is predominant in the central states region, and the vast majority of cultivation, planting, and other field work is done with larger tractors. According to our adjusted analysis, larger tractors were not significantly associated with severe injury. This association was confounded by exposure time and total land in operation; operators who used 100 hp tractor and worked long hours or operated larger land areas had the higher risk of severe injury. To understand injuries from different type of tractors, future studies should address the risk of tractor-related injury from using tractors of different sizes, and should also evaluate the presence and condition of ROPS on tractors, as the requirement of using ROPS on tractors is mandatory only for farms with 11 or greater number of employees (18).

4.5.3.11 Land in use and sales: According to our univariate and multivariate results, operating large land areas was associated with the higher risk of severe injury. Others have reported similar results (15, 16, 38, 70, 107). Those operating larger land areas may work longer hours (38).They may also have higher livestock density and economic pressure to enhance production (8). Larger farms also tend to employ more workers, with more tillable acres, thereby increasing the likelihood of work-related injuries (29). Higher farm sales was a significant risk factor for severe injury in univariate analysis but not in the multivariate analysis. This association was confounded by land in use, work hours and principal occupation (farming/ranching vs. other).

4.5.4 Strengths

This study is based on a surveillance data on agricultural injury of self-employed farmers and ranchers in a seven state area in the central U.S. This study addresses a gap in current national injury surveillance; most of which covers hired workers only. Some national surveillance systems of agricultural operators and workers have existed, but based on current information, will not continue in the future. NIOSH conducted surveillance of young (age < 20 years) and adult farm workers (age > 20 years) from randomly selected stratified sample of 50,000 farm households from across the U.S. in 1998, 2001, 2006, 2009, and 2012 using telephone-assisted interviews, administered by USDA NASS. The surveillance of adult workers (OISPA Survey) for 2012 resulted in annual injury incidence rate of 1.13 injuries / 100 workers among household and hired workers (53). The surveillance of young workers (CAIS) for the same year resulted in the annual incidence rate of 0.81 injuries / 100 workers among household workers (51). These national surveys provided useful information about injury rates and trends specific to targeted populations over time. However, the injury rates in these surveys are much lower than we have observed (6.91 for all injuries and 2.40 for severe injuries, on average). Other large surveys and surveillance systems have produced rates closer to ours and our surveillance may provide a better representation of the true injury incidence in agriculture in the selected states. Our survey also targeted several injury outcomes, and operator and farm characteristics, which allowed us to evaluate a range of risk factors. Detailed information on risk factors helps injury prevention studies to tailor prevention strategies to meet the unique needs of affected subpopulations.

The current study had a high power due to a large sample size that represent 21% of the U.S. farms/ranches. The sample allowed estimation of the risk of injury and identification of common risk factors for injury. The stratified random selection of participants from each of the seven states enabled us to extrapolate the results to the targeted population—farm and ranch operators in the seven-state region. The 3-year data were collected using a validated survey instrument, and a moderate response rate was achieved. Therefore, we believe that results of this study are valid, reliable and generalizable.

The severity of injury was evaluated by the type of medical care, work loss days, and the expenses for the injury. Also the differences between operators with severe injuries and those with minor injuries for common body parts involved in injury and common sources or external causes of injury were reported. For instance, severe injuries commonly occurred to leg/knee/hip while minor injuries commonly occurred to finger. The most common cause of both severe and minor injury was animals. Working surface was the second most common cause of severe injury while hand tools was of minor injury. These findings suggest that the characteristics of injury differ with the type of injury, indicating that severe injuries is a s a special type of injury and hence should be explored further in future studies. Our study provides better information on severe injuries in farm and ranch operator population compared to hospital-based studies or clinical reports. Although hospital-based studies provide in-depth information about the medical aspect of injury and the severity, the data from these studies represent only a fraction of severe injuries that occur on the farm (8, 15, 26). In addition, farm-related risk factor information may not be sufficiently captured from these sources.

One unique aspect of the study was the use of the four injury outcome variables explained earlier to define severity. Severe injury increases the economic burden to the operator and healthcare costs. To reduce this burden, efforts focused on understanding the sources and risk factors for severe injury should be enhanced. The multi-dimensional approach of defining severe injury helps understand severe injury events better and this knowledge can contribute to the success of injury prevention programs.

4.5.5 Limitations

The results should be interpreted taking into account the limitations of the study. The response rate was moderate, but not high. The significant non-response could have led to a selection bias. Attrition of participants could have occurred in either group (injury cases or non-injury cases), resulting in bias towards or away from the null. However, we reduced the attrition bias to some extent by sending a reminder to non-responding farm and ranch operators.

Self-reporting of injury incidents involves the possibility of recall bias, resulting in an incorrect estimation of the risk and/or misclassification of the severity of injury. Some operators could have responded to the survey because they had severe injuries that they could remember, easily, compared to injuries that were minor that they could not readily recall. The concern of recall bias was expressed in other large studies that evaluated risk factors. These included U.S. studies with data collected from five states (21, 22), and Finnish studies that analyzed farm injuries using national administrative records (7, 37). Pratt et al. (15) controlled recall bias by validating the injury outcomes by comparing them to medical records. Because of the large sample size of our study compared to Pratt et al., and other administrative challenges, we were unable to replicate this validation methodology. Indeed, obtaining medical records can be onerous task and can lead to escalation of costs and manpower.

Similar to our study, many researchers used 12 months as a recall period (11, 16, 19, 21, 32, 43, 87), while the recall period was as short as two-months in one study (15). Other U.S. surveillance studies had the recall period of two to three years (51, 53, 54). Tanzanian researchers suggested that the longer recall may underestimate the injury incidence, but it can provide a better picture of the association between risk factors and injury (11). Unlike other research studies, we did not assess the severity of injury using the physical nature of injury (8, 57, 100, 101). In this study, the survey questions did not include probing of responses. Besides, the criteria employed for severe injury was used previously (11, 14, 37). These measures may have overcome the limitation of self-reporting to some extent.

Lastly, we did not investigate the fundamental metric of exposure—work hours spent on individual farm tasks. In the absence of these important data, the risk differences could be confounded. Future studies that evaluate risk factors based on time spent on individual tasks would provide improved estimates of risk of agricultural injuries. No doubt, as Gerberich et al. (21) stated, implementation of such monumental measure is difficult.

CHAPTER 5: CONCLUSIONS AND FUTURE DIRECTIONS

5.1 CONCLUSIONS

The objectives of this study were to evaluate common and emerging risk factors for injury by conducting a systematic review of the available literature and by conducting logistic regression analysis of a three-year annual injury surveillance data from the CS-CASH surveillance system. We evaluated common and emerging risk factors for agricultural injury using available studies. The results of our meta-analysis suggest that intervention efforts should be directed towards farmers who are males, owners/operators, those who had injury in the past, use medication regularly, work full-time, have hearing loss, and have stress or depression symptoms. We also found evidence that older age, higher education, Finnish as native language, non-Caucasian race, on-farm residence, inadequate sleep, high perceived injury risk, challenging social conditions, large farm size, high sales, high income from farming, animal production, large number of hired workers, high cooperation between farms, engaging in unsafe practices, poorly maintained machinery, use of computer and/or internet and accidental exposure to pesticides and/or chemicals to the skin were risk factors for injury. The results of the surveillance study showed that the risk of severe injury tends to be greatest in operators of middle age (45 – 54 years), those who work nearly full-time (75% – 99% of the time), and those who operate farms/ranches that have large land areas (1,000 acres or more).

Agricultural injury is an important public health issue. Agriculture is a hazardous enterprise and farm workers are exposed to risks from machinery, large animals or other sources in their day-to-day lives. Injuries commonly occur in farm and ranch operators, and many of them tend to be severe. Severe injuries can lead to a greater physical and economic burden on the operator compared to minor injury. Further research and prevention efforts should be directed to populations with these risk factors with consideration for co-occurring risk factors. Intervention studies should also consider these risk factors as potential confounders.

5.2 FUTURE DIRECTIONS

We have found the evidence for the 25 risk factors that contribute to agricultural injury. These include demographic, personal/behavioral, farm-related, and safety-related risk factors. Some risk factors such as principal occupation, marital status, experience in farming, off-farm work, health problems, alcohol use, smoking, and safety training did not emerge as risk factors, and need further investigation. Findings of the current study can be used by intervention studies for designing injury prevention strategies. Also, these risk factors can be considered as possible confounders and should be adjusted in agricultural injury investigation and prevention-related research. Risk factor-related information should be updated from time-to-time, because, as agricultural populations, practices, and environments change, risk factors may also change.

To improve our understanding of some risk factors, the following are possible strategies. The risk of age should be assessed by exposure time for workers of different ages. Work time should be assessed in a greater detail than full-time vs. part-time, including seasonal variation in work time. The effects of gender require further study. Work exposure time by task would improve the understanding of risks to each gender. Use of the term ‘principal operator’ in the U.S. Census of Agriculture and studies based on it may lead to an undercount of women owner/operators. Other data sources consider all owner/operators (usually spouses) as equal partners rather than principal and secondary operators. This practice provides a better representation of women farmers.

Race/ethnicity should be evaluated by considering operator status (owner, worker) of workers of different race/ethnicities. Injury characteristics such as worker situation when injury occurred (during work, during other activities) should be considered when analyzing on-farm residence as a risk factor. The quality of management and labor organization should be considered when assessing safety-related risk factors. For determining computer and/or internet use as a risk factor, the effect of farm size, income, sales, number of hired workers, and work hours should be considered. Safety-behaviors should be explored to understand the risk differences in farm operators who consider farming or ranching as primary occupation vs. those who do not. Injury risk in retired farmers can be studied in detail by considering land acreage, farm income and sales, work hours spent on farm-related activities, and principal occupation (farming vs. other). Injury risk on ranches should be explored given that ranches tend to have different environments and populations than those on farms. Sources, characteristics and risk factors for severe and any injury that occur on ranches should be investigated. Although use of ROPS have contributed to the decline of tractor-related fatal injuries, the association between the prevalence of use of ROPS in farms with 11 employees and less and non-fatal injuries that occur from use of tractors of different sizes have not been addressed. Finally, future studies should address mechanisms of non-fatal injuries with the different level of severity that occur in various agricultural populations.

Knowledge of risk factors can be used by farm and ranch operators, health and safety professionals and practitioners, educators, manufacturers of machinery, physicians, veterinarians, insurance professionals, and injury epidemiologists to understand high-risk population for injury. Risk factor information alone may not be sufficient for injury prevention, but it does improve an understanding of agricultural populations that are vulnerable to injury. Intervention researchers can target these populations for effective control of injuries. Each individual can anticipate his/her own risk factors and can take actions to reduce their effect. Strategies for injury prevention work best when the receiver—the farm worker, as well as experts above, work together for a common goal—adopting safe behaviors consistently at work to control preventable adverse events or hazards.

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APPENDIX

Summary of selected studies for the systematic review & meta-analyses. Brief information on the size of the study, location, population targeted, injury types & risk factors found in adjusted analyses is provided.

Study	**Location**	**Design**	**Sample size**	**Population**	**Injury type***	**Risk factors found significant****	**Confounders adjusted in multivariate model*****
Park et al., 2001	USA (Iowa)	Cohort	290	Male farmers	All	Depression test score ≥ 16, worked with animals	Depression score, working with animals, age, education, marital status, smoking, alcohol, farm, health & safety-related risk factors
Xiang et al., 1999	USA (Colorado)	Cross-sectional	113	Male farmers of 60 years old or more	All	Deeply in debt, have high blood pressure, medication used	Status of debt, marriage, blood pressure & medication, alcohol, off-farm work, type of agricultural activities
Thu et al., 1997	USA (Iowa)	Cross-sectional	Survey 1: 2,016, Survey 2,390	Principal operators	All	Survey 1: Have stress, worked in area with bad air quality, increasing cropland acres, education more than high school Survey 2: presence of stress and farm social conditions, age, felt everything at	Survey 1: stress, working in area of bad air quality, cropland size, education, acres in corn production, spouse aged 52 or greater, principal operator aged 54 or less Survey2: same as survey 1 and social condition, feeling of

						effort, felt irritable	irritableness & greater effort
Nogalski et al., 2007	Poland	Cross-sectional	3,791	Patients admitted in hospital as emergency who had agriculture & forestry-related injury	Machinery, fall & animal-related	Male gender, worked with machinery & animals, had falls, moderate & severe injury, have multiple injury	Gender, age, mechanism of injury as machinery, animals, falls & other, multiple injury
Rautiainen et al., 2009	Finland	Cross-sectional	93,550	Farmers insured by Finnish Farmers Social Insurance Institution (Mela)	All injuries, serious injuries (resulted in expenditure of ≥ € 2,000	Older age, Finnish language, higher income, on-farm residence, greater field size, various commodities produced & type of animals	Age, language, income, residence, field size, various, commodity produced, bovines, poultry, sheep, horses
Broucke & Colemont, 2011	Belgium (five provinces)	Cross-sectional	510	Farmers who conducted agriculture, horticulture, animal farming-related activities)	All	Average education	Education, age, gender, farm ownership, main occupation, farming type, safety training
Marcum et al., 2011	USA (Kentucky& South Carolina)	Cohort	1,394	Farmers of 50 years of age & older	All	Increase in 10 years of age, presence of back problems, bronchitis and arthritis, increasing work hours, presence of gender task interaction, suffering from restless nights	Age, education, marital status, state of residence, work hours, gender, gender task interaction, bronchitis, arthritis, restless nights, back problems & a range of other health problems

Moshiro et al., 2005	Tanzania (Dar es Salaam city & Hai District	Cross-sectional	8,188 & 7,035 from Dar es Salaam city & Hai District	Individuals engaged in agriculture, animal keeping & mining	Transport, cut, stab, other, & burn-related	Male gender, rural area & primary education	Gender, age, area, education
Xiang et al., 1998	USA (Colorado)	Cross-sectional	359	Female farmers	All	Depression symptoms present	Depression symptoms, age, experience, sales amount received, agricultural activities, presence of children, farm ownership
Zhou & Roseman., 1994	USA (Alabama)	Cross-sectional	1,000	Farm operators	Incident (injury before last 12 months of study period , residual (injury in lifetime & effects continued)	Younger age, ≥25% of farm work, alcohol consumed, farm ownership , presence of residual injury	Age, work hours, alcohol, farm, status of farm ownership & residual injury ,number of workers on farm, farm size, farm income
Erkal et al., 2008	USA (Minnesota, Wisconsin, North Dakota, South Dakota & Nebraska)	Cross-sectional	7,420	Individuals less than & more than 20 years of age, who sold or produced agricultural goods valued ≥ 1,000	Animal-related	Had injury in the past, greater number of work hours, male gender	Marital status, age, gender, education, history of prior injury, work hours
Day et al., 2008	Australia (Victoria)	Case-Control	252 cases, 504 controls	Cases – males aged ≥ 16 years & had injury during farm work with injury severity	Fatal, non-fatal	Employee/contractor status, increasing hours of farm work per day & per week	Age, season, weekly hours

				score ≥ 2. Controls-age matched community controls			
Erkal et al., 2009	USA (Minnesota, Wisconsin, North Dakota, South Dakota & Nebraska)	Cross-sectional	7,420	Individuals less than & more than 20 years of age, who sold or produced agricultural goods valued ≥ 1,000	Horse-related	Had prior injury, non-white race	Age, gender, marital status, education, state
McGwin et al., 2000	USA (Alabama, & Mississippi)	Cohort	1,246	Caucasian Owners, African American owners, African American workers	All	African American worker, percent-time farming, had prior injury, poor/fair condition of farm machinery	Race, farm ownership
Tiesman et al., 2006	USA (Iowa)	Cohort	1,493	Households in Keokuk county	All	Presence of depressive symptoms, on medication for depression, male gender, have history of prior injury, income ≥ $20,000 a year, less than 7 hours of sleep	Age, marital status, education, CAGE score, depressive symptoms, gender, medication for depression, income, sleep, history of prior injury
Hwang et al., 2001	USA (New York)	Cross-sectional	1,706	Agricultural workers & their families from 12 New York counties	Severe (injury resulted in medical care, work loss or death)	Young age, have hearing loss & joint trouble, greater work hours per day, farm ownership,	Gender, education, years in farming, health insurance coverage, tractor use, age, hearing

						higher sales amount	loss, joint trouble, work hours, farm owner status, sales amount
Carruth et al., 2002	USA (Texas & Louisiana)	Cross-sectional	1,096	Woman farmers	All	Presence of weakness & back pain, greater work-days in a week , greater tractor driving days in a year, presence of large animals, hauls good to market	Weakness, back pain, work-days/week, tractor driving days, large animals, goods hauling
Pickett et al., 1996	Canada (Ontario)	Case-Control	136 cases, 581 controls	Regular or Seasonal farm workers with ≥16 years of age, lived on farm &/or worked full time	All	Farm work exposure ≥ 40 hours/week, comorbid conditions > 2, medication taking alone	Farm ownership, age, education, farm income, use of alcohol, tobacco, farm work exposure hours, comorbid conditions, medication use
Maltais, 2007	Canada	Cross-sectional	2,74,797	Operators were surveyed from farms with gross sales ≥ CAD 10,000	All	Male gender, primary operator status, work hours <20, cattle as farm type, greater land area, greater farm receipts, 12 or more hours of paid work on farm	Gender, operator status, work hours, farm type, land area, farm receipts, paid work hours on farm
Karttunen & Rautiainen, 2013	Finland	Cross-sectional	78,679	Farmers insured by Finnish Farmers	All	Male gender, greater number of	Gender, years of having insurance,

				Social Insurance Institution (Mela)		years of having insurance, lesser number of persons on farm, Finnish language, Farmers Occupational Health Service (FOSH) member, greater farm size, greater farm income, on-farm residence, various regions of Finland	number of persons on farm, language, FOSH membership, farm size, farm income, residence of farm ,various regions of Finland
Craford et al., 1998	USA (Ohio)	Case-control	1,793	Full-time or part-time farmers from cash-grain farms statewide	All	Percentage of time farming >40	Age, total people assisting. Days spent on other farm, education ,marital status, smoking, alcoholic drinks past year, difficulty hearing in right ear, percentage of time farming
Xiang et al., 2000	China	Cross-sectional	1,358	Full-time farmers from study villages	All	Presence of stress & tensions in relationships with neighbors, used pesticide application, greater income per family member	Gender, school years, self-perceived health, use of personal protective equipment, stress, tensions in relationships with neighbors, used, pesticide application use, income

							per family member
Taattola et al., 2012	Finland	Cross-sectional	1,182	Self-employed full-time farmers	All	Male gender, cooperation between farms, computer use in farm management, high perceived injury risk & perceived stress symptoms	Gender, age, cooperation between farms, computer use in farm management, perceived injury risk, perceived stress symptoms
Gerberich et al., 1998	USA (Minnesota, Wisconsin, North Dakota, South Dakota & Nebraska)	Cross-sectional	13,144	Individuals who operated/ worked on farms that generated revenues ≥ $1,000 during one year period	Machine and animal-related	Male gender, marital status as married/aged ≥16 years or separated/widowed/divorced/ aged ≥16 years	Work hours, operation of/worked with equipment, state of residence, age, tillable acreage, farm type , number of large machinery, gender, marital status
Lee et al., 1996	USA (Minnesota, Wisconsin, North Dakota, South Dakota & Nebraska)	Cross-sectional	13,144	Individuals who operated/ worked on farms that generated revenues ≥ $1,000 during one year period	Tractor-related	Older age, male gender, education high school or more, relationship within household as male head or nonfamily, greater number of work hours per week, greater number of annual work hours	Type of farm, farm size, number of tractors in use, age of tractors in use, state of residence, marital status, age, education, relationship within household, work hours per week, annual work hours
Simpson et al., 2004	Canada (Ontario)	Cross-sectional	2,946 married couples from	Farm operators/ workers with farm	All	Life stress as very stressful, life stress	Age, status on farm, exposure to work activities

			2,693 farms	income more than CAD 50,000, produced grain, fruit, vegetables, & didn't use crop pesticides		stratified by employment off-farm: very stressful, sources of stress stratified by money worries: very stressful	such as cultivating, harvesting, disking & heavy lifting
Sprince et al., 2003	USA (Iowa)	Case-control	431 cases, 473 controls	Individuals who operated/ worked on farms that generated revenues ≥ $1,000 during one year period	All	Work hours ≥ 50 per week , presence of large livestock on farm, education more than high school , younger age, medication taken regularly, wears hearing aid	Work hours, large livestock, education, age, medication use, hearing aid use
Sprince et al., 2003 (animal)	USA (Iowa)	Case-control	116 cases, 342 controls	Individuals who operated/ worked on farms that generated revenues ≥ $1,000 during one year period	Animal-related	Work hours ≥ 50 per week , education more than high school , younger age, wears hearing aid, have doctor diagnosed arthritis/rheumatism	Work hours, education, age, hearing aid use, doctor diagnosed arthritis/rheumatism
Sprince et al., 2003 (falls)	USA (Iowa)	Case-control	79 cases. 473 controls	Individuals who operated/ worked on farms that generated revenues ≥ $1,000 during one year period	Fall-related injury	Older age, difficulty in hearing normal conversation with or without hearing aid, have doctor diagnosed arthritis/rheumatism, medication	Age, status of hearing normal conversation with or without hearing aid, doctor diagnosed arthritis/rheumatism, medication use

						taken regularly	
Sprince et al., 2007	USA (Iowa)	Case-control	49 cases. 465 controls	Male farmers who operated/ worked on farms that generated revenues ≥ $1,000 during one year period	Low back	Age less than 45 years, presence of asthma, education more than high school, difficulty in hearing normal conversation with or without hearing aid	Age, asthma status, education, status of hearing normal conversation with or without hearing aid
Sprince et al., 2002	USA (Iowa)	Case-control	205 cases. 473 controls	Individuals who operated/ worked on farms that generated revenues ≥ $1,000 during one year period	Machine -related	Older age, work hours ≥ 50 per week, farm work experience ≤ 25 years, CAGE score high, wears hearing aid	Age, work hours, farm work experience, CAGE score, hearing aid use
Sprince et al., 2008	USA (Iowa)	Case-control	36 cases 473 controls	Individuals who operated/ worked on farms that generated revenues ≥ $1,000 during one year period	Eye	Education > grade 12, married, have farm work experience ≤ 25, wears glasses, aged 20-49 years	Education, age, marital status, farm work experience, glasses wearing status
Choi et al., 2006	USA (Iowa)	Cross-sectional	1,345	Farm, rural non-farm & town households in Keokuk county	All	.Sleep hours < 7.5	Age, sex, general health, current alcohol use, depression status
Nordstrom et al., 1996	USA (Wisconsin)	Case-Control	45 cases 152 controls	Dairy farmers aged 18 years and over in Marshfield	Fall-related	Greater number of hours worked per week (per hour), lived	Greater number of hours worked per week (per hour), lived off-farm, cows

				Epidemiol ogic Study Area		off-farm, cows registered	registered, gender, number of people living on farm
Rautiainen et al., 2004	USA (Iowa)	Cohort (intervention and control)	316	Individuals who operated/ worked on farms that generated revenues ≥ $1,000 during past one year period	All	Aged 45–54 years, general health poor, exposed to chemicals/pesticides, conducted heavy lifting, livestock present, low stress, non-drinking	Off-farm job, year of birth, acres farmed, livestock presence, general health, alcohol consumption, stress, dust and gas exposure, chemical/pesticides exposure, heavy lifting
Hagel et al., 1995	USA (Wisconsin)	Case-control	88 cases 183 controls	Dairy farmers aged 18 years and over in Marshfield Epidemiol ogic Study Area	Machine-related	Greater number of hours worked per week (per hour), lived off-farm, cows registered, cows not fed on barn in summer	Greater number of hours worked per week (per hour), lived off-farm, cows registered, feed status of cows in barn during summer gender, number of people living on farm
Wang et al., 2010	China	Cross-sectional	2,050	Farmers aged 14–70 years from Daur and Han Chinese ethnic groups	All	Current drinker, distilled spirit used, alcohol of 50ml and more used per day, drunk more than 5 times per week, drunk since more than 10 years, got drunk past month	Statuses of drinking, type of alcoholic beverages, amount of alcohol consumed per day, drinking frequency per week, getting drunk past month, drinking since last 10 years

Leppala et al., 2013	Finland	Cross-sectional	565	Members and non-members of Farmers occupational Health Service (FOHS)	All, near-misses	Full-time farmer, Farm size ≥ 80 hectares, main production as animals, dairy cows present, computers used, production plans and goals documented, safety managed well, high injury risk perception, measures to monitor and control risks on farm conducted, FOHS member,	Full time farming status, Farm size, main production, dairy cows, computer use, production plans and goals documentation, safety management, injury risk perception, measures to monitor and control risks on farm, FOHS membership
Lewis et al., 1998	USA (Iowa)	Cross-sectional	390	Principal operators who operated/ worked on farms that generated revenues ≥ $1,000 during one year period		Born after 1940, work limited by impairment, exposed to acids or alkalis	Birth after 1940, work limitation by impairment, exposure to acids or alkalis, other medical, personal, economic, and work practice-related risk factors
McCurdy et al., 2004	USA (California)	Cross-sectional	1,947	Individuals who operated/ worked on farms that generated revenues ≥ $1,000 during past one year period	All	Aged 19–44 years, White ethnicity, hours worked more than 480, percent of time spent on livestock handling 51%–100%	Age, ethnicity, hours worked, percent of time spent on livestock handling, percent of time spent on administrative farm work, Other farm demographic, health, farm-work, and farm-related

							characteristics
Cooper et al., 2006	USA (Texas)	Cross-sectional	267	Migrant farm worker families in Starr County	All	Employer type as contractor/combined, seat-belt used generally, decreasing number of farm jobs	Employer type, general seat-belt use, number of farm jobs, Employer-provided toilet paper
Virtanen et al., 2003	Finland	Cross-sectional	69,629	Farmers insured by Finnish Farmers Social Insurance Institution (Mela)	All	Male gender, Finnish language, farm type as hog and cattle, cultivated land 20 hectares or more, Dairy cows 10 or more	Gender, language, farm type, cultivated land size, number of dairy cows
Pickett et al., 2011	Canada (Saskatchewan)	Cohort	4,769	Residents who had registered their farms in one of the 50 selected rural municipalities	All	Education completed university	Education, economic worry, hours worked, relationship to owner-operator, gender, age, beef commodity produced, safety features on tractors and combines, number of tractors and combines
Layde et al., 1995	USA (Wisconsin)	Case-Control	88 cases 183 controls	Farm residents aged 18 years and over in Marshfield Epidemiologic Study Area	Machine-related	Greater number of hours worked per week/per hour, residence off-farm, cows fed on barn in summer,	Work hours per week/per hour, farm residence, location of cows fed during summer, registration of cows, gender, number of

	cows registered	people living on farm

*- All injuries=No report on subtype of injuries exclusively, **- Statistically significant risk factors found in multivariate analysis (p≤0.05) are listed, ***- adjusted for confounders found in univariate analyses.