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Surveillance of non-fatal agricultural injuries among farm operators in the Central States region of the United States

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SURVEILLANCE OF NON-FATAL AGRICULTURAL INJURIES AMONG FARM OPERATORS IN THE CENTRAL STATES REGION OF THE UNITED STATES

By

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ABSTRACT

Agriculture is a major industry in the U.S. with high rates of fatal and non-fatal occupational injuries. The dynamic nature of the U.S. agriculture industry, regional variations in farming practices, and the diverse workforce make surveillance of injuries challenging. A recent National Academies (U.S.) evaluation reported that data for non-fatal agricultural injury are scarce, and mainly available through national surveys. Limited data are available for employees in the agriculture sector, especially farm owners and operators. The objectives of this study were to- 1) review and evaluate existing survey-based systems for surveillance of non-fatal agricultural injuries on U.S. farms, and 2) determine the incidence of non-fatal agricultural injuries, and risk factors of injuries among farm operators in seven Midwestern states (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota and South Dakota), aka Central States region.

This study evaluated six national-level surveys for non-fatal agricultural injuries using the updated Center for Disease Control and Prevention guidelines for evaluating public health surveillance systems. The system evaluation used information from published reports, peer-reviewed articles, and surveillance system websites. The incidence of injuries and risk factors of injuries were evaluated using data from an annual Central States Farm and Ranch Injury Survey (CS-FRIS) linked with Census of Agriculture data. The CS-FRIS collected data from farm operators in the Central States region in 2011 (n=6953), 2012 (n=6912), and 2013 (n=7000).

The evaluation of surveillance systems identified critical gaps- 1) under coverage of the farm population, 2) insufficient data quality and 3) lack of interoperability among systems reviewed, and with other data sources. The analysis of CS-FRIS data estimated an average 44,887 non-fatal agricultural injuries (6.8/100 operators) per year among farm operators in the Central States during 2011-13. About 88% of injuries were work-related, and 73% required professional medical care. Male gender, age

between 35 and 64 years, farming occupation, and cattle and hog farming increased the risk of injury. In conclusion, the national-level survey-based systems in the U.S. have limited usability attributed to data limitations. The analyses of CS-FRIS data identified males, middle-aged groups (35-64), full-time farmers, and livestock farmers as high-risk groups for farm injuries, and injury prevention efforts for farm operators in the Central States region should consider these findings.

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Acronyms

AgFF -Agriculture, Forestry, Fishing and Hunting

BLS - Bureau of Labor Statistics

CAIS - Children/youth Agricultural Injury Surveillance

CAIPI - Childhood Agricultural Injury Prevention Initiative

CDC - Center for Disease Control and Prevention

CFOI - Census of Fatal Occupational Injuries

CS-CASH – Central States Center for Agricultural Safety and Health

USDOL – United States Department of Labor

ERS - Economic Research Service

NASS – National Agricultural Statistics Service

NIOSH - National Institute for Occupational Safety and Health

NHIS - National Health Interview Survey

NEISS - National Electronic Injury Surveillance System

OISPA - Occupational Injury Surveillance of Production Agriculture

SOII - Survey of Occupational Injuries and Illnesses

USDA - United States Department of Agriculture

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CHAPTER 1

INTRODUCTION

Agriculture is one of the most hazardous industries in the U.S. and globally. The farmers, farm workers, and those living or working in the U.S. have high rates of fatal and non-fatal injuries incurring the medical cost and cost attributed to the loss of work time and farm production, which are a public health concern. To reduce and prevent agricultural injuries, reliable, accurate and timely surveillance data on agricultural injuries are necessary. Surveillance data can help detect and monitor any trends in agricultural injuries over time. Surveillance data are useful for designing data-guided injury prevention and controls, and assessing the effectiveness of these prevention programs.

Currently, the U.S. Census of Fatal of Occupational Injuries (CFOI) is a public health surveillance system that provides reliable and accurate state, regional and national-level data for all work-related fatalities, including those in agriculture. However, there is limited reliable and accurate data for non-fatal agricultural injuries in the U.S. Surveillance data for non-fatal agricultural injuries mainly come from national-level injury surveys, many of which are periodic, and known to undercount injuries, mainly in self-employed farmers, farm owners and unpaid family members (National Institute for Occupational Safety and Health [NIOSH], 2012). In addition, there are several information gaps in current non-fatal agricultural injury surveillance data, one of which is a lack of reliable state- and regional-level estimates for injuries and risk factors for injuries. In lieu of reliable and accurate state or regional data for non-fatal agricultural injuries, it is difficult to monitor any emerging trends in injuries and risk factors for injuries, and assess the effectiveness of injury prevention programs that help decide resource allocation and re-allocation to maintain the health of the population, especially for high agricultural output regions.

Three research studies in this dissertation addressed some of the above-mentioned gaps in knowledge on surveillance of non-fatal agricultural injuries in the U.S. First study reviewed and evaluated national-level survey-based systems for surveillance of non-fatal agricultural injuries in the U.S. The review study identified areas of concern when using currently available surveillance from national-level surveys and briefly discussed other potential data sources for surveillance of non-fatal agricultural injuries.

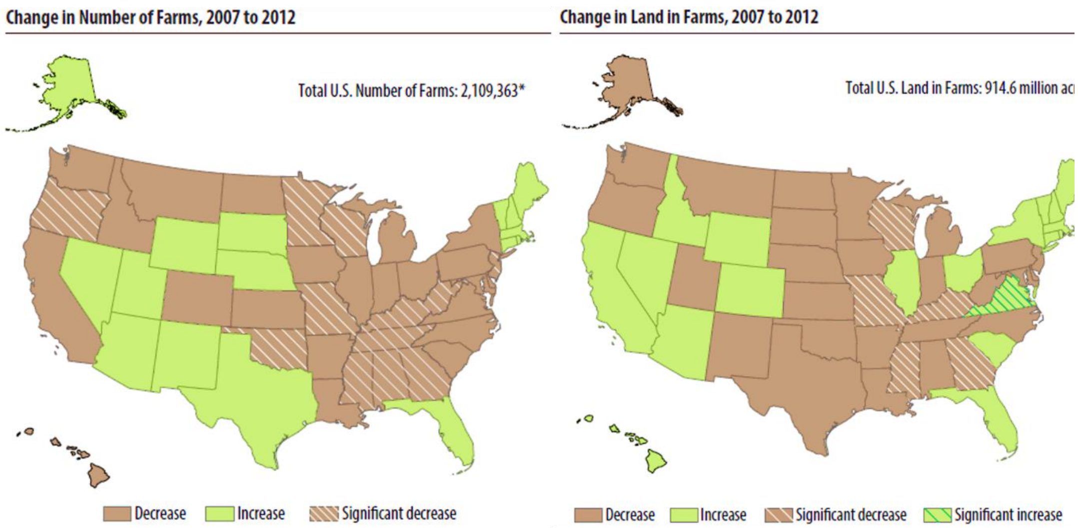
The second and the third studies were a secondary data analyses project using a unique population-level dataset for non-fatal agricultural injuries and other operator and farm characteristics in the seven Midwestern states of the U.S.- Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota; these seven states are also termed as Central States region in this research. The secondary data analyses in the second study calculated population-level estimates of injuries and injury rates by state, farm operator characteristics and farm parameters like farm size, sales, and different types of farm commodities. Lastly, the secondary data analyses in the third study evaluated the risk factors of non-fatal agricultural injuries among farm operators in the Central States region.

This dissertation includes five chapters. Chapter 1 provides a snapshot of the agriculture industry in the U.S. including types of farms, their production activities and demographic shift in farm operator population. This chapter also gives a brief introduction on fatal and non-fatal work injuries in the U.S. agriculture, risk factors of agricultural injuries, and a short introduction to agricultural injury surveillance in the U.S. The first chapter concludes with knowledge gaps in non-fatal agricultural injury surveillance and research, and the specific aims of this dissertation research. The second chapter covers methods, findings, and discussion of findings from the review and evaluation study. The third and fourth chapters each describe the methods, findings, and discussion of findings from the secondary data analyses project to estimate the incidence of and risk factors for non-fatal agricultural injuries among farm operators in the Central States region. The final chapter in this dissertation i.e. chapter 5 discusses the implications of findings from each study conducted in this research, research limitations, and future directions for surveillance of non-fatal agricultural injuries in the Central States region as well as in the U.S.

1.1 The agricultural industry in the U.S.

Agriculture is a major industry in the U.S., and agricultural products from the U.S. hold a strong position in the global trade market. In 2014, U.S. exported agricultural goods worth $152.5 billion. In 2014, China was the largest importer of U.S. agricultural goods ($25.7 billion, 17% of all U.S. exports). Some of the other large markets for U.S. agricultural products include Canada ($21.8 billion), Mexico ($19 billion), Japan ($13 billion) and European Union (EU) ($12 billion) (United States Department of Agriculture [USDA] Economic Research Services [ERS], 2015a). U.S. mainly exported livestock, poultry and dairy ($34 billion) especially beef and veal ($6 billion) and pork ($5.7 billion), oilseeds like soybean ($24 billion), and grains like corn ($11 billion), and these commodities are mainly produced in the Midwestern region of the U.S. comprising of states like Iowa, Minnesota, Missouri, Nebraska, North Dakota, etc. (USDA-ERS 2015a, USDA, 2014a). According to the most recent, i.e. the 2012 Census of Agriculture (Ag Census), both the number of farms and land in farms in the U.S. decreased, since 2007. There were approximately 2.2 million farms in 2007, which reduced to 2.1 million farms in 2012 (USDA, 2014a). Although, there was an overall decline in the number of farms and land in farms, not all states showed a similar pattern. The map to the right in Figure 1 shows the change in the number of farms in the U.S. since 2007 by states in the U.S. The states shaded in brown with white stripes indicate a significant decrease in the number of farms between 2007 and 2012. Similarly, the map to the left in Figure 1 shows the trend in the U.S. land in farms since 2007 by states in the U.S. In the map to left, we can see that the eastern state of Virginia (shaded green with blue stripes) had a significant increase in the land in farms compared to all other U.S. states. On another hand, the state of Kentucky (shaded brown with white stripes) on the right border of the state of Virginia showed a significant decrease in the land in farms since 2007 (Figure 1). This indicates a geographical variation in the number of farms and land in farms in the U.S.

Figure 1: Change in number of farms, and land in farms in the U.S., 2007 to 2012



Source: 2012 USDA Census of Agriculture. U.S. farms and farmers. Available from https://www.agcensus.usda.gov/Publications/2012/Preliminary_Report/Highlights.pdf Accessed June 17, 2016.

The 2012 Ag Census reported that in contrast to the overall decline in the number of farms, the average farm size in 2012 (434 acres) increased by 3.8 %, since 2007 (418 acres). Agricultural output also increased over time. U.S. farms sold $297 billion worth of agricultural products in 2007, which increased by 33% in 2012 with sales of $395 billion (USDA, 2014a). Despite the decline in a number of farms, agricultural production in the U.S. continued to grow higher compared to previous years to meet the increasing demand for food and energy.

1.1.1 Types of farms in the U.S.

Every five years, the U.S. Ag Census enumerates the number of farms and collects information on production activities, sales of agricultural commodities produced, and operator demographics. The most recent U.S. Ag Census was in the year 2012, and the next one will be in 2017. The Ag Census collects data from all 50 states in the U.S. including the District of Columbia. The Ag Census defines a farm as "any place, which produces and sells or normally would sell agricultural products worth $1000 or more annually". (USDA, 2014a). The U.S. Department of Agriculture's Economic Research Service (USDA-ERS) further categorizes farms based on ownership for research and policy development purpose.

Farms are categorized as- family and non-family farms. Farms owned by an operator or individuals related to the operator are defined as family farms. Non-family farms are farms owned by a corporate establishment. Based on annual gross cash farm income (GCFI), family farms are further divided into small family farms (GCFI <$350,000), mid-size family farms (GCFI $350,000-$999,999) and large-scale family farms (GCFI ≥$1,000,000). Based on the primary occupation of the principal operator and GCFI, USDA's ERS classifies small family farms into four groups. The first group of small family farms is retirement farms which are the operated by retired farmers. The second group is off-farm occupation/residential/lifestyle farms, operated by farmers whose primary income comes from off-farm employment. The third group is low sales farming occupation farms, where operator's primary occupation is farming and GCFI is less than $150,000. Lastly, the fourth group of small family farms is moderate sales farming occupation farms, where the operator's primary occupation is farming and GCFI ranges from $150,000 to $349,999 (Hoppe & MacDonald, 2013). The majority of U.S. farms are family farms, mainly small family farms.

According to the 2012 Ag Census, family farms constituted 97% of all farms in the U.S. Approximately 88% of them were small family farms that accounted for 20% of the agricultural production. In contrast, mid-size and large-scale family farms made up only 8% of all U.S. farms but contributed 65% of the nation's agricultural production (USDA, 2014b). Not all states have a similar proportion of small, mid-size and large-scale farms. Where states like Utah (46%), Oklahoma (45%), Tennessee (44%), Indiana (43%), Kentucky (43%), and Texas (43%) had the highest proportion of small family farms; large-scale family farms were highest in North Dakota (11%), Nebraska (8%), South Dakota (7%), Iowa (7%), and California (6%) (USDA, 2014b).

1.1.2 Farm commodities produced by U.S. farms

U.S. farms show a diversity in agricultural commodities produced. In 2012 Ag Census, the top five commodities sold by U.S. farms were cattle and calves ($76.3 billion), corn ($67.3 billion), poultry and eggs ($42.8 billion), soybeans ($38.7 billion) and milk from cows ($35.5 billion) (USDA, 2014a). Besides producing crops and livestock, farms support rural development by engaging in other activities such as energy production, agritourism, value-added agriculture and direct marketing to the consumers (Bagi & Reeder, 2012). To reduce economic and production risks like pests and diseases affecting a crop, farms diversify their production by producing more than one major commodity. Where small family farms specialize mostly in single commodities like cattle and calves or field crops, mid-size and large family farms produce multiple commodities per farm (Hoppe, 2014). Similar to other farm attributes, production and sale of commodities also vary by state. The Midwestern states like Iowa, Nebraska, Minnesota, Kansas, and North Dakota are some of the top field crop and livestock producing states, whereas states like California, Florida, Washington, Idaho, and Arizona were the top five vegetable producing and selling states. Field crops include grains and oilseed crops such as corn, soybean, wheat, barley, rice, etc. (USDA, 2014a). The variation in types of commodities produced by different regions of the U.S. provides a glimpse of geographic diversity in U.S. production agriculture.

1.1.3. Operators on U.S. farms

U.S. farms not only vary in size, sales, and production practices, but also in its workforce. Approximately, 3.2 million farmers operated 2.1 million farms in 2012 (USDA, 2014). The U.S. agricultural workforce includes farm operators, family members, and hired farm workers.

According to the Farm Labor Survey (FLS) of the USDA's National Agriculture Statistics Service (NASS), hired workers make up 1/3rd of the agricultural workforce and the rest 2/3rd are self-employed farm operators and their paid and unpaid family members (USDA ERS, 2014b). A farm operator is "a person who operates a farm, either doing the work or making day-to-day decisions and may be an owner, a member of the owner's household, a hired manager, a tenant, a renter or a sharecropper" (USDA, 2014a). For reporting and research purposes, Ag Census classifies farm operators as principal, second and third operators. Generally, the second operator is the spouse and third is a family member or a helper who lives or works on the farm. Over the years, there has been a notable change in farm operator population in the U.S. agriculture.

The average age of farm operator is rising. The average age of all (principal, second, and third) farm operators was 56.3 years in 2012, up by 1.4 years since 2007, and continuing a 30-year trend of gradual increase. Compared to 2007, the number of Hispanic-operated farms was up by 21% in 2012. In 2012, the majority of farm operators were males (70%) (USDA, 2014a). Although farm operators are mainly self-employed and spend most of their time managing activities on the farm, a high proportion of farm operators had off-farm jobs as well. In 2012 Ag Census, 56% farm operators reported primary occupation other than farming (56%) (USDA, 2014a). One of the main reason for having an off-farm job was employment-based health insurance coverage. According to the USDA's Agricultural Resource Management Survey (ARMS), 57% of farm household members had access to employment-based health insurance from their off-farm jobs in 2011 (USDA-ERS, 2015). Based on the most recent 2012 Ag Census report, we now know that the workforce demographics in the U.S. agriculture is changing. Increasing age, additional work stress attributed multiple jobs, and increasing racial and ethnic diversity may influence and change the safety and health situation and needs of the farming populations over time.

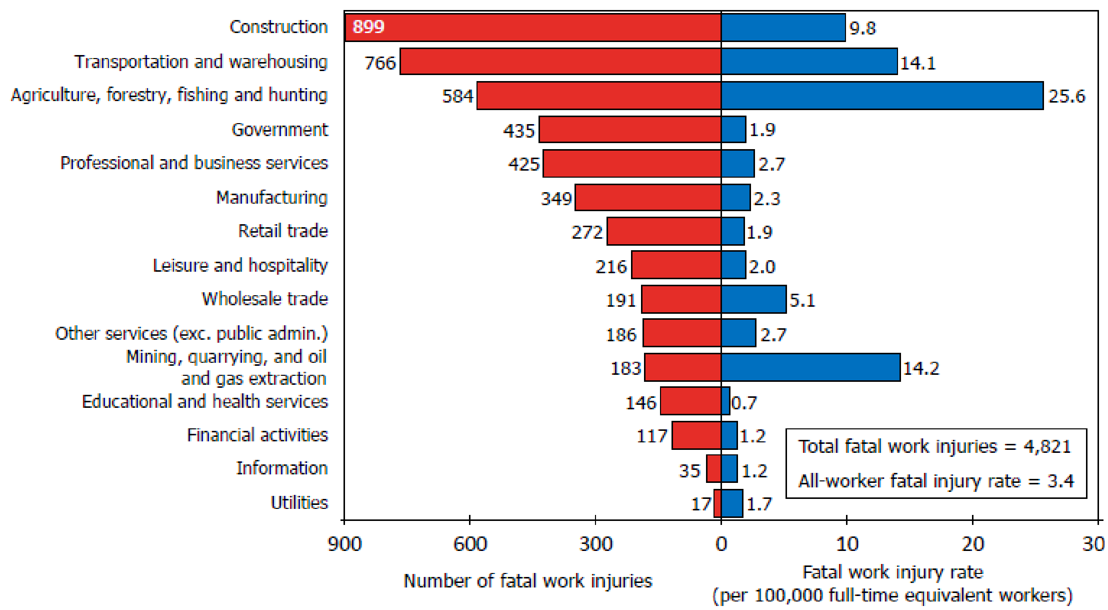
To summarize, the structural and geographic diversity in farm production and farm workforce makes the U.S. agriculture, a unique industry sector compared all other industries in the U.S.

1.2 Burden of agricultural injuries

1.2.1 Fatal agricultural injuries

Agriculture is one of the most hazardous industries in the U.S. According to the U.S. Census of Fatal Occupational Injuries (CFOI), the rate of fatal injuries was highest in the agriculture, forestry, fishing, and hunting sector in 2014 (25.6 fatal injuries per 100,000 full-time equivalent (FTE) workers) (Figure 2). This rate did not include unpaid family members and children/youth under the age of 16 years. In an agricultural mortality study, Waggoner et al. (2011) observed that deaths from injuries were more frequent than deaths from other health conditions such as cancers, heart diseases, and diabetes in agricultural populations.

Figure 2: Number and rate of fatal occupational injuries, by industry sector, 2014



Note: Fatal injury rates exclude workers under the age of 16 years, volunteers, and resident military. Source: 2014 National Census of Fatal Occupational Injuries, U.S. Bureau of Labor Statistics, U.S. Department of Labor. Available from http://www.bls.gov/iif/oshwc/cfoi/cfch0013.pdf Accessed June 17, 2016.

Rautiainen & Reynolds (2002) observed that despite the decline in the number of agricultural fatalities since the 1990s, the rate of agricultural fatalities remains high. In 1999, there were 22.5 fatalities per 100,000 hired workers in agriculture (Rautiainen & Reynolds, 2002). Another study by John Myers and group examining CFOI data on agricultural fatalities for the years 1994 through 2004, reported an average annual fatality rate of 25.4 per 100, 000 workers compared to 3.9 per 100,000 workers in all other U.S. industries. The authors also reported that, the agricultural fatality rates were especially high among farmers and farm workers in age group 55 years and older (45.8/100,000 workers) from the Northeast (66.0/100,000 workers) and the Midwest (57.7/100,000 workers) regions of the U.S., and who worked on crop farms (70.3/100,000) (Myers, Layne, & Marsh, 2009). This tells us that not all farmers and farm workers show similar patterns in fatal agricultural injuries.

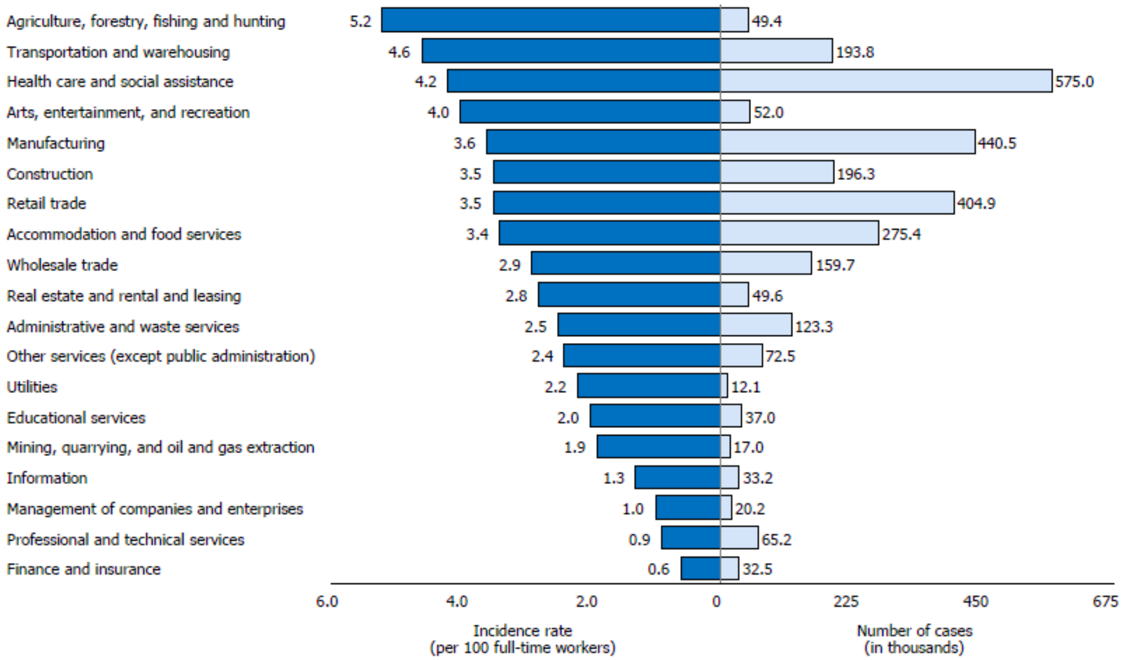
Although there is limited literature estimating the cost of agricultural injuries in different farm populations, recently Landsteiner et al. (2016) examined the economic burden of agricultural injuries in the U.S. state of Minnesota using hospital discharge data and CFOI. The authors reported that an estimated cost of fatal agricultural injuries in Minnesota during 2004-2010 ranged between $8.6 and $17.4 million (as per dollar value in 2010). The majority of the cost of farm injuries was due to indirect costs, which included loss of production or work time that the decedent would have contributed to the society if the incident did not happen. Besides adults, deaths in farm children/youth due to farm exposures are also common.

In the absence of a comprehensive database for agricultural fatalities in children/youth, Goldcamp et al. (2004) examined death certificate data from 1995-2000 for all 50 states in the U.S. collected by National Institute for Occupational Safety and Health (NIOSH). The authors estimated an annual fatality rate of 9.3 deaths per 100,000 youths under the age of 20 years from 1995-2000. Later in 2012, Zaloshnja et al. examined 2001-2006 death certificate data and reported 84 deaths per year among children and youth between 0-19 years of age, that incurred a total cost of $420 million (as per dollar value in 2005) per year. The total cost comprised of medical ($0.5 million), work loss costs ($140 million), and cost of suffering, pain, disfigurement, and lost the capacity to function physically and perform daily activities of life ($280 million). About half (51%) of fatal injuries occurred in the age group 15-19 years. The authors also documented that overall 86% agricultural fatalities in children and youth were not work-related. Agricultural fatalities during 2001-2006 in children and youth between 0-19 years of age mainly occurred as a result of exposure to farm machinery, and fire and explosions (Zaloshnja, Miller, & Lawrence, 2012). Findings from the reports presented in this section highlight the magnitude of fatal agricultural injuries in both adult and child/youth farm populations. Besides the economic loss, the loss of a loved one in a fatal farm incident can have a lasting social and emotional impact on the farm families. In addition to fatal injuries, non-fatal injuries also contribute to the overall burden of agriculture injuries on U.S. farms.

1.2.2 Non-fatal agricultural injuries

Similar to fatal injuries, non-fatal injury rates were also highest in agriculture, forestry, and fishing compared to all other private industries in the U.S. in 2014 (Figure 3). In 2014, the U.S. Survey of Occupational Injuries and Illnesses (SOII) reported a rate of 5.2 non-fatal work-related injuries per 100 full-time hired worker in agriculture compared to a rate of 3.4 non-fatal work-related injuries per 100 full-time workers in all other private industries in the U.S. (Bureau of Labor Statistics [BLS], 2015a). The SOII collects data on work-related non-fatal injuries and illnesses among employees in all industries in the U.S. However, in agriculture SOII data are collected only from hired workers, and those who are self-employed (the majority of the workforce in this sector) are excluded (BLS, 2012).

Figure 3: Incidence rates and numbers of non-fatal occupational injuries by private industry sector, 2014



Source: 2014 Survey of Occupational Injuries and Illnesses, U.S. Bureau of Labor Statistics, U.S. Department of Labor. Available from http://www.bls.gov/iif/oshwc/osh/os/osch0054.pdf Accessed June 17, 2016.

From all non-fatal work-related injuries, some injuries can be minor requiring no medical attention, while some can be near-fatal resulting in temporary to permanent disability and lost work time. Myers et al. (2009) examined the data from the 2001 and 2004 Occupational Injury Surveillance for Production Agriculture survey and reported an estimated 83,940 non-fatal injuries among adults 20 years and older per year. Of these 83, 940 non-fatal injuries, 32% occurred in farmers of age 55 years and older and nearly half of the injuries in older farmer resulted in 14 or more restricted work days compared to farmers younger than 55 years of age. On another hand, a review study by Deboy et al. (2008) estimated a range of disability prevalence in U.S. farm populations using multiple data sources. The authors reported that out of 11.5 million people in the agricultural workforce and farm households, 1.6 million had a disability in 2006. Severe or disabling also incur the high medical cost of care and cost of lost work time.

Landsteiner et al. (2016) reported that the cost of hospitalized farm injuries in the U.S. state of Minnesota ranged between $4.6 million and $7.1 million (as per dollar value in 2010) during 2004-2010; total annual cost for non-hospitalized farm injuries during 2004-2010 was an average $5.1 million. Missikpode et al. (2015) examined the Iowa state trauma registry data and observed an annual increase of 20% in the number of hospitalizations and emergency department visits for severe/critical non-fatal injuries between 2005 and 2013. Another study looked at the patterns in payments for agricultural injuries seeking medical care and examined 295 agricultural injury hospitalizations in the state of Kentucky during 2003-2007. The author reported that Medicare or Medicaid covered 38% (112) of hospitalized agricultural injuries (Costich, 2010). These statistics indicate that increasing number of non-fatal injuries in agriculture are requiring medical care, ultimately contributing to the rising health care cost burden, especially on public funding sources. Like adults, non-fatal injuries in farm children and youth are a public health concern.

Hendricks & Hendricks (2010) examined the data from the Childhood Agricultural Injury Surveillance (CAIS) survey and reported a non-fatal injury rate of 13.9 injuries per 1000 children/youth between ages 0-19 working, living or visiting U.S. farms in 1998. This non-fatal agricultural injury rate among children/youth in the age group 0-19 years, declined by 34% in 2006 (9.8/1000). Although there was an overall decline in injury rates among children/youth in 0-19 years old, this decline varied by age and gender. In males, the decline in injury rates was only significant in the age group 0-10 years (rate ratio=0.6, p=0.01). In females, though not statistically significant, non-fatal injury rates among females specifically between ages 16 to 19 in 2006 showed an increase from baseline i.e. 1998 (rate ratio=2.4, p=0.1). These trends indicate a gender disparity in incidence of non-fatal injuries among farm youth. Another study looking at the cost of non-fatal injuries in farm youth (0-19 years) using 2001-2006 CAIS data reported an average 26, 570 injuries per year during 2001-2006 costing $1,003 million (as per dollar value in 2005). This cost includes medical ($93 million), work loss costs ($373 million), cost of suffering, pain, disfigurement, and lost the capacity to function physically and perform daily activities of life ($537 million). Out of these 26, 570 injuries annually, 29% were farm work-related (Zaloshnja et al., 2012). Although, no accurate estimates are available on the prevalence of disability or cost of non-fatal injuries, the burden of non-fatal injuries among farm populations (adult and youth) is substantial.

Based on the findings from reports cited in this section (non-fatal injuries), we can conclude that often non-fatal injuries incur higher costs to the health care system, and can influence the quality of life post-injury.

1.2.3 Risk factors of agricultural injuries

The World Health Organization (WHO) defines a risk factor as "any attribute, characteristic or exposure of an individual that increases the likelihood of developing a disease or an injury" (WHO, 2015). Agricultural safety and health researchers have identified several risk factors for injuries in adult and youth farm populations. They include male gender, previous history of injury, being a farm owner, full-time farmers, farm income and size, livestock farming, hearing loss, stress and depression, as well as exposure to specific farm tasks or hazards (Thomas A. Arcury et al., 2012; Jadhav, Achutan, Haynatzki, Rajaram, & Rautiainen, 2015; Stephen A. McCurdy et al., 2013; Rautiainen, Ledolter, Donham, Ohsfeldt, & Zwerling, 2009). Besides these known risk factors, several other parameters may influence the occurrence of injuries such as farm work environment or a particular method for performing farm tasks or etc. However, lack of reliable population-level data on such parameters limits further exploration.

Livestock animals and farm machinery like tractors are some of the most common sources of agricultural injuries. Murphy et al. (2010) who examined the Census of Fatal Occupational Injuries (CFOI) data reported the significantly higher risk of fatal tractor overturn injuries for farmers in age groups 45-54, 55-64, 65-74 and ≥75 years (vs. 25-34 years). Similarly, another study looking at CFOI data found that fatal tractor overturns injuries were higher on crop farms (vs. livestock), and farms in the Midwest, Northeast and South regions (vs. West) of the

U.S. (Myers & Hendricks, 2010). Douphrate et al. (2006) analyzed 10-years of Colorado's workers' compensation claim records, and reported that claims associated with livestock handling were most severe, had highest-cost, and 78% of them occurred on large operations. Some of the other factors contributing to injuries in farm populations include poor postures at work, longer work hours, fatigue and sleep.

Davis & Kotowski (2007) reported poor postures, and types of farm tasks performed as one of the contributing factors of musculoskeletal disorders among farmers and farmworkers. DeWit et al. (2015) found that farmers in the Saskatchewan Farm Injury Cohort (SFIC) who worked for 35 hours or more per week had ten times (95% CI: 2.2-47.5) higher risk for injuries compared to those who worked less than 10 hours per work. Besides long work hours, farmers with excessive daytime sleepiness and sleep deprivation in the SFIC were more likely to get injured (OR=1.3, 95% CI: 0.9-2.0) and poor overall health status (OR=2.2, 95% CI: 1.5-3.3) compared to those who did not indicate excessive daytime sleepiness (King et al., 2014). In addition, researchers also found that farmers in SFIC who reported high levels of perceived economic worry had poor farm safety practices (Hagel, Pahwa, Dosman & Pickett, 2013). The reports cited here suggest that myriad of parameters influence increase the risk of farm injuries among farmers. To prevent and control injuries, it is important to collect reliable and accurate data on farm injuries and risk factors for injuries in some of the high-risk farm populations such as full-time farmers, older (55 years and above) and youth farmers (19 years and younger), livestock farmers, etc. through public health surveillance.

Surveillance data can help track injuries and known risk factors for injuries as well as help identify any emerging risk factors for injuries or vulnerable farm populations, and using this information, we can develop tailored interventions, and evaluate their effectiveness over time, ultimately making farm families and farm workers safer and healthier.

1.3 Surveillance of agricultural injuries in the U.S.

According to the U.S. Center for Disease Control and Prevention (CDC) public health surveillance is "an ongoing systematic collection, analysis, and interpretation of health-related data essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to those who need to know. The final link in the surveillance chain is the application of these data to prevention and control" (CDC, 1986). Since the establishment of the Occupational Health and Safety Act in 1970, occupational health surveillance became an essential part of the activities of the National Institute for Occupational Safety and Health (NIOSH) and the U.S. Department of Labor (USDOL).

In 1972, the USDOL's Bureau of Labor Statistics (BLS) designed the annual Survey of Occupational Injuries and Illness (SOII). Later in the 1990s, BLS implemented the Census of Fatal Occupational Injuries and Illnesses (CFOI) in all 50 states, including the District of Columbia. Both CFOI and SOII provide occupational fatal and non-fatal injury data for all U.S. industries, including agriculture, with some limitations. Soon after CFOI, NIOSH developed the Traumatic Injury Survey of Farmers (TISF) and collaborated with the USDA's NASS to administer the surveys. TISF was conducted in 1993, 1994, and 1995 (Gunderson et al., 1990; Hard, Myers, & Gerberich, 2002). Between 1995 and 1999, several regional studies by academic researchers provided estimates on fatal and non-fatal agricultural injuries and indicated the need for continued surveillance of agricultural injuries (Hard et al., 2002; Mongin et al., 2007).

To address one gap, 1999 marked the implementation of the Childhood Agricultural Injury Prevention Initiative (CAIPI). Under CAIPI, the NIOSH implemented the Childhood Agricultural Injury Survey (CAIS) for surveillance of agricultural injuries in children/youth on U.S. farms. In conjunction with CAIS, NIOSH initiated Occupational Injury Surveillance for Production Agriculture (OISPA) survey for adults working in U.S. production agriculture and discontinued TISF. OISPA and CAIS, both were conducted every three years and collected injury and demographic data from a nationally representative sample (Hard et al., 2002). Other than injury surveys, NIOSH conducts fatality investigations in states participating in federal and state-based Fatality Assessment and Control Evaluation (FACE) programs. The FACE programs conduct on-site fatality investigations of high-risk scenarios for workplace injuries (NIOSH, 2014c) In addition, NIOSH funds agricultural safety and health centers (Ag Centers) across the U.S. These Ag Centers conduct surveillance activities via grant-funded projects to examine the injury burden and emerging issues in farm safety and health. The Ag Centers also provide education and outreach to farm communities in the geographic regions they serve.

1.4 Knowledge gap

Agriculture, forestry, fishing and hunting (AgFF) is the most dangerous industry sector in the U.S. Within AgFF, the agriculture subsector, sometimes called production agriculture, employs the majority of the workforce (Henderson, 2013; USDA, 2014a). The dynamic nature of the industry and its workforce, structural and geographic diversity, and seasonality of work make surveillance of agricultural injuries challenges. To date, SOII has focused primarily on surveillance of injuries and illnesses in hired farm workers. The NIOSH surveys, OISPA and CAIS have collected some information on self-employed farmers, hired workers, visitors and children/youth on farms. However, a recent NIOSH AgFF program review report indicated that NIOSH surveys OISPA and CAIS have several limitations in data quality attributed to low response rates and need further examination (Gunderson, 2012). Existing data, specifically for non-fatal injuries and its risk factors, medical cost, and disabilities resulting from injuries are limited, and based on periodic surveys. This suggests that there is a lack of reliable and valid data for non-fatal agricultural injuries, particularly among farm owners and self-employed farmers and ranchers.

In addition to the data gap, there are no studies available on comprehensive review and evaluation of U.S. national surveys providing surveillance data for non-fatal agricultural injuries. Periodic evaluation of public health surveillance system attributes such as simplicity of operating a system, the system's ability to integrate with other existing systems (i.e. flexibility), acceptability, quality, representativeness, and timeliness of systems providing surveillance data are essential to identify critical areas for improvement in the system (German et al. 2001).

As discussed earlier in this chapter, agricultural production activities, farm workforce, and occurrence of injuries vary from region to region in the U.S. Earlier studies reported higher rate of non-fatal injuries among adult and youth farm operators in Midwestern states compared to states in the Northeast, South and West region of the U.S. (Forst & Erskine, 2009; Goldcamp, Myers, Hendricks, Layne, & Helmkamp, 2006; Gross, Young, Ramirez, Leinenkugel, & Peek-Asa, 2015; Jawa et al., 2013; Rautiainen & Reynolds, 2002; Sanderson et al., 2006; Zaloshnja, Miller, & Lawrence, 2012). The 1999 Regional Rural Injury Study-II collected injury data for farm operators and their family members from five Midwestern states- Minnesota, Nebraska, North Dakota, South Dakota, and Wisconsin. Among all the five states, the RRIS-II documented highest rate of farm injuries in the state of North Dakota (90.3 farm injuries per 1000 persons) (Mongin et al., 2007). Recently, Landsteiner et al. (2015) reported 14.0 to 18.5 serious farm-related injuries requiring medical care per 1000 persons living or working on farms in Minnesota, per year between 2000 and 2011. Another research group reported 83 injuries requiring trauma care per 100,000 hired workers, farm operators and ranchers in Iowa, per year during 2005-2013 (Missikpode et al., 2015). The state-based hospital discharge data and trauma registry data, regional injury survey (RRIS-II), indicate high rates of farm injuries among the farming population in Midwestern states of the U.S.

Existing national-level surveillance systems CFOI and SOII, both provide state-level data on injuries in agriculture. However, not all states covered by CFOI and SOII. For example, no CFOI data are available for high agricultural output states like North and South Dakota. Similarly, SOII estimates on injuries for one state cannot be compared with another due to methodological issues (Wiatrowski, 2014). Given the high concentration of farms, high agricultural production output, and high rates of injuries in Midwestern states of the U.S., it is vital to examine the incidence of injuries, risk factors for injuries, and emerging issues among farm populations in this high agricultural output region.

1.5 Dissertation research and specific aims

The current research project provides a comprehensive report on survey-based non-fatal agricultural injury surveillance systems in the U.S. The current research project also estimated the incidence of non-fatal agricultural injuries in seven Central States i.e., Iowa (IA), Kansas (KS), Minnesota (MN), Missouri (MO), Nebraska (NE), North Dakota (ND), and South Dakota (SD), and identified the risk factors for agricultural injuries.

The comprehensive report on survey-based non-fatal agricultural injury surveillance systems in the U.S. used data from existing literature and published documents by organizations maintaining the surveillance systems. Whereas the incidence of and risk factors for non-fatal agricultural injuries was evaluated through secondary data analysis of the Central States Farm and Ranch Injury Survey (CS-FRIS). The CS-FRIS collected data on injuries from farm operators in the seven Central States annually. The Central States Center for Agricultural Safety and Health (CS-CASH) at the University of Nebraska Medical Center in Omaha, Nebraska is one of the ten NIOSH-funded Ag Centers in the U.S. CS-CASH works with the agricultural community in the Central States region and conducts research, intervention, education and outreach activities. Surveillance of agricultural injuries is an integral part of the Center's research. CS-CASH collaborated with the United States Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS) Iowa field office and initiated the annual Central States Farm and

Ranch Injury Survey (CS-FRIS) in 2012. The CS-FRIS collected data on operator demographics and injuries in the previous calendar year from farm operators in the seven central states. The NASS linked CS-FRIS responses with selected farm variables from the existing Ag Census data. This provided a rich dataset with information on operator demographics, physical characteristics of the farm (size, sales, etc.), and farm commodities. The secondary data analysis used this unique CS-FRIS data for the years 2011, 2012 and 2013.

The specific aims of this dissertation were:

Specific Aim 1: To review and evaluate existing survey-based non-fatal agricultural injury surveillance systems in the U.S.

Specific Aim 2: To estimate the non-fatal agricultural injury incidence among farm operators, and to compare injury incidence by operator and farm characteristics in the Central States region.

Specific Aim 3: To identify risk factors contributing to the occurrence of non-fatal agricultural injuries among farm operators in the Central States region.

CHAPTER 2

REVIEW OF SURVEILLANCE SYSTEMS FOR NON-FATAL AGRICULTURAL INJURIES IN THE U.S.

Agriculture is one of the most hazardous industries in the U.S. The persistent injury prevention and control efforts has resulted in a gradual decline in the number of agricultural injuries. However, agriculture still has the highest rate of fatal and non-fatal work-related injuries compared to all other private industries in the U.S. Therefore, it is important to track injuries and risk factors for injuries, and monitor for trends over time. Surveillance data are also useful in developing data-guided injury prevention and control programs and evaluating their impact over time. Surveillance data for fatal work-related injuries are available from the U.S. Census of Fatal Occupational Injuries, and data for non-fatal work-related injuries mainly come from national surveys. In the past, studies used data from these national surveys to describe injuries in agricultural populations and briefly described the corresponding system, and their pros and cons. However, no formal review or evaluation of these national-level, survey-based surveillance systems was published.

A surveillance system is effective and efficient if it provides accurate, reliable, representative and timely data, which is useful for public health action (here injury prevention and control). Evaluations help determine if there needs to be any modification in the system to improve its operability and to meet its intended purpose. This paper addresses the first specific aim of the dissertation research i.e., to review and evaluate existing survey-based non-fatal agricultural injury surveillance systems in the U.S. The evaluation used the updated Center for Disease Control and Prevention (CDC) guidelines for evaluating a public health surveillance system. Data used to conduct this review and evaluation mainly included published materials on surveillance system websites, peer-reviewed journal articles. Chapter 2 covers the first paper of this dissertation and includes the sections background, methodology, results, and discussion.

2.1 Background

The agriculture industry is unique compared to all other industries. Often the place of work and residence is the same, which why farmers and their families are exposed to various farm hazards and are at a risk of injuries. Tracking and monitoring agricultural injuries and risk factors for injuries in farm populations is a step towards prevention and control. The need for improving surveillance of injuries and illnesses in agriculture has been long recognized (NORA, 2008); but the lack of regulatory and insurance infrastructure, the large number, small size and rural location of the enterprises; the diversity in types of enterprises and working populations; seasonality of agricultural work; and other barriers pose major challenges for surveillance of agricultural injuries.

Despite the challenges in surveillance of agricultural injuries, there are systems to track fatal and non-fatal agricultural injuries in specific farm population groups. Fatal agricultural injury data are available for the agriculture sector from the Census of Fatal Occupational Injuries (CFOI). CFOI is a census of fatal work-related injuries for all industries in 50 states and the District of Columbia (BLS, 2012). In addition to the CFOI, the Fatality Assessment and Control Evaluation (FACE) program conducts in-depth investigations for many agricultural fatalities. National Institute for Occupational Safety and Health (NIOSH) and state-based FACE programs conduct on-site fatality investigations of high-risk scenarios for workplace injuries (NIOSH, 2014c). Besides the CFOI and FACE programs, agricultural safety researchers have examined press clippings as a source of injury data. However, with all the existing efforts, in 2012, the National Academies evaluated the NIOSH-AgFF program and reported: “current surveillance data are only adequate for fatal occupational injuries” (NIOSH, 2012).

While substantial information on fatal agricultural injuries exists, surveillance data for non-fatal injuries are sparse and are vital to estimate the total burden of agricultural injuries and to develop evidence-based interventions. The United States Department of Labor (USDOL) and the National Institute for Occupational Safety and Health (NIOSH) each conduct national-level injury surveys, which are the main sources of non-fatal agricultural injury data for different farm population groups in the U.S. The NIOSH works with the United States Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS) to administer injury surveys (BLS, 2012; NIOSH, 2014a; NIOSH 2014b; NIOSH 2014d; NIOSH 2015e; USDOL, 2014). A recent independent NIOSH-AgFF program review recommended- “1) examining current definitions of vulnerable working populations (child labor and hired workers), and 2) exploring limiting characteristics of USDA surveillance efforts on which NIOSH is dependent” (Gunderson, 2012). The report emphasized re-evaluation of USDA's NASS surveys because of low response rates in recurring NASS surveys. The report also recommended: “1) improving the validity of Childhood Agricultural Injury Survey (CAIS) by extending its sample to include labor aggregators, and 2) explore the feasibility to collaborate with USDOL's National Agricultural Workers Survey (NAWS) to initiate a survey of hired children and youth farm workers on crop farms” (Gunderson, 2012). To date, periodic evaluations of USDOL surveys have been conducted to improve data quality and analysis methods (Huband & Bobbitt, 2013; Wiatrowski, 2014), but the NIOSH-USDA injury surveys have never been formally evaluated (K. J. Hendricks, personal communication, April 27, 2015).

In the past, review studies either evaluated a single source of agricultural injury data or provided a brief description of several data sources for agricultural injuries (Earle-Richardson, Jenkins, Scott, & May, 2011; Hard et al., 2002; Leigh, Du, & McCurdy, 2014; Rosenman et al., 2006; Stallones, 2012). The updated Centers for Disease Control and Prevention (CDC) guidelines recommend evaluation of system attributes like data quality, timeliness, representativeness, sensitivity, the ability of a database to integrate with other, and simplicity to use and maintain the system (German et al., 2001). None of the studies using the USDOL or NIOSH surveys systematically examined the system attributes of the surveillance databases for both adult and children/youth non-fatal agricultural injury surveillance systems collectively. To fill this knowledge gap, the current study described the survey-based data systems for adult and youth non-fatal agricultural injury surveillance and examined their strengths and weaknesses using the updated CDC guidelines for surveillance system evaluation. This study identified gaps and provided recommendations that are critical when using survey-based data systems for agricultural injury surveillance research.

2.2 Methods

The study focused on national-level survey-based systems for surveillance of non-fatal agricultural injuries that covered all 50 states and the District of Columbia. In order to make the review comprehensive, this study included systems for both adults and children/youth. Inclusion criteria for a system to be included in this study were: 1) provides national estimates for non-fatal work/non-work-related agricultural injuries in adults or children/youth, 2) used surveys/interviews for data collection, and 3) surveys active at the start of the study (August 2014). Only survey-based systems were included because- 1) NIOSH-AgFF program review reported the need for evaluation of national surveys for agricultural injury surveillance to identify areas of improvement (Gunderson, 2012), and 2) most recently available data for non-fatal agricultural injury for hired workers, self-employed farmers and ranchers, and children are based on survey data. This study excluded surveys not active at the start of the study period (August 2014), because the goal was to identify critical gaps and areas of improvement in current non-fatal agricultural injury surveillance.

2.2.1 Search Strategy

This review study searched 3 sources for relevant reports: 1) Medline/Pubmed for peer-reviewed articles, 2) catalog of U.S. government publications, and 3) websites of relevant government agencies.   The principal author (KP) developed two different search strategies to identify and obtain information on national-level survey-based data sources for surveillance of non-fatal agricultural injuries- 1 for Medline/PubMed and catalog of U.S. publications and 1 for website search. The search in Medline/PubMed and catalog of U.S. publications used the following keywords: occupational, agricultural, farm*, injur*, and United States. This study included all reports and articles published before January 1, 2016. The principal author consulted co-authors with expertise in public health surveillance (SWG) and agricultural injury research (RR) and identified three government agencies most likely to fund, or conduct agricultural injury surveillance activities. The principal author initiated a website search from three major government agency websites (the U.S. Department of Labor, the U.S. Department of Agriculture, and the U.S. Department of Health and Human Services) to identify potentially relevant surveillance systems for review. The government website search included terms such as occupational, agriculture, injury, non-fatal, national, and survey. Website search also identified additional articles and reports on the national-level surveys for non-fatal agricultural injuries.

2.2.2 Study selection and data abstraction

The principal author (KP), reviewed titles, abstracts, and full-text articles obtained in the PubMed and catalog of U.S. government publications search to identify relevant articles. The database and website search identified survey-based data sources for non-fatal agricultural injuries meeting the inclusion criteria. This study excluded articles and reports on fatal injuries, non-survey data, and those based on state-based or regional surveys as these were out the scope of this study. In case the information was unavailable publicly, KP contacted selected surveillance system’s program officer via telephone or email. Data for surveillance systems selected for review and evaluation were abstracted in a table to document the following: institution conducting surveillance, the purpose of the surveillance system, data collection period, inclusion and exclusion criteria, sampling, data collection methods, case definitions, type of information collected and injury estimates generated. Because the cost of operating a system was not available for all surveillance systems selected for review, this component of excluded from the review and evaluation.

2.2.3 Evaluation of surveillance systems

This study adopted the updated CDC guidelines for describing and evaluating the surveillance systems (German et al., 2001). We examined eight attributes of each surveillance system as per the CDC guidelines- simplicity, flexibility, data quality, acceptability, sensitivity, representativeness, timeliness, and stability. The simplicity of a surveillance system examined a system's structure (sampling, data collection, management, analysis, and dissemination plan) and ease of operation. The ability of a surveillance system to adapt to changing information needs and technology within minimal resources defined its flexibility. The validity and completeness of data recorded determined the data quality. Acceptability of a system was the willingness of people or organizations participating in it. Sensitivity was the proportion of true cases and trends detected by the system, which was synonymous with the completeness of data here. The system was representative if it had the ability to describe the injury occurrence for the survey year as well as over time for the population of interest. The time taken by a system at each step from sampling to reporting of injury to data dissemination reflected the timeliness of a system. Finally, stability measured the ability of a system to collect, manage, disseminate the data properly without any outages, and make it available to the public and stakeholders.

We evaluated the eight system attributes using the information abstracted for each system, and the measurement criteria recommended in updated CDC guidelines (for details refer German et al., 2001). If only injury counts were available for some surveys, we calculated annual non-fatal agricultural injury rate per 100 persons using the formula

$$\frac{number\ of\ new\ non-fatal\ injury\ cases\ detected\ in\ the\ given\ year\ (in\ adults\ or\ chidlren)}{total\ agricultural\ population\ (adult\ or\ children)\ in\ the\ given\ year} \times\ 100.$$

KP (principal author) developed the data extraction table, and reviewed and evaluated each system. Co-author SWG verified the review and evaluation methods, and co-author conducted a content review of the information presented on each system in review and evaluation results. In the case of any disagreements related to methods or content in the review, co-authors met with each other and reviewed the results together to reach a consensus.

2.3 Results

2.3.1 Search results

A review of total 2,287 citations and 15 government organization websites (these organizations are a part of three federal agencies – US DHHS, USDA, and USDOL) and identified 153 citations and nine national-level data sources for non-fatal work and/ non-work-related injuries in agriculture. Of these nine national-level data sources eight were surveys, out of which six surveys provided data for non-fatal work and/ non-work-related injuries in agriculture (Figure 4). The three national-level data sources for non-fatal work and/ non-work-related injuries excluded from this review were – the Behavioral Risk Factor Surveillance System (BRFSS), the National Health Interview Survey (NHIS), and the National Electronic Injury Surveillance System- Work (NEISS-Work). The BRFSS is the nation's largest telephone survey designed to collect data on health-related risk behaviors (e.g. smoking, diet, and physical activity), chronic health conditions, and use of preventive services since 1984. In recent years, optional modules on work-related injury, and industry and occupation, but not all states use this module (CDC, 2016a). The CDC's National Center for Health Statistics (NCHS) conducts the NHIS, which is the main source of information on injuries, illnesses, and disability for adult and children/youth civilian noninstitutionalized populations in the U.S. The NHIS is a household sample survey, and administers additional supplements periodically (e.g. occupational health) on a need basis (NIOSH, 2015a). The CDC did not design the BRFSS and the NHIS to capture agricultural injuries, and therefore, the sample selected for the survey may not represent the U.S. farm population, so we excluded these two surveys from this review. On another hand, we excluded the NEISS from this review because it was not a survey-based surveillance system. The U.S. Consumer Product Safety Commission (CPSC) collaborates with NIOSH to operate NEISS-Work. NEISS-Work collects information on non-fatal occupational injuries (including agricultural) treated in emergency departments from a nationally representative probability sample of U.S. hospitals annually (NIOSH, 2015b). The six national surveys reviewed in this study were further separated based on surveillance data available for adult vs. children/youth.

Figure 4: Search strategy results

Pubmed/catalog of U.S. government publications search keywords: occupational, agricultural, farm*, injur*, and United States

Website search keywords: occupational, agriculture, injury, non-fatal, national, and survey

- 2,287 citations (Pubmed and catalog of U.S. government publications search)
- 15 websites (Search on USDOL[a] USDA[b] and DHHS[c] web sites)

Potentially relevant articles, reports and systems for review

- 153 articles and reports
- 9 national-level data sources for non-fatal work and non-work-related injuries in agriculture

Met the inclusion criteria for review

91 articles and reports on six national-level survey-based systems for surveillance of agricultural injuries in adult and youth in the U.S.

1. Survey of Occupational Injuries and Illnesses (SOII)
2. National Agricultural Workers Survey (NAWS)
3. Occupational Injury Surveillance of Production Agriculture (OSIPA)
4. Minority farm operator - Occupational Injury Surveillance of Production (M-OISPA)
5. Childhood Agricultural Injury Survey (CAIS)
6. Minority farm operator - Childhood Agricultural Injury Survey (M-CAIS)

[a] USDOL: United States Department of Labor.
[b] USDA: United States Department of Agriculture.
[c]US DHHS: United States Department of Health and Human Services.

2.3.2 Review and evaluation of surveillance systems

2.3.2.1 National surveys for adult non-fatal agricultural injuries

Four national surveys for surveillance of adult non-fatal agricultural injuries reviewed were- Survey of Occupational Injuries and Illnesses (SOII), National Agricultural Workers

Survey (NAWS), Occupational Injury Surveillance of Production Agriculture (OISPA), and Minority Farm Operator Occupational Injury Surveillance of Production Agriculture (M-OISPA) (Table 1). Each surveillance system was evaluated using CDC's recommended guidelines examining the simplicity, flexibility, data quality, acceptability, sensitivity, representativeness, timeliness, and stability. Table 2 provides a detailed assessment of each surveillance systems for adult injuries.

Table 1: National surveys of adult non-fatal agricultural injuries

System title	**Data systems**			
	Survey of Occupational Injuries and Illnesses (SOII)	**National Agricultural Workers Survey (NAWS)**	**Occupational Injury Surveillance of Production Agriculture (OISPA)**	**Minority Farm Operator Occupational Injury Surveillance of Production Agriculture (M-OISPA)**
Organization responsible	USDOL's BLS	USDOL's ETA and CDC, NIOSH in the U.S. DHHS	CDC, NIOSH in the U.S. DHHS and USDA's - NASS	CDC, NIOSH in the U.S. DHHS and USDA's - NASS
Purpose	Mandatory employment-based survey to estimate the number of work-related injuries and illnesses.	Employment-based survey to monitor conditions of farm workers.	Survey to estimate the number of farm workers and the number of occupational injuries among farm workers.	Survey to estimate the number of minority farm workers and the number of occupational injuries among minority farm workers.
Data collection period	First survey: 1940 Annual Data available: 1971 – present	First survey: 1989 Annual Data available: 1989 -2012	First survey: 2001 Data available: 2001, 2004, 2009, 2012	2003: First survey Data available: 2003, 2008

Inclusion & exclusion criteria	Included: Employers included in the Bureau of Labor Statistics Quarterly Census of Employment and Wages. For agricultural production, establishments with ≥11 employees. Excluded: Self-employed persons, private households, federal government employees.	Included: Establishments classified in North American Industrial Classification System as crop production (NAICS code 111) or support activities for crop production (NAICS code 1151). Excluded: Employees not performing crop-related work, crop workers with an H-2A visa (a temporary employment visa for foreign agricultural workers) and farm workers not currently employed.	Included: Paid and unpaid adults ≥20 year working on the farm, household members, hired workers and working visitors identified through Census of Agriculture. Excluded: Contract farm workers.	Included: Racial minority* paid and unpaid adults ≥20 years working on the farm; household members, hired workers and working visitors identified through Census of Agriculture Excluded: Contract farm workers.
Sampling	Sampling frame: Quarterly Census of Employment and Wages (QCEW) Sampling technique: Two-stage sampling Selection levels include- 1) all eligible establishments that are required to participate as	Sampling frame: Quarterly Census of Employment and Wages (QCEW) Sampling technique: Multi-stage sampling Stages of sample selection are- 1) geographic region, single counties or	Sampling frame: Census of Agriculture Sampling technique: Stratified (by geographic region) random sampling Conducted in conjunction with the Childhood Agricultural Injury Survey (CAIS). Out of 50,000 farm households	Sampling frame: Census of Agriculture Sampling technique: Stratified (by geographic region) random sampling Conducted in conjunction with the Minority Childhood Agricultural Injury Survey (M-CAIS). Out of 50,000 to

	sampling units and 2) sample cases (those involving days away from work). Each year ~ 230,000 establishments sampled from 44 participating states and territories (including District of Columbia).	group of counties “farm labor area (FLA)” as primary sampling unit, 2) ZIP code, 3) employer, and 4) worker or the survey respondent. A total of 1500-3600 workers included in the survey annually.	sampled for CAIS, a stratified subsample of 25,000 selected for the OISPA.	55,000 minority operated farm households selected for M-CAIS, a stratified subsample of 25,000 selected for the M-OISPA.
Data collection method	The survey was administered to the employers via internet, automated fillable form, telephone, and mail. It was required that the information in the SOII fillable form should be the same as recorded in the employer maintained OSHA 300 logs.	Structured face-to-face interviews of farm workers are conducted throughout the year over three interviewing cycles to account for seasonal variations in crop agriculture workforce. Interviews were conducted at the worksite but location may change based on respondent’s convenience.	Structured telephonic interviews of an adult operator in the sampled farm households were conducted during the survey year. Most time the respondents were a female head of the households.	Structured telephonic interview of an adult operator in the sampled farm households were conducted during the survey year. Most time the respondents were a female head of the households.

Injury case definition	Non-fatal injury resulting in loss of consciousness/ days away from work /restricted work activity or job transfer/ medical treatment beyond first aid, and physician or health care professional diagnosed a medical condition.	Injuries that resulted in either scenario where respondent was unable to work at all or at least four hours/ sought medical treatment, including first aid/ took strong medicine (other than over the counter) to continue working.	Occupational Injury - any traumatic event that resulted in at least 4 hours of restricted activity or required professional medical attention, and occurred while performing activities that had a direct impact on the farming operation as a business, regardless of whether the activity was performed for pay.	Occupational Injury - any traumatic event that resulted in at least 4 hours of restricted activity or required professional medical attention, and occurred while performing activities that had a direct impact on the farming operation as a business, regardless of whether the activity was performed for pay.
Information collected	Employee hours worked, average employment, industry, occupation, age, race/ethnicity, gender, duration of employment, nature of the injury, body part affected, the source of injury, exposure, time and day of the injury, cases with days away from work, work restriction or job transfer.	Age, gender, place of birth, education level, first entry in the U.S. (if foreign born), race/ethnicity, first language, ability to speak and read English, employment and migration details, hourly earnings, insurance benefits, worksite water and toilet availability, medical history (injuries and illnesses), safety training, location and type of	Age, gender, type of adult worker, geographic region, farm type, relationship to farm, injury type, event**, source**, and body part affected. Injury information collected for up to two most recent injury events that occurred on the farm.	Age, gender, type of adult worker, geographic region, farm type, relationship to farm, injury type, event**, source**, and body part affected. Injury information collected for up to two most recent injury events that occurred on the farm...

		housing, personal income, assets, social services and legal status in the U.S.		
Estimated non-fatal agricultural injury	In 2013, injury incidence rates were 5.5/100 full-time employees in crop production and 6.2/100 full-time employees in animal production.	In 2002-2004, 2%[a] of interviewed hired workers in crop agriculture had sustained injuries in the past 12 months from interview date.	In 2012, 61,057[b] all cause agricultural work-related injuries to adults 20 years and older on U.S. farms; rate: 0.25/100 adults,	In 2008, estimated agricultural work-related injuries to adults on racial minority operated were 2,029[b] (rate: 0.37/100 adults) and Hispanic operated farms were 1,222[b] (rate: 0.34/100 adults).

USDOL: U.S. Department of Labor, BLS: Bureau of Labor Statistics, and ETA: Employment and Training Administration; both BLS and ETA are divisions in USDOL.
CDC: Center for Disease Control and Prevention, NIOSH: National Institute for Occupational Safety and Health; NIOSH is a part of CDC, and CDC is in the U.S. Department of Health and Human Services (U.S. DHHS).
USDA: U.S. Department of Agriculture; NASS: National Agricultural Statistics Service, which is the statistics division of USDA.
[*]Racial minorities include Black/African American, American Indian/Native Alaskan, Asian/Native Hawaiian/Pacific Islander, multiracial, or other self-defined minority races. Being Spanish, Hispanic, or Latino origin, regardless of their race was termed, Hispanic operators.
[**]Source code includes an object, substance, bodily motion, or exposure that directly inflicted the injury or illness and event code includes the manner in which the injury was inflicted. These codes are as per codes in the Bureau of Labor Statistics Occupational Injury and Illness Classification System (OIICS version 1).[§]NAICS 111 comprises establishments such as farms, orchards, groves, greenhouses, and nurseries that are primarily engaged in growing crops, plants, vines, or trees and their seeds. NAICS 1151 includes establishments primarily engaged in providing support activities for growing crops. [a]Weighted percentage of non-fatal agricultural injuries in the population. [b]These are weighted estimates of non-fatal agricultural injuries in the population.

Table 2: Evaluation of national surveys of adult non-fatal agricultural injuries by surveillance system attributes

	Data system				
System Attributes	**Measurements**	**Survey of Occupational Injuries and Illness (SOII)**	**National Agricultural Workers Survey (NAWS)**	**Occupational Injury Surveillance of Production Agriculture (OISPA)**	**Minority Farm Operator Occupational Injury Surveillance of Production Agriculture (M-OISPA)**
Simplicity	Is the case-ascertainment method easy per case definition?	Yes; relies on employer maintained injury OSHA 300 log.	Yes; relies completely on self-report.	Yes; relies completely on self-report	Yes; relies completely on self-report.
	Is other information related to the injury and the person available?	Yes.	Yes.	Yes.	Yes.
	Is more than one organization involved in receiving case reports?	No.	No.	Yes.	Yes.
	Are survey sampling and data collection easy to follow? Are they time-consuming?	Yes; sample notified of selection a year in advance; data collection year start to mid-summer.	Complex sampling; data collected three times a fiscal year (October-September); each interview 60 minutes.	Yes; data collection takes 1-2 months.	Yes; data collection takes 1-2 months.
	Are data management methods easy to follow? Are they time-consuming?	Yes; data processed mid-summer to mid-October.	Manual data entry; time-consuming.	Yes; time taken for data entry was 3 months and processing was 1 month.	Yes; time taken for data entry was 3 months and processing was 1 month.

	Are methods for analyzing and disseminating data available and easy to follow? Are they time-consuming?	Yes; published mid-October.	Special analysis procedure needed; combined 2 years data published.	Yes; time to analyze and publish (3-9 months).	Yes; time to analyze and publish (3-9 months).
Flexibility	How a system has responded to new demand such as case definition change, new questions by the demand of a specific state/region, IT, funding and reporting sources? Is it interoperable?	Multiple data collection options, central internet data collection facility, case-definition changed in 2002 to align with Occupational Safety and Health recordkeeping guidelines, and industry and occupation stratification changed to align with 2003 revised industry and occupational classification system. Inter-operability with workers' compensation claims database is being explored.	Survey modified on a need basis; paper-based data collection; four-year data combined for regional analysis; no state-level data, except California; program adjusted over time to reduce cost; not inter-operable.	In initial OISPA no information on injuries in racial minority and Hispanic operations, so M-OISPA developed; not inter-operable (data cannot be merged with other existing databases). No variables added or removed from the survey. No major methodologic changes were made to the system over time.	None; not interoperable (data cannot be merged with other existing databases). No variables were added or removed from the survey. No major methodologic changes were made to the system over time.
Data quality	What was the percentage of missing items or invalid entries?	No information.	No information.	Average 51% incomplete interviews.	Average 56% incomplete interviews.
	Quality control steps in data collection and management	Standardized questionnaires; random probability	Random probability sampling; standardized	Most recent data for sample selection;	Most recent data for on racial minority or Hispanic

		sampling; standardized occupational injury and illness classification codes.	sampling protocol; three interview cycles/year to account for seasonality; interview at the workplace; validated structured bilingual questionnaire; intense interviewer training; all interviewers bilingual; $20 honorarium for respondents.	random probability sampling; standardized occupational injury and illness classification codes.	operated farms; random probability sampling; breakdown of data by racial minority and Hispanic operated farms; standardized occupational injury and illness classification codes.
	Other data limitations	Possible that injuries may have been missed and were not recorded in OSHA logs, inconsistency in data capture from state to state.	Recall bias.	Recall bias; no verification of data; nonresponse bias (survey nonresponse or missing data for a survey question/s); potential for non-differential misclassification as data are self-reported.	Recall bias; no verification of data; nonresponse bias (survey nonresponse or missing data for a survey question/s); potential for non-differential misclassification as data are self-reported.
Acceptability	What was the subject or agency participation rate?	Average response rate 90-95%.	Average response rate: employer 59-66% and worker 90-92%.	Average response rate 78%. OISPA adjusted response rates for non-contact and farms out of business.	Average response rate 83%. M-OISPA adjusted response rates for non-contact and farms out of business

	What were the interview completion rates and question refusal rates (if the system involves interviews)	No interviews.	Information not available.	Average 51% complete interviews.	Average 56% complete interviews.
	How timely was the data reporting?	Forms sent out at year start and need to respond in 30 days.	Injury reported during interviews.	Injury reported during interviews.	Injury reported during interviews.
Sensitivity	How sensitive was the survey to detect injury cases?	Potential underreporting; cases occurring during year-end missed, as data collection time does not coincide; state-wise inconsistencies in case capturing.	Potential underreportin g.	Potential underreporting because respondents are often times the female head of the household who may miss reporting hired worker injuries; no follow-up of refusals; measurement error; counts up to two most recent injuries.	Potential underreporting because respondents are often times the female head of the household who may miss reporting hired worker injuries; no follow-up of refusals; measurement error; counts up to two most recent injuries.
	Was the survey able to collect info on other morbidity or risk factors possibly related to the injury?	Not extensively.	Other morbidity data not present; health conditions present at the time of interview reported; work-relatedness of another morbidity not assessed; narrative text on injury	No other morbidity data; info on some risk factors-demographic and farm characteristics.	No other morbidity data; info on some risk factors-demographic and farm characteristics.

			circumstances recorded		
Representativeness	Did it choose an appropriate denominator for rate calculations?	The sum of a number of hours worked by 100 full-time employees in given calendar year as the denominator for the rate.	No rate; weighted injury percent calculated.	No rate or percentage calculated. OISPA publishes injury and demographic estimates based on survey data, which can be used to calculate rates.	No rate or percentage calculated. M-OISPA publishes injury and demographic estimates based on survey data, which can be used to calculate rates.
	Did it use specific analytical methods used in survey-based surveillance?	Sample-based weighted demographic and injury estimates, injury rates and percent relative standard errors are calculated and published for public access.	Sample-based weighted demographic, other parameters and injury estimates and standard errors are calculated and published for public access.	Sample-based weighted demographic and injury estimates are calculated and published for public access, but standard errors are available on request.	Sample- based weighted demographic and injury estimate are calculated and published for public access, but standard errors are available on request.
	Was there a case ascertainment bias or selection bias or differential misclassification?	Selection bias minimized using two-stage random sampling; differential misclassification and inconsistencies minimized by verifying with employers	Workers not in agriculture work over a year and undocumented workers excluded; stratified multi-stage sampling minimizes selection bias	Case ascertainment bias; probability sampling minimizes selection bias; exclusion of contract workers	Case ascertainment bias probability sampling minimizes selection bias

Timeliness	Was there a time lapse between event reporting and information release to stakeholders?	Takes 3 years from sampling to disseminating data; web-based data collection reduced time.	Takes at least 2 years from sampling to dissemination; data on injury estimates are disseminated only after combining two years of survey data.	Takes 2 years from sampling to data dissemination; not an annual survey.	Takes 2 years from sampling to data dissemination; not an annual survey.
Stability	Were there frequent unscheduled outages or system down?	No information.	No information.	No information.	No information.
	Was there a heavy cost of system hardware and software repair?	No information.	No information.	No information.	No information.
	How much of the time was the system fully operational (in percentage)?	System operational all year round; constantly updated with a news release, reports and publications, data updates and any changes made to the system.	Public use data files, codebook, and summary data tables are released for two years combined; to reduce cost burden number of interviews conducted decreased; no other information on system operation available.	Tables published summarize aggregate data; no other information on system operation available.	Tables published summarize aggregate data; no other information on system operation available.

SOII

Of all the four systems reviewed for adult non-fatal agricultural injuries, SOII was by far the most comprehensive database that provided state- and nationwide estimates for work-related injuries and illnesses for all industries, including agriculture.

The U.S. Department of Labor's (USDOL) Bureau of Labor Statistics (BLS) conducted and maintained the SOII. Compared to all other surveys reviewed in this paper for agricultural injuries in adults, SOII had better injury case detection, trend identification and timely data dissemination plan for stakeholder and public use. The SOII data provided annual injury estimates by state, region and nationally and detected trends in injury occurrence and exposure-related risk factors of injuries. SOII data are useful to evaluate the effectiveness of injury prevention and control programs, explore new methods in occupational injury research and identify priority and high-risk populations. Other strengths of SOII include annual on-going surveys, relatively large sample size, multiple data collection channels, the possibility of verifying the data with employers, periodic evaluation of the system and constant efforts to improve the data capture and analysis. However, SOII had limitations as well. SOII excluded self-employed farmers, unpaid farmers, and establishments with <11 employees; there were inconsistencies across states in data capture; there was potential underreporting by employer or employee for several reasons such as worker's fear loss of job or retaliation from an employer or either of them lack awareness on reporting requirements, etc.

As a system, SOII was simple, flexible, acceptable, with acceptable data quality and timely compared to all other surveys reviewed in this paper. However, SOII was not representative of the farming population as completely because it fails to capture data on self-employed farmers, family members and those working on small farms with less than 11 employees.

NAWS

Other than SOII, the USDOL was also responsible for conducting and maintaining the NAWS. In response to the Immigration Reform and Control Act of 1986 (IRCA), the USDOL initiated NAWS to collect demographic, employment and migration data on hired crop workers in 1989; the injury supplement was added in 1999. NAWS is a national sample of crop production workers, which provides regional but no state-based injury estimates. SOII and NAWS have been active for decades, but after the year 2015, the DOL discontinued the injury supplement of NAWS.

Among all other agricultural injury surveys for adults reviewed in this paper, NAWS was the only surveillance database with information on injury and health conditions of seasonal crop agriculture workers, including immigrants working on U.S. farms. Besides NAWS, none of the systems reviewed collected employment, income and assets, worksite characteristics and health and safety training details. Standardized and robust sampling strategy, farm/worker selection protocols, and accounting for seasonal nature of industry ensured representativeness of NAWS data for hired crop workers. However, the survey sampling and data collection were most complex compared to all other agricultural injury surveys reviewed in this paper. NAWS collects data three times a year in cycles (February, June and October) to account for seasonal nature of work in agriculture and each interview cycle lasted ten to twelve weeks. More than half (59-66%) of the employers who were contacted by NAWS responded. Once an employer agreed for NAWS, most workers participated in the survey (90-92%). It is unknown if workers and injuries to workers from participating employers are different from non-participating employers, but statisticians at USDOL are currently exploring the effect of this nonresponse bias on survey results. No data on interview completion rates was available, but we expect the face-to-face interviews have good survey completion rates and minimal missing data. To minimize interviewer bias, NAWS conducted vigorous training of interviewers and used structured questionnaires and protocol for data collection, but information on injuries was self-reported and subject to self-report bias. NAWS was the most time-consuming survey (average 60 mins per interview); had a small sample size that limited analysis for a single year and subgroup analysis required merging at least four years of data. In addition to these weaknesses, no state-level data were available in NAWS, except for California.

Compared all other agricultural injury surveys for adults reviewed in this study, NAWS was least simple, timely, and flexible system. Attributed to robust sampling methods and survey weighting, NAWS had acceptable data quality and was the only system to capture injuries among seasonal and migrant hired workers in crop production.

OISPA and M-OISPA

In partnership with the USDA's NASS, NIOSH designed two surveys (OISPA and M-OISPA) to track non-fatal injuries in adults aged 20 years and above living on, working or visiting farms, including self-employed and farm owners. OISPA and M-OISPA were periodic surveys and represented a national sample; yearly and state-based data were not available. NIOSH developed M-OISPA from OISPA because there was an increasing number of minority operated U.S. farms in the Census of Agriculture, and injury data for these farms were lacking. Both surveys (OISPA and M-OISPA) used the same injury definition. However, an overall injury estimate for minority farm operations could not be generated, because estimates for Hispanic and racial minority farm operators in M-OISPA were not mutually exclusive. Some operators may have reported themselves being a racial minority and Hispanic origin. OISPA and M-OISPA collected same information from different population groups in the U.S. production agriculture. After the year 2015, the NIOSH discontinued both the OISPA and the M-OISPA.

Evaluation of OISPA and M-OSIPA found that sampling and data collection was simple and efficient as it used a subset of the sample selected for the youth agricultural injury surveys (CAIS and M-CAIS). Although the survey/interview response rates were good (OISPA=78% and

M-OISPA=83%), there were biases attributed to missing data because nearly half of the interviews were incomplete. The average interview completion rates for OISPA and M-OISPA were 51% and 56% respectively. The recall period for an injury incidence reported in OISPA and M-OISPA was 15 months since NASS administered both surveys in spring (late March- early April) and recorded injury data for previous calendar year. Both OISPA and M-OISPA detected injuries but the accuracy of the data was questionable because data were self-reported, unverified, subject to recall bias and potential misclassification. In addition to these biases and residual sampling errors, the adult responding to the telephone interview (i.e. survey) provided information on injuries to other adult members on the farm, resulting in proxy bias and underreporting. Using OISPA and M-OISPA data, we can generate summary tables for each survey year describing the injury and demographics of working adults on U.S. farms and made available to the public.

To summarize, both the OISPA and the M-OISPA were simple, acceptable, fairly representative survey-based systems, but were not flexible (or interoperable databases). The data quality of both OISPA and M-OISPA was somewhat acceptable.

2.3.2.2 National surveys for youth non-fatal agricultural injuries

Of the six survey-based surveillance systems selected for review and evaluation, two were for children/youth. Table 3 describes the two national surveys for surveillance of non-fatal agricultural injuries among youth less than 20 years of age on farms- Childhood Agricultural Injury Survey (CAIS), and Minority Farm Operator- Childhood Agricultural Injury Survey (M-CAIS). We evaluated each surveillance system attribute for both the CAIS and the M-CAIS; Table 4 summarizes these evaluation findings.

Table 3: National surveys of youth non-fatal agricultural injuries

	Data system	
System descriptors	**Childhood Agricultural Injury Survey (CAIS)**	**Minority Farm Operator Childhood Agricultural Injury Survey (M-CAIS)**
Organization responsible	CDC, NIOSH in the U.S. DHHS and USDA's - NASS	CDC, NIOSH in the U.S. DHHS and USDA's - NASS
Purpose	Survey to collect demographic and injury data for youth on U.S. farms.	Survey to collect demographic and injury data for youth on minority operated U.S. farms.
Population base	Youth aged less than 20 years on U.S. farms.	Youth aged less than 20 years on racial or Hispanic minority operated U.S. farms.
Data collection period	First survey: 1999 Data available: 2001, 2004, 2006, 2009 and 2012	First survey: 2001 Data available: 2003 and 2008
Inclusion & exclusion criteria	Included: Household members, hired workers, or visitors <20 years of age on U.S. farms. Excluded: Young contract farm workers.	Included: Household members, hired workers or visitors <20 years of age on racial minority* and Hispanic* operated U.S. farms in the most recent Census of Agriculture. Excluded: Young contract farm workers.
Sampling	Sampling frame: U.S. Census of Agriculture. Sampling technique: Stratified (by a geographic random sample of 50,000 U.S. farm households nationwide.	Sampling frame: U.S. Census of Agriculture Sampling technique: A census of primary racial minority and Hispanic operated (between 50,000 -55,000) U.S. farm households nationwide.
Data collection and sources	Survey administered via structured telephonic interview to farm operator of farm households sampled during the survey year. Most times the respondents were a female head of the farm households sampled for the survey.	Survey administered via structured telephonic interview to farm operator of farm households sampled during the survey year. Most times the respondents were a female head of the farm households sampled for the survey.
Injury case definition	Injury - any traumatic event occurring on the farm operation resulting in at least 4 hours of restricted activity, or requiring professional medical treatment. Work-injury - any injury that occurred while performing work or	Injury - any traumatic event occurring on the farm operation resulting in at least 4 hours of restricted activity, or requiring professional medical treatment. Work-injury - any injury that occurred while performing work or chores on the

	chores on the farm that was associated with the farm business, regardless of whether the work was performed for pay.	farm that was associated with the farm business, regardless of whether the work was performed for pay.
Information collected	Age, gender, type of youth (household/working household/hired/visitors), geographic region of US, relationship to farm, farm type, injury type, event[**], source [**], and body part affected. Injury information was collected for up to four most recent injury events that occurred on the farm.	Age, gender, type of youth (household/working household/hired/visitors), geographic region of US, relationship to farm, farm type, injury type, event[**], source [**], and body part affected. Injury information was collected for up to four most recent injury events that occurred on the farm.
Estimated non-fatal agricultural injury rate	In 2012, the injury rate was 0.05 injuries/100 youth with 13,996 injuries among all youths <20 years of age on U.S. farms.	In 2008, estimated agricultural work-related injuries to all youth <20 years on racial minority operated U.S. farms were 516 [a] (rate: 0.06/100 youth) and Hispanic operated U.S. farms were 254[a] (rate: 0.05/100 youth).

CDC: Center for Disease Control and Prevention, NIOSH: National Institute for Occupational Safety and Health; NIOSH is a part of CDC, and CDC is in the U.S. Department of Health and Human Services (U.S. DHHS).
USDA: U.S. Department of Agriculture; NASS: National Agricultural Statistics Service, which is the statistics division of USDA.
[*]Racial minorities include Black/African American, American Indian/Native Alaskan, Asian/Native Hawaiian/Pacific Islander, multiracial, or other self-defined minority races. Being Spanish, Hispanic, or Latino origin, regardless of their race was termed, Hispanic operators.
[**]Source code includes an object, substance, bodily motion, or exposure that directly inflicted the injury or illness and event code includes the manner in which the injury was inflicted. These codes are as per codes in the Bureau of Labor Statistics Occupational Injury and Illness Classification System (OIICS version 1). [a] These weighted estimates of non-fatal agricultural injuries in the population.

Table 4: Evaluation of national surveys of youth non-fatal agricultural injuries by surveillance system attributes

System Attributes	**Measurements**	**Childhood Agricultural Injury Survey (CAIS)**	**Minority operated farm Childhood Agricultural Injury Survey (M-CAIS)**
Simplicity	Is the case-ascertainment method easy per case definition?	Yes; relies completely on self-report.	Yes; relies completely on self-report.
	Is other information related to the injury and the person available?	Yes.	Yes.
	Is more than one organization involved in receiving case reports?	Yes.	Yes.
	Are survey sampling and data collection easy to follow? Are they time-consuming?	Yes; data collection takes 1-2 months.	Yes; data collection takes 1-2 months.
	Are data management methods easy to follow? Are they time-consuming?	Yes; time taken for data entry (3 months) and processing (1 month).	Yes; time taken for data entry (3 months) and processing (1 month).
	Are methods for analyzing and disseminating data available and easy to follow? Are they time-consuming?	Yes; time taken in months for data), analyzing and publishing (3-9 months).	Yes; time taken in months for data), analyzing and publishing (3-9 months).
Flexibility	How a system has responded to new demand such as case definition change, new questions by the demand of a specific state/region, IT,	Cannot be merged with other NIOSH agricultural surveys or other databases. No variables were added or removed from the survey over time. No major methodologic changes were made to the system over time.	M-CAIS off-shot from CAIS because initial CAIS survey did not provide information about youth injuries on racial minority and Hispanic operations. No major changes. Cannot be merged with other NIOSH

	funding and reporting sources? Is it interoperable?		agricultural surveys or other databases.
Data quality	What was the percentage of missing items or invalid entries?	Average 52% complete interviews.	Average 54% complete interviews.
	Quality control steps in data collection and management	Most recent data for sample selection; random probability sampling; standardized and acceptable occupational injury and illness classification codes.	Most recent data on racial minority or Hispanic operated farms for sample selection; breakdown of data by racial minority and Hispanic operated farms; standardized and acceptable occupational injury and illness classification codes.
	Other data limitations	Recall bias; no verification of data; nonresponse bias (survey nonresponse or missing data for a survey question/s); the potential for non-differential misclassification as data are self-reported.	Recall bias; no verification of data; nonresponse bias (survey nonresponse or missing data for a survey question/s); the potential for non-differential misclassification as data are self-reported.
Acceptability	What was the subject or agency participation rate?	Average response rate 78%.	Average response rate 81%.
	What were the interview completion rates and question refusal rates (if the system involves interviews)	Average 52% complete interviews.	Average 54% complete interviews.
	How timely was the data reporting?	Injury reported during telephonic interviews.	Injury reported during telephonic interviews.
Sensitivity	How sensitive was the survey to detect injury cases?	Potential underreporting because respondents are often times female head of the household who may miss reporting hired youth worker injuries; no follow-up assessment of refusals;	Potential underreporting because respondents are often times female head of the household who may miss reporting hired youth worker injuries; no follow-up assessment of refusals;

		possible measurement error; counts up to four most recent injuries	possible measurement error; counts up to four most recent injuries
	Was the survey able to collect info on other morbidity or risk factors possibly related to the injury?	No other morbidity data; info on some potential risk factors-demographic and farm characteristics	No other morbidity data; info on some potential risk factors-demographic and farm characteristics
Representativeness	Did it choose an appropriate denominator for rate calculations?	No rate or percentage published by CAIS. CAIS publishes injury and demographic estimates based on survey data, which can be used to calculate rates.	No rate or percentage published by M-CAIS. M-CAIS publishes injury and demographic estimates based on survey data, which can be used to calculate rates.
	Did it use specific analytical methods used in survey-based surveillance?	Sample-based weighted demographic and injury estimates; standard errors are available on request	Sample-based weighted demographic and injury estimate; standard errors are available on request
	Was there a case ascertainment bias or selection bias or differential misclassification?	Possible case ascertainment bias; probability sampling minimizes selection bias	Possible case ascertainment bias
Timeliness	Was there a time lapse between an event occurrence, recognition by reporting source, and event reporting and information release to stakeholders.	Takes 2 years from identifying a sample to processing and disseminating the information; not an annual survey.	Takes 2 years from identifying a sample to processing and disseminating the information; not an annual survey.
Stability	Were there frequent unscheduled outages or system down?	No information.	No information.
	Was there a heavy cost of system hardware	No information.	No information.

	and software repair?		
	How much of the time was the system fully operational (in percentage)?	Tables published summarize aggregate data; no other information on system operation available.	Tables published summarize aggregate data; no other information on system operation available.

CAIS and M-CAIS

Under the Childhood Agricultural Injury Prevention Initiative, NIOSH initiated the Childhood Agricultural Injury Survey (CAIS) and Minority Farm Operator-Childhood Agricultural Injury Survey (M-CAIS) in partnership with the USDA's NASS in 1996. The injury data includes work and non-work-related farm injuries. The data included injury type, event or exposure causing injury, body part injured, farm type, and demographics. Unlike OISPA and M-OISPA, both youth injury surveys collected information on - two most recent work-related and two most recent not work-related injuries to youth on farms participating in the surveys. After the year 2015, the NIOSH discontinued CAIS and M-CAIS. Being the only national data sources for non-fatal agricultural injuries in child/youth on U.S. farms, the discontinuation of surveys left a data gap.

Like OISPA and M-OISPA, the response rate for CAIS and M-CIAS was good (CIAS 78% and M-CAIS 81%), but the interview completion was not optimal (CAIS 52% and M-CAIS 54%). Similar to OISPA and M-OISPA, CAIS and M-CAIS too were subject to recall bias, proxy bias, potential misclassification, missing data bias, residual sampling errors. Periodic nature of surveys limited trend analysis. Most of the surveillance system evaluation attributes for CAIS and M-CAIS gave same findings as for OISPA and M-OISPA. This was because the OISPA surveys used a similar methodology, sampling frame, data analysis and dissemination protocol as CAIS and M-CAIS.

In brief, each adult and youth agricultural injury surveillance system reviewed in this paper was unique, and covered different farm population groups, not accounted for by the other system. The injury case definitions for each of the data system for adults varied, with an exception of OISPA and M-OISPA having the same definition. Both youth injury surveys had used same injury case definition. Evaluation of systems attributes for each system identified strengths and weaknesses of each survey-based surveillance database. Because of limited or no relevant information, we could not examine the stability of the surveillance systems fully.

2.4 Discussion

Evaluation of public health surveillance systems determines whether the systems meet their objectives and identify any necessary changes to improve the operation and sustainability of the system. This is the first comprehensive review and evaluation of survey-based data systems for surveillance of adult and youth non-fatal agricultural injuries using CDC's criteria for evaluating surveillance systems. This paper identified several critical gaps in existing survey-based surveillance databases for non-fatal agricultural injuries and provided potential ways to address these gaps.

2.4.1. Critical gaps and recommendations

2.4.1.1 Population coverage

To summarize, the purpose and the population covered by each survey-based system for non-fatal agricultural injury surveillance in this evaluation report was different. None of the surveys evaluated here collected injury data for migrant youth farm workers. NAWS could collect demographic and injury data by expanding it to include migrant and seasonal farm workers younger than 14 years of age, but this no longer possible. With the discontinuation of the injury supplement of NAWS, there would be limited or no surveillance data for non-fatal work injuries in adult and youth migrant and seasonal crop workers. At the same time, discontinuation of

OISPA, M-OISPA, CAIS and M-CAIS left a data gap regarding non-fatal agricultural injuries in self-employed farmers and farm owners, and children/youth living, working or visiting U.S. farms.

2.4.1.2 Technical components

Injury case definition and reporting criteria

In the survey-based systems reviewed here, case definition and reporting criteria used to track injuries in specific populations covered by each system were different. For example, SOII collected data as defined and required by the OSHA. The NIOSH injury surveys developed case definition and reporting criteria to identify injuries through a phone interview, based on self-report. This suggests that it is difficult to have one standard definition and reporting criteria for recording injuries, because each system's purpose, population covered and data collection methods are different. Injuries occurring at off-work hours are often underreported or prone to misclassification as non-farm injury. Injuries occurring at road-side, on the road, while commuting from farm to residence, or transporting a farm commodity will be underreported or misclassified as road-traffic injury. There is a need for clearer case definition for farm-related injuries to minimize the undercount and misclassification biases (Gunderson et al., 1990; Layde, 1990; Leigh et al., 2014; Murphy, Purschwitz, Mahoney, & Hoskin, 1993; Rautiainen & Reynolds, 2002).

Undercount

All survey-based systems reviewed in this paper tend to undercount agricultural injuries. Undercount may have occurred due to – 1) exclusion of certain population groups from the survey; 2) undercount of the employed population in agriculture or population living, working or visiting farms (for youth surveys); and 3) underreporting. For example, SOII excludes self-employed, unpaid family members, and farms with <11 employees. According to the 2015 BLS Current Population Survey (CPS), there were 2,422,000 individuals of age 16 years and above working in agriculture, of which 36% were self-employed workers and unpaid family members. CPS is an annual survey of a national sample of 60,000 households (BLS, 2016a). Meaning, in 2015 SOII missed out injuries in 1/3rd of the working population in agriculture. Leigh et al. (2014) estimated that in 2011, SOII missed 77.5% of injuries in agriculture. Studies examining the completeness of SOII data have also indicated that SOII not only undercounts injuries in agriculture but also in other industry sectors (Boden & Ozonoff, 2008; Rosenman et al., 2006; Wiatrowski, 2014). As discussed undercount of the population in agriculture too, can lead to an undercount when selecting a sample or calculating rates.

For example, SOII and NAWS both used Quarterly Census of Employment Wages (QCEW) to obtain estimates on the employed population in agriculture. Other commonly used data source for employment statistics is the CPS. However, Leigh al. (2014), studying the undercount of occupational injuries in agricultural using government surveys, reported SOII, QCEW, and CPS undercounted the employment in agriculture. This may be due data-gathering problems attributed to the transient nature of work in agriculture and extent of employment unaccounted for undocumented workers. Building partnerships with the farm labor management companies and farm labor associations can help obtain employment and demographics data for hard to reach populations such as migrant and seasonal farmworkers. Even with such efforts, it would be difficult to cover undocumented workers and those visiting farms for recreational or work-related purposes. Another data source for information on farm populations and farm characteristics is the Census of Agriculture. The NIOSH surveys reviewed in this study used Census of Agriculture as its sampling frame and estimated the farm populations and injuries to them. Despite a representative sampling frame, data from the NIOSH surveys were not generalizable to farming populations covered by them. This indicates the importance of taking necessary quality control steps at each stage of surveillance- from selecting a sample to survey development to data collection and analysis.

Studies examining the non-fatal agricultural injury burden using NIOSH surveys reviewed in this paper reported recall bias, inability to verify accuracy and completeness of data, proxy bias, and undercounting as limitation of both OISPAs, and CAISs (Goldcamp, 2010; Goldcamp, Hendricks, Layne, & Myers, 2006; Hendricks & Goldcamp, 2010; Layne, Goldcamp, Myers, & Hendricks, 2009). In any occupational injury survey, underreporting can be at several levels- 1) supervisor or employer level, 2) health care provider level and 3) worker or interviewer level. Underreporting is dependent on multiple factors including lack of awareness and understanding, incentive, fear of losing a job, higher insurance premiums, and no regulatory requirement (Azaroff, Levenstein, & Wegman, 2002). To address this issue, apart from increasing awareness among populations under surveillance and those involved in reporting injuries, we need to explore incentives that can encourage farmers, workers, employers and medical care providers to report farm injuries.

Additional information needs

To guide injury prevention and control strategies within the resource constraints, it is vital to identify high-risk population groups and contributing factors of injuries. Besides, SOII, none of the survey-based systems collected data on exposure or work hours. Lack of data on actual hours of work/exposure in NIOSH surveys restricts calculation of injury rates based on hours worked (Goldcamp et al., 2006; Hendricks & Goldcamp, 2010; Hendricks & Hendricks, 2010; Myers, Layne, & Marsh, 2009). Using the current data from NIOSH injury surveys, it is difficult to estimate the true burden of agricultural injuries because of limited or no information on consequences of injury including the medical care taken, the cost of care, lost work time, and disability status. SOII was the only survey in this review that collected data for injuries requiring days away from work, or work restriction, or job transfer, but has no information on the cost of injury. Information farm characteristics, such as the type of farming (crop v. livestock), farm size and sales would also be helpful. Some of the variables that were mentioned here – work hours, type of farming, co-morbidities like hearing loss, depression, medication use are known risk factors for agricultural injuries (Jadhav, Achutan, Haynatzki, Rajaram, & Rautiainen, 2015; Rautiainen et al., 2009). The reason why it is important to study some these variables especially for severe non-fatal agricultural injuries is to determine the social and economic consequences of severe injuries, which ultimately affect the quality of life and contribute to the rising cost of health care (Costich, 2010; Leigh et al., 2001; Zaloshnja et al., 2011). Designing and maintaining a comprehensive system that covers all unique farm population groups and collects voluminous data would be resource-intensive and not plausible. An alternative to developing an all-in-one system is using data from other existing systems to complement the current data from USDOL and NIOSH injury survey, which is feasible but poses unique challenges. For example, Zaloshnja et al. (2011) used the data from CAIS and data from other existing surveys such as the Health Care Utilization Project – National Inpatient Sample (HCUPS-NIS) and Medical Expenditure Panel Survey (MEPS), and estimated that during 2001-06, the medical cost incurred by nonfatal youth injuries was $1 billion (in 2005 dollars) annually. However, neither HCUPS-NIS nor MEPS had data on property damage or loss of productivity because they are not designed for occupational injury and illness surveillance, and hence, the indirect costs of injuries could not be estimated which can be substantial.

2.4.2. Future of agricultural injury surveillance

The 2012 U.S. Census of Agriculture reported a continued decline in the number of farms and the farm workforce over the last few decades (USDA, 2014a). Surveillance data from the national-level injury survey (NIOSH surveys and USDOL surveys) too reported a decline in the number of agricultural injuries (Goldcamp, 2010; Goldcamp, Hendricks, & Myers, 2004; Hendricks & Goldcamp, 2010; Hendricks & Hendricks, 2010; Tonozzi & Layne, 2016). Given this scenario, to obtain statistically reliable national-level injury estimates NIOSH injury surveys would have to increase the sample sizes, which would be resource intensive, and was not plausible (CDC, 2015). In addition to the cost and sample size issue, this evaluation study found that the NIOSH injury surveys were not interoperable, and had several data quality concerns-undercounting of injuries, potential misclassification, measurement error, incomplete surveys, nonresponse bias, recall bias, etc. German et al (2001) indicated that usefulness of a surveillance system depends on all of its attributes. For a surveillance data to be useful for public health (here injury prevention and control), the data should be reliable, accurate, representative, and timely, and all of these parameters were lacking to an extent in the NIOSH injury surveys. Even if resources were available, and the sample size was increased, data limitations would restrict usability of the survey data. Discontinuation of these surveys would help channelize resources to identify newer, cost-effective and sustainable methods for surveillance of agricultural injuries. Besides, the NIOSH injury surveys and NAWS injury supplement did not provide state-level estimates for agricultural injuries, which limits examination of any patterns in injuries and farm populations by state.

Studies using NIOSH injury surveys showed regional variations in incidence of non-fatal injuries among different farm populations, and reported high rates of non-fatal injuries among adults and youth on farms in the Midwestern region of the U.S., but no state-specific results were available (Goldcamp, 2010; Hendricks & Goldcamp, 2010; Myers et al., 2009). On another hand, the 1999 Regional Rural Injury Study- II (RRIS-II) conducted injury surveys among farm operators and their household members on living or working farms in five Midwestern States (Minnesota, Nebraska, North Dakota, South Dakota and Wisconsin). The 1999 RRIS-II reported that among the five Midwestern states, South Dakota had the highest rate of farm-related injuries (Mongin et al., 2007). The 2012 U.S. Census of Agriculture showed variations in farm populations and farm production by state and geographic regions. For example, concentration of farms run by Hispanic-operators is higher in Southern and Southwestern states like Texas and California, and concentration of non-Hispanic white farm operator is higher in the Midwestern states like Nebraska and Iowa of the U.S. Similarly, states in the Midwestern region of the U.S. mainly produce cattle, corn, soybean and hogs, whereas states like Florida and California have higher concentration of farms growing fruits, nuts, and vegetables (USDA, 2014a). Some of these farm and operator characteristics discussed above are risk factors of injury (Hwang et al., 2001; Jadhav et al., 2015; McCurdy et al., 2004; Mongin et al., 2007). Data on state and/ regional level injury estimates can help identify any trends specific to the farming populations and farming practices in that state/region, and prevention programs can be designed accordingly. A possible solution for this could be using state-based administrative databases like hospital discharge database; workers' compensation claims records etc., or regional injury surveys by NIOSH-funded agricultural safety centers (Ag Centers).

2.4.2.1 Administrative databases as a source of data for agricultural injuries

Recent studies examined the potential of hospital discharge data, ambulance reports, Workers' Compensation claims records, and state trauma registries to detect non-fatal farm injuries (Douphrate, Rosecrance, Stallones, Reynolds, & Gilkey, 2009; Earle-Richardson et al., 2011; Foley, Ruser, Shor, Shuford, & Sygnatur, 2014; Forst & Erskine, 2009; Jawa et al., 2013; Meyer & Hayes, 2011; Scott, Krupa, Horsman, & Jenkins, 2015).

Hospital discharge database (HDD), one of the commonly used administrative data source for injury and illness surveillance in the U.S., can not only detect injuries (Meyer & Hayes, 2011; Scott et al., 2015), but also provide details on cost and disability due to an injury (Costich, 2010). Besides HDD, the hospital emergency department (ED) records and state trauma registries (STR) are also a valid source of surveillance data for work-related injuries treated in EDs of hospitals (Jawa et al., 2013; Landsteiner, McGovern, Alexander, Lindgren, & Williams, 2015; Missikpode et al., 2015; Mustard, Chambers, McLeod, Bielecky, & Smith, 2012). For injuries requiring urgent medical attention, but not hospitalization can be captured from the emergency medical service (EMS) pre-hospital database or the pre-hospital care reports (PCR)

(Forst & Erskine, 2009; Mustard et al., 2012; Scott, Krupa, Sorensen, & Jenkins, 2013). There are several advantages of using medical records for public health surveillance activities.

Benefits of using medical records include –1) availability of data for both adults and children/youth in the same database, 2) reduced information bias (self-report, volunteer, interviewer/interview and recall) and 3) information on other injury-related health consequences and medical care characteristics (treatment, cost etc.). However, there are drawbacks of using medical records as well. There can be inaccuracy in identifying farm injuries when using the limited options in the International Classification of Diseases (ICD) - Clinical Modification (CM) Version 9 or 10) codes for farm-related external causes of injury 'E-code'. Also, there is limited to no data on industry, occupation, work exposure and duration of work/employment data in current medical record databases.(Costich, 2010; Forst & Erskine, 2009; Jawa et al., 2013; Scott et al., 2013). In addition to these limitations, accessing medical records databases for surveillance and research purpose may have additional challenges attributed patient privacy and confidentiality concerns.

Another consideration is, injury to a farm visitor could be included as a farm injury in the hospital and PCR data but counting visitors in the denominator for injury rates is difficult. Scott et al. (2015) accessed PCR and hospital data (inpatient, outpatient, and ED) to detect farm and logging injuries in the State of Maine. The authors found variation in injuries captured by PCR vs. hospital data (41.9 % vs. 59.7% of the cases were farm injuries), and of those reported in hospital data, only 3.4% injuries had an ambulance run indicating most agricultural injuries used other transportations to arrive at the hospital. This suggests using any single data source; HDD, ED, STR or PCR will not provide a complete picture of the non-fatal farm injury burden.

With health information exchange going increasingly electronic, an alternative to this problem is merging databases for a complete picture of the injury burden. However, merging databases requires compatibility between data sets that are being merged, availability of unique identifiers or matching variables and access to appropriate financial, human and technical resources (Scott et al., 2013; Scott et al., 2015). Hence, one must consider some the limitations discussed here when using surveillance data from current administrative datasets like HDD, trauma registry and ambulance reports.

Another potentially useful administrative data source is the Workers' Compensation Claims (WCC) records. One challenge is that WCC data are typically available for employees in larger agricultural operations, but not for self-employed farmers or short-term employees on small agricultural operations. Secondly, many differences exist in Workers Compensation systems by state. And thirdly, not every non-fatal or fatal injury results in a workers' compensation claim system (Douphrate et al., 2009; Douphrate, Rosecrance, & Wahl, 2006; Foley et al., 2014). The private insurance companies administering WCC may have different database structures and access to these data may be very limited. However, with these limitations too, WCC data has a potential for use in surveillance and research of agricultural injuries. WCC data can provide insights on compensable injuries, which tend to be severe in nature. Besides, WCC includes data on parameters like time taken to return to work, resulting temporary or permanent disability, the cost of agricultural injury to the WCC system, which are not available in other data sets.

In lieu of national-level surveys for non-fatal agricultural injuries, administrative data sources discussed here can provide data to supplement the injury surveillance and research activities, but cannot substitute injury surveys.

2.4.2.2 NIOSH-funded agricultural safety centers (Ag Centers) and injury surveillance

Through the extramural research and training program, NIOSH currently funds ten Ag Center in the U.S., including the National Children's Center for Rural and Agricultural Safety and Health. The distribution of Ag Centers in different geographic regions helps in addressing the surveillance, research, and intervention needs specific to the farming population in that region (NIOSH, 2016). Of the ten, six Ag Centers have on-going injury surveillance projects focusing on specific farm population or industry sub-groups in agriculture using different data sources and data collection methods. For example, the Central States- Center for Agricultural Safety and Health covering farm populations in seven Central States (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota) collaborated with the NASS Iowa field office and conducts annual injury surveys since 2012. This novel mail-based self-administered cross-sectional injury survey collects demographic and injury data for up to three adult operators and three children/youth on living or working on the farm in the Central States region. The survey also data on the approximate cost of injury and work time lost. The survey responses linked with the data from the most recent Census of Agriculture provide information on farm characteristics and production practices. Besides, injury surveys CS-CASH collects fatal and non-fatal injury data using press-clippings (CS-CASH, 2015).

On another hand, the Northeast Center for Occupational Health and Safety: Agriculture, Forestry and Fishing (NEC) provides services to farm communities in eleven Northeastern states extending from Maine to West Virginia. Currently, NEC is exploring the feasibility of using existing medical databases (Ambulance reports and EMS/Hospital Discharge Data) to establish a low-cost, sustainable system providing data on agricultural injuries medical care. Using location at the time of the incident, E-codes, and narrative text (for ambulance reports), NEC identifies injuries among populations in Maine and New Hampshire, further details on are described by Scott et al. (2013) elsewhere. The NEC is working with health care organizations in New York, New Jersey, Vermont, and Maryland, to expand the surveillance activities for agricultural injuries

(NEC, 2015). Where CS-CASH and NEC collect injury data for adult and child farm populations using different methods, the National Children's Center for Rural and Agricultural Health and Safety (NCCRAHS) leads the effort to fill in gaps in child agricultural injuries.

One of the projects of NCCRAHS currently explores the feasibility to use existing survey data- Health Behavior in School-Aged Children (HBSC) and administrative datasets – National Emergency Medical Services Information System (NEMSIS) and National Trauma Data Bank (NTDB). The HBSEC is a cross-national survey of school students aged 11, 13, and 15 years old, and the survey collects on health and health-related behaviors. Currently, 45 countries collectively from Europe and North America collaborate with the World Health Organization (WHO) to conduct this survey every four years. One of the questions in HBSC is injuries, making it a unique and large data set, and results potentially comparable with other member countries (HSBC, 2016). NCCRAHS is reviewing a mock dataset to examine the relationship between youth injury and farm social environment and mental health. NCCRAHS is examining NEMSIS and NTDB datasets to determine potential variables that can help identify child farm injuries (NCCRAHS, 2015). The NEMSIS, a national repository with a potential to collect and archive EMS data from all the states in the U.S. (NEMSIS, 2016). The NTDB on another hand is aggregated data from state trauma registries in the U.S. and managed by the American College of Surgeons. (NTDB, 2016). All three approaches used by the three Ag Centers in this section, reflect innovative ways of using a combination of new and existing data sources or a combination of multiple existing data sources for agricultural injury surveillance in adult and youth.

2.4.2.3 Agricultural injury surveillance in other developed countries

Similar to the U.S., industrialized nations like Canada, Australia, New Zealand, and countries in the European Union (EU) rely on health surveys or administrative databases like hospital discharge records and workers' insurance claims records or a combination of both for surveillance of agricultural injuries. For example, in Finland, the Farmers' Social Insurance Institution (MELA) collects comprehensive individual-level data on all farm-related incidents under the statutory Farm Accident Insurance Act since 1982. The MELA covers all farmers including farm owner-operator and their spouses and paid family members on farms with 5 hectares or more (i.e. at least 12.4 acres) of land under operation, which is a unique system. In addition to accident insurance, MELA also has statutory sickness and pension insurance. In a case where MELA excludes a farm due to small size, the farmer can opt for an accident insurance policy voluntarily. Although detailed reliable and valid data on injuries and farmer demographics are available in MELA's farm accident insurance records, information on exposure or work hours are not available, which is difficult to collect attributed to the seasonal and transient nature of work (Karttunen & Rautiainen, 2013; Official Statistics of Finland [OSF], 2010).

Similar to Finland, the Social Insurance Institution for Farmers (Sozialversicherungsanstalt der Bauern, SVB) in Austria provides statutory health, accident, and pension insurance to farmers based on the Farmers' Social Security Act, 1979. The SVB provides compulsory accident insurance to farm operators including self-employed farmers and their family members if the assessed value of farm entity (farm production) equals 150 EUR or more, those not meeting these criteria are eligible to opt for voluntary accident insurance policy. Reliable and valid occupational farm injury data in Austria available from these SVB accident records. Non-work related farm injury data for adults and children are available through the European Union (EU) Injury Data Base (IDB) – Austria (SVB, 2016; Trichopolous, Petridou, Spyridoplous, & Alexe, 2004).

Surveillance approach for farm injuries in other EU like France, Denmark, Sweden, Netherlands are also similar, where there are a nationally representative occupational fatality and non-fatal work-related injuries database based on insurance records, medical records, and death registries. For non-work-related farm injuries, the EU countries use data from EU Injury Data

Base (IDB). The IDB is a standardized cross-national database on external causes of injuries treated in emergency departments of hospitals from participating in the European Union. Because it is currently not possible to collect data for all injuries from all hospitals in the EU, a nation-wide representative sample of hospitals is selected from participating countries in the EU to (European Commission [EC], 2016; Trichopolous et al., 2004). Where EU countries have national databases for occupational injuries including in agriculture, Australia uses data from multiple sources to obtain work-related farm injury data.

Safe Work Australia uses multiple sources to obtain data on work-related farm injuries, which include the Work-related Injury Survey (WIS), Workers' Compensation Claims, and a database of hospitalizations. The workers' compensation claims data are available from the National Dataset for Workers' Compensation Statistics, an annual compilation of all accepted claims under state and territorial Australian Worker's Compensation (WC) act. The WC records do contain data for self-employed farmers or their family members like in some of the European countries. Hospitalization database used to detect farm work-related injuries is mainly a national patient discharge database maintained by the Australian Institute of Health and Welfare, and does not include injuries treated in ambulatory clinics or emergency department rooms (Safe Work Australia, 2013). The WIS is a part of a larger annual Multi-Purpose Household Survey (MPHS) conducted annually among a nationally representative sample of households. The WIS collects data on work-related in the past calendar year from individuals of age 15 years and older (Australian Bureau of Statistics [ABS], 2015). Hence, the U.S. and Australian approach have some common deficiencies in surveillance of non-fatal agricultural injuries- undercount of farm injuries and underrepresentation of farm populations.

Lastly, the bordering country of the U.S., Canada has an integrated national program known as the Canadian Agricultural Injury Reporting (CAIR), which collects data on fatal and hospitalized agricultural injuries from all provinces in Canada through collaborations with the office of the coroner, chief medical examiner, vital statistics system, ministries of transportation, and farm safety associations. However, the 2011-2012 CAIR annual report indicated challenges in obtaining case-level data on non-fatal hospitalized injuries across the country attributed to increasing cost to obtain data, and limited access to data because of new privacy regulations for personal health information. The CAIR is currently exploring other existing data for surveillance of non-fatal injuries in agriculture (CAIR, 2012). This indicates that several other industrialized nations like the U.S. face similar challenges in developing one single system for surveillance of all agricultural injuries (fatal and non-fatal) for adults and youth farm populations. The approaches used by countries like Finland and other EU countries like Austria and Sweden show a promise for a nearly comprehensive system for agricultural injuries. Though not same as the social insurance for all, there may be an opportunity to build on existing injury prevention programs the new health reform under the Affordable Care Act continues.

To summarize, the national-level survey-based systems for non-fatal agricultural injuries evaluated in this paper undercounted injuries in adults and youth on U.S. farms. None of the survey-based systems evaluated in this paper are interoperable attributed to the differences in the scope of population captured, information collected and operational differences. Discontinuation of NAWS injury supplement and NIOSH injury surveys after the years 2015 resulted in a loss of injury surveillance data for the populations they covered because there is no on-going, systematic national data collection systems in place to detect and monitor injuries in self-employed farmers and ranchers and migrant and seasonal farm workers. Both the 2008 National Agriculture, Forestry and Fishing Agenda, and the 2012 National Action Plan for protecting children/youth in agriculture have emphasized the need for improving data systems for injury surveillance and timeliness and public access to data (Lee, Gallagher, Liebman, Miller, & Marlenga, 2012; NORA, 2008). Despite challenges in the administrative databases such as hospital records and workers' compensation claims data, they are potential data sources currently available to supplement data from injury surveys.

CHAPTER 3

INCIDENCE OF NON-FATAL AGRICULTURAL INJURIES AMONG FARM OPERATORS IN TH CENTRAL STATES REGION, U.S

The dynamic nature of the agricultural industry makes surveillance of agricultural injuries a challenge. Although, adequate are available for fatal work injuries in agriculture, data on non-fatal work injuries in agriculture are sparse and less accurate and reliable. National injury surveys tend to undercount injuries in agriculture. There is limited state-level data are available on estimates of farm populations, injuries, and injury rates.

The second paper in dissertation research aimed to estimate the non-fatal agricultural injury incidence among farm operator in seven Midwestern of the U.S., also as called Central States region in this study-Iowa (IA), Kansas (KS), Minnesota (MN), Missouri (MO), Nebraska (NE), North Dakota (ND), and South Dakota (SD). This research used a unique population-level dataset, which includes the Central States-Farm and Ranch Injury Survey (CS-FRIS) data linked with variables from Census of Agriculture data. -

The third chapter describes the research conducted in the second paper, and includes background, study methods, results, and a brief discussion.

3.1 Background

Agriculture ranks among the most hazardous industry sectors in the United States. In 2014, the Census of Fatal Occupational Injuries (CFOI) reported a fatal work injury rate of 24.9 fatalities per 100,000 full-time equivalent (FTE) workers in agriculture. This was 7.5 times higher than the all-industry average of 3.3 per 100, 000 FTE workers. CFOI data showed that occupational fatalities in agriculture increased by 16% from 2013 (n=500) to 2014 (n=584) (Bureau of Labor Statistics [BLS], 2016b). Furthermore, the number of non-fatal work-related injuries in agriculture was also high and many required days away from work, job transfer or work restriction. In 2014, the Survey of Occupational Injuries and Illnesses (SOII) estimated a non-fatal injury rate of 5.2 per 100 FTE hired workers in agriculture, fishing and forestry sector, which was higher than that for all other private industries combined (3.2 per 100 FTE workers) (BLS, 2015). To date, CFOI and SOII are the main sources of surveillance data for fatal and non-fatal occupational injuries in the U.S.

Where CFOI provides comprehensive data on all work-related fatalities, SOII only covers hired farm workers on farms with 11 and more employees, excluding self-employed farmers and employees on small operations (BLS, 2012). Leigh et al. (2014) estimated that SOII missed 77.6% of all agricultural work-related injuries. Besides SOII, two other government surveys collected data for agricultural work-related injuries through surveys, periodically - 1) National Agricultural Workers Survey (NAWS) and 2) Occupational Injury Surveillance for Production Agriculture (OISPA). The United States Department of Labor Employer and Training Administration (USDOL/ETA) conducted NAWS to collect employment and injury information for hired crop workers, while the National Institute for Occupational Safety and Health (NIOSH) conducted OISPA, covering self-employed farmers and ranchers (NIOSH, 2013; USDOL, 2014). However, discontinuation of the injury supplement of NAWS, and OISPA surveys after the year 2015 left the majority of the agricultural workforce without a national occupational injury surveillance system (Center for Disease Control and Prevention [CDC], 2015).

Despite the sparse surveillance data for non-fatal farm injuries, researchers evaluated the incidence of and risk factors for injuries in farmers, farm workers, and farm children and youth (Douphrate et al., 2009; Forst & Erskine, 2009; E. M. Goldcamp, 2010; Hard et al., 2002; J. R. Myers et al., 2009; Rautiainen et al., 2009; Zaloshnja, Miller, & Lawrence, 2012). A recent systematic review of 31 studies identified several significant risk factors for agricultural injury including male gender, prior injury, medication use, and hearing loss (Jadhav et al., 2015). Livestock handling, large farm machineries like tractors, augers, balers and storage structures like grain bins are leading causes of agricultural injuries (Douphrate et al., 2009; C. Missikpode et al., 2015; J. R. Myers et al., 2009; Reiner, Gerberich, Ryan, &

Mandel, 2016). An earlier review of surveys and censuses showed that disability resulting from non-fatal injuries affected about 20% of individuals living or working on U.S. farm or ranch operations (Deboy et al., 2008). While available information is limited, it is clear that disabling injuries constitute a considerable burden for agriculture, restricting work, and affecting the productivity of the sector.

To develop well-informed injury prevention strategies, it is essential to understand the incidence, risk factors, sources and circumstances of injuries, as well as characteristics of the populations and agricultural work in the region where the interventions take place. Surveillance of injuries and health conditions has been an integral part of the NIOSH-funded Central States Center for Agricultural Safety and Health (CS-CASH) based in Omaha, Nebraska, which serves the agricultural communities in the Central States (IA, KS, MN, MO, NE, ND, and SD) region. The Central States Farm and Ranch Injury Survey (CS-FRIS) is a major component of on-going surveillance efforts of CS-CASH in partnership with the National Agricultural Statistics Service (NASS). This unique survey covers farm operators in the Central States region, including self-employed and unpaid family members, which the SOII excluded. The annual injury survey collects information on non-fatal injuries and details on the physical location of the injury, part of body affected, source of injury, type of care required, lost farm work time and cost for most serious injuries. Another feature of CS-FRIS is an augmentation of variables from the most recent Census of Agriculture (Ag Census) describing farm characteristics to the injury survey, which allows evaluation of potential farm-level risk factors of injuries, in addition to personal risk factors.

The objective of this report was to estimate the average annual non-fatal agricultural injury incidence by the state during 2011-13 and examine variations in injury incidence by operator demographics and farm attributes such as farm acres, farm sales and commodities produced. This paper also examined the characteristics of the most serious injuries reported by the operators.

3.2 Methods

3.2.1 Study population, design, and sampling

This study used de-identified data from the Central States Farm and Ranch Injury Survey (CS-FRIS) for the years 2011, 2012 and 2013. USDA-NASS, Iowa field office administered the injury survey annually for CS-CASH. Surveys were mailed between March and April in 2012, 2013 and 2014 to adult farm operators (19 years and older) in the seven Central States (IA, KS, MN, MO, NE, ND, and SD) who were also respondents in the 2007 or 2012 Ag Census. NASS defined a farm operator as "the person running the farm and making day-to-day farm management decisions who could be the owner, or a member of owner's household, or a hired manager, or a tenant, or a renter, or a sharecropper" (USDA, 2014a).

The sampling frames were the most recent Ag Census respondent list. The 2007 Ag Census for the 2011 and 2012 injury surveys, and 2012 Ag Census for 2013 injury survey. Each year, NASS sampled 7000 farms in the region using a stratified disproportionate random sampling (1000 farms from each of seven states), with equal allocation and without replacement. NASS mailed one survey with a return envelope and a cover letter to each sampled farm. The participation was voluntary. In the case of a nonresponse, NASS sent one reminder survey. Table 5 gives details on the participant recruitment process for each survey year.

Table 5: Central States Farm and Ranch Injury Survey: Participant recruitment process for 2011, 2012 and 2013 injury surveys

	Central States Farm and Ranch Injury Survey		
Injury survey year	2011	2012	2013
Sampling frame –Census of Agriculture (N): Farms in the Central States region(1)	458,055	458,055	437,042
Year of Census of Agriculture	2007	2007	2012
Sample:	7000	7000	7000

1000 eligible(2) farms from each state using stratified disproportionate random sampling with equal allocation and without replacement			
Number of farms removed(3) from the sample	48	88	0
Total number of mail surveys sent (n1)	6953	6912	7000
Number of surveys received back (n2)	2299	2316	2574
Survey response rate= (n1-n2)*100	33.1%	33.5%	36.8%
Number of farms in survey responses by state			
Iowa	387	386	423
Kansas	349	359	366
Minnesota	379	390	438
Missouri	315	326	390
Nebraska	292	217	455
North Dakota	265	324	184
South Dakota	312	314	318

(1) The Central States region consists of seven states, which are IA=Iowa, KS=Kansas, MN=Minnesota, MO=Missouri, NE=Nebraska, ND=North Dakota, SD=South Dakota.
(2) Farm operators aged ≥19 years, who responded to the most recent U.S. Census of Agriculture.
(3) These farms had an agreement with National Agricultural Statistics Service to receive only one survey per calendar year.

3.2.2 Study data

3.2.2.1 Data from Central States Farm and Ranch Injury Survey (CS-FRIS)

The CS-FRIS was a cross-sectional, self-administered survey that was designed and pilot-tested by CS-CASH. The CS-FRIS resembles the Ag Census form, in terms of the language used, format and type of information collected. Similar to the Ag Census, the CS-FRIS collected information on demographic and work characteristics for up to three farm operators per farm, and the principal operator receiving the Census form fills the information. One main difference is that the CS-FRIS collects information about both adult and children that lived or worked on the operation while the Ag-Census only collects information about adults. The analysis for this study included data only for adult operators (i.e., age ≥19 years).

In CS-FRIS, an injury was defined "the result of a sudden, unexpected, forceful event, which has an external cause, and which results in bodily damage or loss of consciousness." CS-FRIS defined the farm-related activities to include any work and leisure activities on the farm operation, plus commuting, transport, and business trips for the farm operation. The survey asked each operator to indicate whether he/she had 0, 1, 2, or 3 or more injuries in the previous calendar year. The analysis used additional details on the single most serious injury reported for each operator. Additional details included- 1) the location where the injury occurred and whether it happened during work or leisure, 2) the source of the injury, 3) the body part(s) affected, 4) the care received for it, 5) lost farm work time resulting from injury, and 6) estimated out-of-pocket and insurance paid cost from the injury.

3.2.2.2 Data from Census of Agriculture

After collecting and linking the survey responses with Ag Census data, NASS provided de-identified data files to CS-CASH. The files consisted data from 2007 Ag Census linked with 2011 and 2012 injury surveys, and 2012 Ag Census data linked with 2013 survey. NASS conducts the U.S. Ag Census every five years to enumerate farms, and collects information on farm characteristics, and farm production (USDA, 2014a). Variables from Ag Census used in this study include: the type of organization (family, partnership operation, incorporated under state law and other), farm size (in acres), gross sales for the census year (in the U.S. dollars), the types of commodities produced and types of tractors used on the operation (<40, 40-99, and ≥100 horsepower).

3.2.3 Sample weighting

A total 7189 farm operators responded to the injury survey with an overall response rate of 34.5% (33.1% in 2011, 33.5% in 2012 and 36.8% in 2013). After cleaning, editing, and coding the data, we the calculated stratum state-specific base weights as an inverse of selection probability for a farm from each state, in each survey year.

3.2.3.1 Item nonresponse adjustment

In the Ag Census the percentage of missing data were higher than 5% in many variable - farm sales (10.5%), types of tractors (<40, 40-99, and ≥100 horsepower) used on the farm (10.8%, 7.8% and 10.3%), and commodities produced by the farm (ranging from 6-18%). Further analysis showed that the pattern of missingness for these Ag Census variables was arbitrary, and not related to the outcome (injury). Assuming that data are missing at random, missing values for these Ag Census variables were imputed using base-weighted hot deck imputation technique (nearest neighbor) (Chen & Shao, 2000; Fay, 1999; Little & Rubin, 2014; Tutz & Ramzan, 2015). In CS-FRIS survey, missing data were minimal; therefore, we did not impute for missing data for the survey.

3.2.3.2 Unit nonresponse adjustment

This analysis used generalized raking procedure (truncated linear method) to calibrate base weights for each stratum to adjust for survey nonresponse and to reduce sampling variability. Raking uses the information from auxiliary variables from the source population to adjust the sample weights, such that the sums of weights in the margins are equal to the population counts (Deville & Särndal, 1992; Deville, Särndal, & Sautory, 1993; Izrael, Battaglia, & Frankel, 2009). We used farm size and gross sales as auxiliary variables for raking adjustment because proportions of these two variables in survey responses were different from that in the source population (Ag Census). The published 2007 and 2012 Ag Census reports provided information on marginal totals for the two auxiliary variables. We conducted raking adjustments for stratum-specific base weights in each survey year. Both weighted hot deck imputation and raking procedures were performed using XLSTAT Pro Version 2015.4.01.2016 © Addinsoft 1995-2015 in Microsoft Excel.

3.2.3.3 Benchmarking survey data

Benchmarking is the process of re-weighting the sample-based estimates such that the estimated population counts equal the actual population counts. In this study, estimates from 2012 survey data were benchmarked to match farm operator counts published in 2012 Ag Census report. However, according to

2012 Ag Census report, there was an overall decline in operator population from 2007 (680,169 operators) to 2012 (658,412) in the Central States region with an average decline of 4351 operators per year [USDA, 2012]. If we had benchmarked estimates from 2011 survey data to match farm operator counts published in 2007 or 2012 Ag Census reports, it would have over- or underestimated the operator population in 2011. Therefore, assuming that the rate of decline remained the same from 2007 to 2013, we calculated the total number of farm operators in 2011 and 2013. Lastly, we benchmarked the estimates of farm attributes, operator demographics, and injury characteristics based on 2011 and 2013 surveys to farm operator counts calculated in 2011 and 2013.

3.2.4 Data analysis

This paper used three years of combined CS-FRIS data (2011, 2012 and 2013 surveys) for analysis. This paper reported the estimates of operator characteristics, farm attributes, and injuries as annual averages, and injury incidence rates as average annual injury rates.

The injury question asked if an operator had 1, or 2, or ≥3 injuries in a calendar year. If response=1, it was counted as 1 injury. If response=2, it was counted as 2 injuries. However, if the response was ≥ 3, we counted it as 3 injuries. We calculated the numerator for injury rate using the following two steps. Step 1 was a summation of estimated number of 1, 2, and 3 injuries to operators for all three years combined. Step 2 was a division of a total number of injuries to operators for all three years combined by 3. This two-step calculation provided the estimated average annual number of injuries during 2011-13 i.e., the numerator for injury rate calculations.

The benchmarked survey data gave estimated the number of operators in 2011, 2012 and 2013. During the benchmarking process, we accounted for the observed decline in the number of operators from 2007 to 2012, such that population counts for 2011, 2012 and 2013 are not under or overestimated. We estimated the average annual operator population in the Central States region during 2011-13 using two steps. Step 1 was a summation of the estimated number of operators for all three years combined. Step 2 was division of the total estimated number of operators for all three years combined by 3. This analysis used the estimated average annual population counts as the denominators for calculating injury rates, as no usable work hours data were available for farm operators.

The average annual injury rate per 100 operators was the estimated average annual number of injuries divided by estimated average annual operator population in the Central States region during 2011-13, multiplied by 100. Standard errors and 95% confidence intervals for demographics and injury estimates were calculated using Taylor series linearization method for stratified/complex survey designs (Kalton & Flores-Cervantes, 2003; Little & Rubin, 2014). Percent relative standard error (%RSE) was used to detect estimates with high sampling error. Estimates and injury rates for variable categories with percent RSE greater than 30% were less reliable and not presented in this paper.

Injury rates were compared by operator demographics and farm variables; statistically significant differences were detected at $p<0.05$ level using two-tailed Rao-Scott Chi-square test of independence. We used descriptive statistics to summarize characteristics of the most serious injuries to operators. All estimates and variances were obtained using SAS Surveyfreq procedure (SAS/STAT 9.3, Copyright © 2002-2010, SAS Institute Inc., Cary, NC). The University of Nebraska Medical Center Institutional Review Board approved the research (IRB protocol 452-11-EX).

3.3 Results

3.3.1 Population characteristics

During 2011-2013, an estimated average 658,412 (2011=662,763, 2012=658,412, 2013=656,074) operators operated 437,042 farms annually in the Central States region. Of the seven Central States, Missouri and Iowa had the higher percentage of operator population compared to other five states in the Central States region (Table 6).

The majority of farm operators in the Central States region were males (79.9%), belonged to age groups 55 and above (55-64yrs = 30.6% and ≥65yrs = 30.8%), reported farm/ranch work as primary occupation (53.2%), and spent 50% or more time working on a farm operation (50.9%). Most operators worked on individual/family run operations (85.3%). Approximately 45% operators worked on small farms (1-179 acres). Most operators lived or worked on operations producing field crops (51.2%), hay/forage (47%), and cattle/calves (46.7) (Table 6).

Table 6: Farm operator characteristics: States in the Central States region, socio-demographic variables and farm characteristics, 2011-13

	Farm operators		
	Sample[(1)]	**Estimate[(2)]**	**%[(2)]**
Total	9507	658,412	100.0
State			
Iowa	1536	131,535	20.0
Kansas	1422	92,892	14.1
Minnesota	1578	111,311	16.9
Missouri	1374	152,817	23.2
Nebraska	1318	75,855	11.5
North Dakota	994	45,015	6.8
South Dakota	1285	48,987	7.4
Gender			
Male	7,610	526,389	79.9
Female	1,747	121,834	18.5
Unknown	150	10,189	1.5
Age (years)			
19-35	710	47,683	7.7
35-54	2,875	198,261	30.1
55-64	2,924	201,162	30.6
≥65	2,867	202,511	30.8
Unknown	131	8,795	1.3
Primary Occupation			
Farm/ranch work	5,213	350,560	53.2
Other than farming	4,127	295,369	44.9
Unknown	167	12,483	1.9

Percentage of time spent working on farm/ranch			
<50%	4,291	307,896	46.8
≥50%	5,003	334,829	50.9
Unknown	213	15,687	2.4
Type of organization			
Individual/ Family	8,059	561,577	85.3
Partnership operation	759	51,287	7.8
Incorporated under state law	559	36,702	5.6
Other(3)	130	8,846	1.3
Farm size (acres)			
1-179	4,013	297,813	45.2
180-999	3,465	245,377	37.3
≥1000	2,029	115,222	17.5
Gross sales(4)			
<$10,000	2,930	220,843	33.5
$10,000-99,999	2,730	193,946	29.5
≥$100,000	3,847	243,623	37.0
Tractor type: 40 horse power(4,5)	4,134	289,092	43.9
Tractor type: 40-99 horse power(4,5)	6,520	457,935	69.6
Tractor type: ≥100 horse power(4,5)	5,494	364,944	55.4
Types of commodities produced(6)			
Field crop(4)	5061	337,184	51.2
Hay/forage(4)	4428	309,726	47.0
Cattle/calves	4366	307,377	46.7
Horses/ponies	1861	125,622	19.1
Other animals(4,7)	1534	109,860	16.7
Poultry(4)	658	46,211	7.0
Hogs/pigs	399	30,279	4.6
Sheep/lambs(4)	417	26,981	4.1
Vegetables/melons(4)	119	8,648	1.3
Fruit/nuts(4)	101	7,273	1.1
Bees	84	5,545	0.8
Nursery/greenhouse(4)	64	4,539	0.7
Berries(4)	42	3,195	0.5

Woodland crop[4]	20	1,570	0.2
Aquaculture	6	292	0.04

Sample: Number of operators in survey responses for all three years combined.
Estimate: Estimated average annual number of operators during 2011-13.
(1) Raw counts, no weighting applied.
(2) Nonresponse adjusted sampling weights applied.
(3) Other type of organization includes estate or trust, prison farm, grazing association, American Indian Reservation etc.
(4) This variable had >10% missing data, so missing values were imputed using weighted sequential random hot-deck imputation technique.
(5) Each type of tractor is an independent variable and was recorded as yes/no. Example: type of tractor <40 horsepower = yes or type of tractor <40 horsepower = no
(6) Types of commodities produced: Each type of commodity was an independent variable, and was recorded as yes/no. Example: cattle=yes or cattle=no.
(7) Other animals include alpacas, llamas, bison, deer in captivity, elk in captivity, live mink, and rabbits.

3.3.2 Average annual non-fatal agricultural injury incidence

3.3.2.1 Injuries by state

Farm operators in the Central States region reported an estimated average 44,887 injuries per year during 2011-13, and the average annual injury rate was 6.8 per 100 operators. Compared to IA, KS, MN, MO, and NE, the average annual injury rate was higher in the two Dakotas (ND and SD), but this difference was not statistically significant (Table 7).

Table 7: Average annual non-fatal agricultural injury rates /100 farm operators in the Central States region by state, socio-demographic variables, and farm characteristics: 2011-13

	Injuries[1]			
	Estimate[2]	**Rate[2,3]**	**CI $_{95\%}$[2,4]**	**p-value[5]**
Total	44,887	6.8	6.3-7.1	
State				0.42
Iowa	8,810	6.7	5.4-7.3	
Kansas	6,258	6.7	5.4-7.4	
Minnesota	7,207	6.5	5.3-7.1	
Missouri	9,702	6.3	5.1-7.0	
Nebraska	5,163	6.8	5.4-7.5	

North Dakota	3,822	8.5	6.8-9.4	
South Dakota	3,925	8.0	6.5-8.8	
Gender				0.005
Male	38,343	7.3	6.7-7.6	
Female	6,134	5.0	4.0-5.6	
Unknown	410	[-]	[-]	
Age (years)				0.0008
19-35	3,292	6.9	5.0-7.9	
35-54	17,414	8.8	7.7-9.3	
55-64	14,179	7.0	6.1-7.5	
≥65	9,668	4.8	4.0-5.2	
Unknown	334	[-]	[-]	
Primary Occupation				<.0001
Farm/ranch work	30,920	8.8	8.1-9.2	
Other than farming	13,622	4.6	4.0-4.9	
Unknown	345	[-]	[-]	
Percentage of time spent working on farm/ranch				<.0001
<50%	14,419	4.7	4.1-5.0	
≥50%	29,936	8.9	8.2-9.3	
Unknown	532	[-]	[-]	
Type of organization				0.48
Individual/ Family	38,908	6.9	6.4-7.2	
Partnership operation	3,485	6.8	5.0-7.7	
Incorporated under state law	2,270	6.2	4.2-7.2	
Other(6)	224	[-]	[-]	
Farm size (acres)				0.0005
1-179	16,507	5.5	4.8-5.9	
180-999	17,674	7.2	6.3-7.6	
≥1000	10,706	9.3	8.0-9.9	
Gross sales(7)				0.0001
<$10,000	11,606	5.3	4.4-5.7	
$10,000-99,999	12,659	6.5	5.6-7.0	
≥$100,000	20,622	8.5	7.6-8.9	
Tractor type: 40 horse power(7, 8)	21,083	7.3	6.5-7.7	0.03

Tractor type: 40-99 horse power(7, 8)	32,80	7.2	6.5-7.5	0.15
Tractor type: ≥100 horse power(7, 8)	30,505	8.4	7.6-8.7	<.0001
Types of commodities produced(9)				
Field crop(7)	27,458	8.1	7.4-8.5	0.0007
Hay/forage(7)	24,185	7.8	7.0-8.2	0.02
Cattle/calves	24,380	7.9	7.1-8.3	<.0001
Horses/ponies	10,124	8.1	6.8-8.7	0.04
Other animals(7,10)	9,518	8.7	7.3-9.4	0.11
Poultry(7)	4,007	8.7	6.5-9.8	0.33
Hogs/pigs	3,535	11.7	8.5-13.3	0.0002
Sheep/lambs(7)	1,837	6.8	4.4-8.0	0.17
Vegetables/melons(7)	288	[-]	[-]	n/a
Fruit/nuts(7)	149	[-]	[-]	n/a
Bees(7)	334	[-]	[-]	n/a
Nursery/greenhouse(7)	113	[-]	[-]	n/a
Berries(7)	223	[-]	[-]	n/a
Woodland crop(7)	0	0	0-0	n/a
Aquaculture(7)	67	[-]	[-]	n/a

Sample: Number of operators in survey responses for all three years combined.
Estimate: Estimated average annual number of injuries during 2011-13.
[-] Injury rate and its 95% confidence interval were suppressed in this table as the percent relative standard error (%RSE) was >30%, which indicates that the estimates were unstable with high variability.
(1) An injured operator could report 1, 2 or 3 injuries. All injuries to each operator were included. The total number of injuries to each farm operator was calculated as the sum of all injuries to a farm operator in a given calendar year.
(2) Nonresponse adjusted sampling weights applied.
(3) Rate presented here is the average annual incidence of non-fatal agricultural injuries per 100 farm operators per year. The non-fatal agricultural injury rate was calculated as the estimated average annual number of non-fatal injuries to farm operators divided by the estimated average annual number of farm operators in the Central States region during 2011-13, multiplied by 100.
(4) 95% confidence intervals (CI) and standard errors were obtained using Taylor series linearization method for variance estimation.
(5) P value is obtained using two-tailed Rao-Scott chi-square test for independence at the level of significance 0.05.
(6) Other type of organization includes estate or trust, prison farm, grazing association, American Indian Reservation etc.
(7) This variable had >10% missing data, so missing values were imputed using weighted sequential random hot-deck imputation technique.
(8) Each type of tractor is an independent variable and was recorded as yes/no. Example: type of tractor <40 horsepower = yes or type of tractor <40 horsepower = no

(9) Types of commodities produced: Each type of commodity was an independent variable, and was recorded as yes/no. Example: cattle=yes or cattle=no.
(10) Other animals include alpacas, llamas, bison, deer in captivity, elk in captivity, live mink, and rabbits.

3.3.2.2 Injuries by socio-demographic variables

There were statistically significant differences in non-fatal agricultural injury rates by operator characteristics (Table 7). During 2011-13, about 85% of injuries occurred to male operators. The average annual injury rate was highest among operators in the age group 35-54 years, and lowest in operators 65 years and older. Operators with primary occupation as farming and ranch work had an average annual injury rate, which was nearly twice as much as compared to operators with a primary occupation other than farming. Similarly, operators who reported spending 50% or more of their time working on a farm/ranch had nearly twice as much injury rate than operators who reported spending less than 50% of their time working on a farm/ranch.

3.3.2.3 Injuries by farm characteristics

Farm operator injuries did not differ by type of farm organization. However, there was a statistically significant variation in injury incidence by farm size and gross sales group. Operators on larger (1000 or more acres) farms, and on farms with gross annual sales $100, 000 had higher rates of injury (Table 7).

Compared to farmers who lived or worked on operations without greater than or equal to 100 horsepower tractors, the rate of injury was 1.7 times higher in operators living or working on farms having tractors greater than or equal to 100 horsepower. Of all the different crop commodities produced in the Central States region, operators growing field crops accounted for approximately 61% of total injuries. The rate of injury among operators growing field crops was 1.5 times higher than those who did not grow field crops. Hay/forage producers had the second highest rate of injury. Among all operators who lived or worked on farms producing livestock commodities, the estimated average annual number of injuries was highest in cattle/calves farmers (24,380 injuries). Despite a small (4.6%) percentage of operators producing hogs/pigs, the average annual injury rate was highest in them (11.7 per 100 operators). Due to a smaller number of operators and injuries on farms growing vegetables, berries, nursery or greenhouse crops, fruits/nuts, bees, and aquaculture the rates of injuries calculated for these commodities were unstable with high variability. Hence, we did not present these rates. To summarize, the commodity-specific average annual injury rates for operators producing field crops (8.1), hay/forage (7.8), hogs/pigs (11.7), horses/ponies (8.1), cattle/calves (7.9), poultry (8.7), and other animals (8.7) were higher than the overall rate of injury (6.8) during 2011-13.

3.3.2.4 Characteristics of "most serious injury" reported by farm operators

There were an estimated 35,579 most serious injuries reported by farm operators per year during 2011-13. About 80% percent of most serious injury occurred to farm operators while working, whereas only 11% happened at leisure. Farmyard (37.5%), field/pasture (32.9%) and farm building (16.6%) were the most common places where the most serious injuries occurred to farm operators. Livestock, farm machinery, hand tools, and tractor were the most common sources or substances causing most serious non-fatal injury to farm operators. Leg/knee/hip, back, and arm/shoulder were the most commonly injured body parts. Out of 35,579 most serious injury reported by farm operators, 21,374 (60.1%) required a doctor/clinic visit and 4,348 (12.2%) required hospitalization. Approximately 66% of the most serious injury reported by farm operators lost farm work time ranging from less than half a day to 30 days or more. Among injured operators, 12.7% lost farm work time for 30 days or more, whereas 27.2% lost farm work time anywhere from 2 to 29 days attributed to a serious injury (Table 8).

Table 8: Characteristics of "most serious injury" reported by farm operators in the Central States region, 2011-13

Variables	Injured farm operators reporting "most serious injury" (3)		
	Sample(1)	Estimate(2)	95% CI for Estimate(2)
Total number of injured operators	550	35,579	32,700 - 42,358

Injury took place-			
While working	463	31,595	30,520-32,6271
At leisure	57	3,931	2,890-4,973
Unknown	30	2,053	-
Location of injury			
Home/office	32	2,284	1,482-3,086
Farm building	82	5,896	4,671-7,120
Farm yard	196	13,358	11,791-14,924
Field/pasture	173	11,726	10,199-13,252
Road/off-farm	32	2,119	1,354-2,884
Unknown	35	2,196	-
Object/substance causing injury(5)			
Livestock	159	10,971	10,748-11,193
Machinery	62	3,998	3,880-4,116
Hand tool	55	3,797	3,639-3,895
Tractor	54	3,772	3,663-3,911
Working surface	51	3,381	3,256-3,506
ATV	34	2,028	1,950-2,107
Power tool	31	2,181	2,088-2,273
Truck/automobile	26	1,794	1,729-1,858
Water	7	314	314-315
Other vehicle	6	351	322-381
Chemical/pesticide	2	125	124-126
Other	95	6,651	7,025
Body part injured(5)			
Leg/knee/hip	132	8,861	8,662-9,060
Back	114	7,520	7,341-7,698
Arm/shoulder	108	7,194	7,019-7,368
Finger	85	6,071	5,912-6,229
Head/neck	80	5,375	5,245-5,505
Hand/wrist	56	3,910	3,776-4,045
Foot	44	2,633	2,539-2,727
Chest/trunk	29	1,845	1,749-1,941
Eye	16	1,069	1,012-1,126

Toe	10	713	654-771
Other	22	1,433	1,368-1,498
Professional medical care required			
None	164	11,632	11,396-11,867
Doctor/clinic visit	318	21,374	21,087-21,660
Hospitalization	65	4,348	4,204-4,492
Unknown	3	225	-
Lost farm work time due to injury			
None	162	11,527	9,993-13,061
<1/2 day	85	5,649	4,485-6,812
1/2 to 1 day	64	3,764	2,846-4,682
2-6 days	93	6,292	5,032-7,552
7-29 days	45	3,384	2,383-4,386
>=30 days	67	4,527	3,463-5,601
Unknown	34	2,436	-

Sample: Number of operators in survey responses for all three years combined.
Estimate: Estimated average annual number of injured operators during 2011-13.

(1) Raw counts, no weighting applied.
(2) Nonresponse adjusted sampling weights applied to obtain.
(3) An injured operator could report more than one injury. However, this table is limited to information about the most serious injury identified by the respondents, out of all injuries to them in a given calendar year.
(4) 95% confidence intervals (CI) and standard errors were obtained using Taylor series linearization method for variance estimation.
(5) An injured operator could report more than one source of injury or body part injured. Therefore, the totals may not add up.

3.4 Discussion

According to the 2012 Ag Census, 20.4% of all U.S. farm operators lived and/or worked on farm/ranch operations in the seven Central States. Six out of seven states in the Central States region ranked in top 10 states for the number of farms, farm sales, crop and livestock sales, and contributed to a large share of agricultural production in the United States. (USDA, 2014a). Therefore, it is imperative that we track and monitor safety and health of farm populations in a region with high agricultural activities. Over the years, research groups have studied injuries among farming populations in different states. However, population-level estimates for agricultural injuries to farm operators in the Central States region were lacking. The collaboration between CS-CASH and NASS made it possible to conduct systematic, on-going injury surveys providing population-level data for farm operators in the Central States region.

3.4.1 Central States Farm and Ranch Injury Survey (CS-FRIS)

During 2011-13, CS-FRIS estimated an average 44,887 injuries per year among farm operators in the Central States region. The rate of non-fatal agricultural injury among farm operators in the Central States region (i.e. 6.8 injuries per 100 operators) was substantially higher than injury rates presented by national surveys (SOII, OISPA, and NAWS) for other farming populations in the U.S. The 2014 SOII estimated an overall U.S. rate of 5.5 injuries per 100 full-time hired workers in agriculture, whereas 2012 OISPA estimated 2.6 injuries per 100 operators living, working or visiting on all U.S. farms (BLS 2014; NIOSH, 2013). The most recent report using 2008-2010 NAWS estimated an injury rate of 2.9 per 100 week-based full-time hired crop workers(Tonozzi & Layne, 2016).

We observed a high non-fatal injury rate in the Central States region, which could be due to several reasons. First, the CS-FRIS covered all types of farm operators, including farm owners, self-employed, unpaid family members, and operators on farms with less than 11 employees/farmers. Second, use of robust nonresponse adjustment (raking and imputation) techniques, which minimized the sampling error and bias due to missing data. Third, we used a denominator that was representative of the source population.

There are couple data sources that provide estimates on the employed population in U.S. agriculture. The government occupational injury surveys in the U.S. use data from these employment databases as the denominator for calculating injury rates. SOII collects data from employers on hours worked by employees and uses the Quarterly Census of Employment Wages (QCEW) to calculate injury estimates, and hour-based injury rates. On the other hand, OISPA uses estimates of employed population in agriculture from its own survey data, as well as from the Current Population Survey (CPS) to calculate injury rates (Goldcamp, 2010; Myers et al., 2009). CPS is a sample survey of households that collects monthly data to estimate employment and unemployment rates in U.S. populations (United States Census Bureau [USCB], 2015a). However, a recent study by Leigh et al., (2014) evaluating the undercount of injuries and illnesses in agriculture, highlighted the drawbacks of SOII, QCEW, and CPS in gathering data for agriculture workforce due to the transient and seasonal nature of the industry. Leigh and team estimated that QCEW undercounted 14.3% of the employed population in agriculture, which contributed to the underestimation of injuries and illnesses based on SOII data. Further, authors identified CPS and Census of Agriculture as two data sources that provide estimates of the population employed in agriculture but indicated the inability of CPS and Ag Census to provide full-time equivalent (FTE) counts for workers in agriculture (Leigh et al, 2014). The American Community Survey (ACS) conducted by United States Census Bureau is another sample survey that provides estimates on working population, including in agriculture (USCB, 2015b). Recently, Landsteiner et al., (2015) examined Minnesota's hospital discharge data to estimate injury rates of serious farm-related injuries during 2000-2011 and used a combination of ACS and Ag Census data to estimate the total population living or working on farms in Minnesota. Although the authors acknowledged that their approach was unique, it provided only a rough estimate of the number of individuals living or working on farms in Minnesota (Landsteiner et al., 2015). In addition to underreporting of injuries, lack of valid denominator for rate calculations is another factor that explains the underestimation of injuries in U.S. agriculture by surveillance systems like SOII and OISPA.

The denominator used for calculating injury rates in this study was the estimated average number of adult farm operators in the Central States region during 2011-2013; we calculated the denominator using information on farm operators from the most recent Ag Census. The use of denominator derived from Ag Census data was more accurate and appropriate for this study because -1) Ag Census was designed to enumerate farms and operators living or working on U.S. farms; 2) CS-FRIS used Ag Census respondents as sampling frame and hence, denominator was representative of the source population, and

3) Census data are generally more complete. Therefore, injury estimates and rates based on CS-FRIS data were generalizable to the farm operator population in the Central States region.

Although the differences in injury rates by state in the Central States region was statistically non-significant, the estimated average annual injury rates per 100 operators in North Dakota and South Dakota were slightly higher compared to Iowa, Kansas, Minnesota, Missouri, and Nebraska. Findings from this study were consistent with those of the Regional Rural Injury Study (RRIS)-II in 1999. RRIS-II showed a higher rate of agricultural injury in South Dakota (90.3 per 1000 persons per year) and North Dakota (76.7 per 1000 persons per year) compared to Minnesota, Nebraska, and Wisconsin. RRIS-II was a population-based survey covering farm operators and their family members in five Midwestern states-Minnesota, Nebraska, North and South Dakota and Wisconsin (Mongin et al., 2007a). However, it is unclear why the rates of injury were higher in North Dakota, and South Dakota compared to other states, and warrants further investigation.

Besides RRIS-II, independent research groups have recently examined incidence and trends in agricultural injury incidence in Iowa and Minnesota. Missikpode et al., (2015) evaluated the Iowa trauma registry and found that the rate of non-fatal agricultural injuries requiring trauma care per 100,000 hired workers, ranchers, and farm operators in Iowa in 2013 (83.0) was nearly 3 times the rate in 2005 (30.49). The authors indicated that the rate of non-fatal agriculture injuries requiring trauma care in Iowa increased by 11% per unit increase in a year from 2005 to 2013. The research group from Minnesota used Minnesota hospital discharge data and reported an annual injury rate of all farm-related injuries ranging from 14.0 to18.5 per 1,000 persons living and/or working on farms in Minnesota from 2000-2011 (Landsteiner et al., 2015). The CS-FRIS injury data are mainly self-report, whereas the studies from IA and MN used administrative data sources to identify injuries. Therefore, authors recommended caution when comparing injury rates for Iowa and Minnesota using CS-FRIS data, and data from the two studies.

In recent years, several research groups have explored emergency department visit records, trauma registries, hospital discharge and pre-hospital data, and discussed the pros and cons of using these datasets for surveillance of agricultural injuries. There are advantages of using a medical records database for surveillance of agricultural injuries. First, medical records include details on injury event such treatment procedures, medical cost, other comorbidities and consequences of injury. Second, medical records are not subject to biased associated surveys such as selection bias, and other sampling errors, volunteer, and self-report. Third, most state health departments have access to medical record databases, eliminating the need and additional cost of designing and maintaining a new data collection system (Forst & Erskine, 2009; Gross, Young, Ramirez, Leinenkugel, & Peek-Asa, 2015; Landsteiner et al., 2015; Scott et al., 2015). However, there are several challenges in using these datasets for surveillance purpose.

Firstly, the purpose of administrative datasets like hospital discharge data (HDD) is to collect data for billing and quality assurance, and therefore, may not have all the necessary variables to identify agricultural/occupational injuries. Secondly, not all farm injuries require medical care and therefore, administrative datasets like HDD and state-based registries fail to capture these farm injuries. Thirdly, each state has different reporting requirements, which makes state-to-state comparison difficult (Forst & Erskine, 2009; Gross et al., 2015; Landsteiner et al., 2015; Missikpode et al., 2015; Scott et al., 2015). For example, Iowa trauma registry has mandatory data field to identify if a case was farm-related or not, but Nebraska's trauma registry does not have this mandate (Jawa et al., 2013; Missikpode et al., 2015). Because of existing challenges in using administrative datasets, SOII, NAWS, and OISPA remains main data sources for population-level estimates on agricultural injuries.

SOII provides occupational injury data for most U.S. states, but no data are available for North and South Dakota (BLS, 2015a). Other national-level agricultural injury surveys, the NAWS, and the OISPAs both do not provide state-level injury estimates. Given this scenario, CS-FRIS filled a critical data gap by providing regional as well as state-level estimates of non-fatal agricultural injuries and injury rates for farm operator population in seven Central States. Also, the unique linkage between CS-FRIS and

Ag Census data this study examined injury incidence by type of farm organization, farm size, gross farm sales, and different farm commodities, for which information was lacking.

3.4.2 Non-fatal agricultural injuries among farm operators in the Central States region

Some findings from analysis of CS-FRIS data were consistent with existing literature, and some were unique to this study. For example, in the Central States region too, males, individuals younger than 65 years of age, and those with farming or ranching as primary occupation presented a higher incidence of non-fatal agricultural injuries compared to other population sub-groups. This was similar to findings from other studies examining agricultural injuries among farm operators in Alabama, California, New York, and five Midwestern states (Regional Rural Injury Study-II) (Hwang et al., 2001; McCurdy et al., 2004; Mongin et al., 2007; Zhou & Roseman, 1994). In Regional Rural Injury Study or RRIS-II too, the rates of injury per 1000 operators were higher in males (110.9) and adults in age groups 35-44 (136.0) and 55-64 (157.7) (Mongin et al., 2007). The California Farmer Health Study (CFHS), which was also a population-based telephone interview survey of randomly selected farm operators like Regional Rural Health Study (RRIS)-II, suggested a higher risk of injuries in males, individuals less than 65 years of age, and those who spent more than half of their time working on a farm/ranch (McCurdy et al., 2004). Similarly, the New York State Farm Family Health and Surveillance (NYS FFHS) reported higher rates of injuries in males, operators in the age group 35-44, and those who spent on an average more than 8 hours working on a farm per day (Hwang et al., 2001). Males and operators in younger age groups 35-64 make up a larger proportion of the agricultural workforce (USDA, 2014a), and tend to work longer hours, operate heavy and complex farm machineries, and work with large animals, which exposes them to known hazards for agricultural injuries (Jadhav et al., 2015). This explains the high rates of injuries among these population sub-groups.

It is known that large farm size, high gross sales, and livestock and crop farming increase the likelihood of agricultural injuries in both adults and children/youth on farms (Hwang et al., 2001;

McCurdy et al., 2004; Rautiainen et al., 2009; Zaloshnja et al., 2012). The NYS FFHS estimated an injury incidence rate of 6.5 per 1000 persons on farms growing cash crops, 10.4 on livestock and dairy farms, 12.5 on large farms (>1000 acres) (Hwang et al., 2001). A recent study by Reiner et al., (2016) using RRIS-II data estimated 12.8 injury events per 1000 persons per year in the five Midwestern States (MN, NE, ND, SD, and WI) attributed to large agricultural machinery. Similarly, in this study, operators on large and high sales farms, having larger and powerful tractors, and those producing hog, horse, cattle and field crop had higher rates of injury, which was as expected.

Research has shown that non-fatal agricultural injuries incur the substantial medical cost and result in temporary to permanent disability depending on the severity of the non-fatal injury (Costich, 2010; Deboy, 2008; Gross et al., 2015). In this study, the majority of the injured operators required some form of professional medical care (clinic visit/hospitalization) and around 38% lost more than 2 days of farm work time due the injury. Consistent with our findings, the RRIS-II found that about 82% of injuries occurring in operators and household members required some form or professional medical, and 47% of injured operators reported some amount of lost farm work time (Mongin et al., 2007). Loss of work time during peak seasons can have a serious impact on the production activities on the farm. Given that, either the operator would substitute someone as his replacement to continue the farm work, or suffer production loss. In either case, there is an indirect cost incurred due to the injury. Other aspects such as the cost of transportation to clinic/hospital, damage to the farm commodity or equipment during injury are some of the other costs that can be associated with an injury. Leigh et al., (2001) estimated that for agricultural injuries in 1992, indirect costs were 65% of the total costs (4.5 billion dollars). The indirect costs were primarily lost earnings, lost fringe benefits, lost home production and re-staffing. A recent study evaluating Minnesota's CFOI, and hospital discharge data found that the majority of total costs for agricultural injuries were attributed to indirect costs (Landsteiner et al., 2016). We did not estimate the indirect and direct cost as it was out of the scope of this study. However, CS-FRIS collected information for insurance paid, and out of pocket expense for injuries. We recommend future research using CS-FRIS data to examine the costs by injury characteristics and operator demographics.

The CS-FRIS was a cross-sectional self-administered survey and was subject to recall bias, underreporting and misclassification errors. The survey was self-report, and there was no mechanism to verify that information provided on injuries was accurate. It is possible that the principal operator filling out the survey missed to report the injury to other operators on the farm, or did not remember less severe injuries or the information on the source of injury was misclassified. This could have resulted in underreporting, and potentially misclassification bias. However, despite the limitations, the CS-FRIS remains a potential source of population-level data on injuries among farm operators in the Central States region.

In conclusion, the CS-FRIS data estimated an average 44,887 injuries per year among operators in the Central States region during 2011-13. A vast majority of injuries occurred in males, individuals in age groups 35-54 and 55-64 years, operators with farming as a primary occupation, on large farms, and farms growing livestock commodities like cattle, hogs, and horses, and crop commodities like field crops. With the discontinuation of NIOSH surveys- OISPA and NAWS injury supplement in 2015, CS-FRIS can be a useful data source providing regional and state-level surveillance data annually. Further evaluation of CS-CASH agricultural injury surveillance model can help identify the barriers and potential solutions for a sustainable, on-going agricultural injury surveillance system at a regional-level.

CHAPTER 4

RISK FACTORS OF NON-FATAL AGRICULTURAL INJURIES AMONG FARM OPERATORS IN THE CENTRAL STATES REGION, UNITED STATES

Agriculture is one of the high-risk industries in the U.S. Over time, the agriculture industry has grown more diverse and complex. Geographic variations exist in farm populations, farm types, and production practices. Therefore, it is important to identify and monitor risk factors of agricultural injuries in different farm populations.

The third and final papers in dissertation research aimed to evaluate the risk factors of non-fatal agricultural injuries among farm operators in seven Midwestern States- Iowa (IA), Kansas (KS), Minnesota (MN), Missouri (MO), Nebraska (NE), North Dakota (ND), and South Dakota (SD) - also called as the Central States region in this study. This research examined the effects of operator demographics and farm parameters on the occurrence of injuries in farm operator population. Similar to previous research (in chapter 3), this paper too, used data from the Central States- Farm and Ranch Injury (CS-FRIS) and Census of Agriculture (Ag Census).

Chapter 4 describes the research conducted in the third paper and includes background, study methods, results, and a brief discussion section.

4.1 Background

Farming is one of the most dangerous occupations in the U.S. and globally. In 2014, agriculture had the highest rate of fatal work injury rate compared to all other private industries in the U.S. (25.6 vs 3.2 per 100,000 full-time workers) (Bureau of Labor Statistics [BLS], 2016). Despite the hazardous nature of work and risks involved, farmers and their family members continue to live and work on farms to earn their livelihood, and contribute to the production of food and energy. However, agriculture industry sector in the U.S. is changing.

According to the 2012 U.S. Census of Agriculture (Ag Census) was a 4.3 % decline in the number of farms (2.2 to 2.1 million) and 3.1% decline in farm operator population (3.3 to 3.2 million) since 2007. The farm operator population was older, more diverse, and a high percentage of operators held off-farm jobs to support their living compared to previous years. Farms became larger, and production of agricultural goods diversified with geographic variations. Midwestern states like Iowa, Kansas, Minnesota, Nebraska, North Dakota and South Dakota accounted for 29% of agricultural sales in 2012, predominantly in corn, soybean, wheat, cattle and hog production (USDA, 2014a). Some these above-mentioned operator and farm characteristics are risk factors for agricultural injuries. With the change in farm operator demographics and farming practices, it is important to update the information on these risk factors of agricultural injuries and identify emerging issues in farm populations.

Earlier studies conducted among farmers reported gender, age, race/ethnicity, long farm work hours, history of prior injury, existing medical conditions like hearing loss, depression, farm size and sales as risk factors of agricultural injuries (Chae et al., 2014; Choi et al., 2005; Hartman et al., 2004; Jadhav, Achutan, Haynatzki, Rajaram, & Rautiainen, 2015; Low, Griffith, & Alston, 1996). Exposure to various hazards like farm animals, heavy and complex machinery (tractors, combines, augers), and extreme temperatures (heat or cold) also contribute to fatal and non-fatal injuries in farming populations (Carlson et al., 2005; Erkal, Gerberich, Ryan, Renier, & Alexander, 2008; Fleischer et al., 2013; Jawa et al., 2013). There is also a link between farm injury and stress, fatigue, and sleep deprivation (Kidd, Scharf, & Veazie, 1996; Spengler, 2004). Several behavioral and non-behavioral, work and non-work parameters are associated with the occurrence of farm injuries in different farm populations. The identification of high-risk populations and their exposure to potential risk factors of agricultural injuries are vital for prioritizing and designing injury prevention strategies.

This study aimed to evaluate risk factors of non-fatal agricultural injuries among farm operators in the Central States (IA, KS, MN, MO, NE, ND and SD) region. The Central States region accounted for 17% of U.S. farms and 21% of farm operator population in 2012 (USDA, 2014a). Previous research showed a high incidence of non-fatal agricultural injuries in these Midwestern states of the U.S. (Erkal, Gerberich, Ryan, Alexander, & Renier, 2009; Goldcamp, 2010; Landsteiner et al., 2015; Missikpode et al., 2015; Mongin et al., 2007; Myers, Layne, & Marsh, 2009). Studies have examined the effect of demographic parameters and work environment on the incidence of non-fatal farm injuries among some states in this region. However, there are limited population-level data on risk factors of non-fatal agricultural injuries among farm operators specific to the Central States region.

This used secondary data from the existing Central States Farm and Ranch Injury Survey (CS-FRIS) data linked with data from the Census of Agriculture (Ag Census). The objective of this study was to examine the effect of operator demographics, farm characteristics like farm size, sales, types of tractors used, and different farm commodities on the incidence of non-fatal agricultural injuries among farm operators in the Central States region. This study also examined the effect of interactions between operator and farm variables on the occurrence of injuries among farm operators.

4.2 Methods

4.2.1 Study design overview

This cross-sectional study used de-identified data from 2011, 2012 and 2013 Central States Farm and Ranch Injury Survey (CS-FRIS). The Central States-Center for Agricultural Safety and Health (CS-CASH) at the University of Nebraska Medical Center collaborated with the National Agricultural Statistics Service's (NASS) Iowa field office and conducted injury surveys between March and April months in 2012, 2013, and 2014. NASS administered the injury survey to adult (19 years and older) farm operators in the seven Central States (IA, KS, MN, MO, NE, ND, and SD), who responded to the most recent Ag Census (2007 or 2012). NASS defined a farm operator as "the person running the farm and making day-to-day farm management decisions who could be the owner, or a member of owner's household, or a hired manager, or a tenant, or a renter, or a sharecropper" (USDA, 2014a).

4.2.2 Survey instrument

CS-CASH designed the CS-FRIS, a self-administered survey to collect demographic and injury information for three adult operators and three children/youth living or working on farms in the Central States region. The farm owner or principal operator receiving the survey filled out the information for the other two operators and children/youth on the farm. In CS-FRIS, an injury was "the result of a sudden, unexpected, forceful event, which has an external cause, and which results in bodily damage or loss of consciousness"; and farm-related was defined as "work and leisure activities on this operation, plus commuting, transport, and business trips for this operation". CS-FRIS asked each operator to indicate whether he/she had 0, 1, 2 or 3 or more injuries in the previous calendar year.

4.2.3 Data collection

NASS used the most recent Ag Census list as a sampling frame- 2007 Ag Census for 2011 and 2012 surveys, and 2012 Ag Census for 2013 survey. In each survey year, NASS selected a sample of 7000 farms (1000 from each of the seven states) using a stratified disproportionate random sampling with equal allocation and without replacement. However, not all sampled farms received a survey. If the operator of sampled farm had a previous agreement with NASS to receive only one survey per calendar year, then NASS removed that farm from the sample. Each eligible sampled farm received one survey with a cover letter and a return envelope via mail. A month after the first mailing, NASS sent a repeat survey with a reminder postcard. NASS sent a total 20,865 surveys to eligible farm operators over a period of three years (6953 in 2011, 6912 in 2012, and 7000 in 2013).

NASS collected injury survey responses, linked the responses the Ag Census data, and provided a de-identified dataset to CS-CASH. This study used data from the de-identified dataset. NASS linked data from 2007 Ag Census with 2011 and 2012 surveys, and data from 2012 Ag Census with 2013 survey. Ag Census data included variables- type of farm organization (family vs. partnership operation vs. incorporated under state law vs. other), farm size (in acres), gross sales for the census year (dollars), commodities produced and types of tractors used on the operation (less than 40 vs. 40-99 vs. 100 and higher horsepower).

4.2.4 Sample weighting and imputation

After cleaning, editing, and coding the data, we calculated stratum-specific base weights as the inverse of selection probability for a farm from each state, in each survey year.

4.2.4.1 Imputation for missing data

We examined variables from CS-FRIS and Ag Census data for missing data. Missing data in CS-FRIS data was minimal. However, many Ag Census variables had missing data higher than 5% - farm sales (10.5%), type of tractors (less than 40 vs. 40-99 vs. 100 and higher horsepower) used on the operation (10.8%, 7.8% and 10.3%), and farm commodities (ranging from 6-18%). The pattern of missing data in these variables was arbitrary, and was not associated with the outcome “injury”. Assuming that the missingness was random, missing values for these Ag Census variables were imputed using base-weighted hot deck imputation technique (nearest neighbor) (Chen & Shao, 2000; Fay, 1999; Little & Rubin, 2014; Tutz & Ramzan, 2015).

4.2.4.2 Survey nonresponse adjustment

During 2011-13, we received responses from 7189 farm operators who received the injury survey, with an overall response rate of 34.5% (33.1% in 2011, 33.5% in 2012 and 36.8% in 2013). To adjust for survey nonresponse, and reduce the sampling variability, stratum-specific base weights for each survey year were calibrated using generalized raking procedure (Deville & Särndal, 1992; Deville et al., 1993; Izrael et al., 2009). Farm size and gross sales were the auxiliary variables used for the raking adjustments because the proportion of these two variables in survey responses differed from the source population (Ag Census). After combining data for all three years, the raked weights were re-weighted, such the estimated population counts were to equal the actual population counts (published in Ag

Census).This process is called benchmarking. Both imputation and raking procedures were performed using XLSTAT Pro Version 2015.4.01.2016 © Addinsoft 1995-2015 in Microsoft Excel.

4.2.5 Statistical analysis

For this paper, outcome variable "injury" was dichotomized, and reported as injury=yes or injury=no. Independent or predictor variables included– gender, age, primary occupation, and percentage of time spent on a farm, farm size, gross sales, type of farm organization, type of tractors used on the farm, and commodities produced. Age was categorized as 19 35, 35-54, 55-64, and 65 years and older. We also categorized the size of a farm as 1-170, 180-999, and 1000 and more acres, and gross sales of a farm as less than $10,000, $10,000-99,999, and $100,000 and more. Each type of tractor (less than 40, 40-99, and 100 or higher horsepower) variables and all commodity variables were dichotomous- yes or no. For example, cattle=yes or cattle=no.

We used Proc Surveyfreq procedure to calculate frequencies (unweighted), and weighted percentages, and Rao-Scott Chi-square p-values at 0.05 significance level for operator demographics, operator injuries, and farm variables. The initial two-way analysis determined the association between injury and all other independent variables.

Crude (univariate) and adjusted odds ratios, confidence intervals for odds ratios and p-values were calculated using SAS Surveylogistic procedure. We used Proc Surveylogistic to obtain statistically weighted and unbiased sample estimates and account for stratified sampling design. Using Taylor series linearization method, we calculated confidence intervals and standard errors for parameter estimates and odds ratio. Predictor variables that were significant at $p<0.05$ level in univariate regression were introduced into a full multivariate model. The authors developed a final multivariate model using the backward selection process. In the backward selection process, variables from the full model were removed until all remaining variables in the model reached $p<0.05$ significance level or if removing the variables resulted in a poorer model fit. We tested multicollinearity between predictor variables of injury using the Variance Inflation Factor (VIF), and tolerance procedures. We examined interactions between predictor variables of injury. Max-rescaled R-square and Akaike Information Criteria (AIC) determined the model fit for multivariate models. All statistical analysis were performed in SAS version 9.3 (SAS Institute Inc., Cary, NC, Copyright © 2002-2010).

4.3 Results

4.3.1 Study population characteristics

During 2011-13, about a quarter of the farm operator population lived or worked on farms in Missouri, and this variation in operator population by states was statistically significant (p<.05) (Table 9). In the Central States region, farm operators were predominantly males (80%), lived or worked on an individual or family-owned operations (85%), field crop (51%), hay (47%), and cattle (46%) producers. More than half of the farm operator population in the Central States region reported primary occupation as farming. A significantly higher proportion of operators lived on farms with 1-179 acres of land under operation (p<.0001), and on a farm with ≥$100,000 of sales (p<.0001).

Table 9: Characteristics of farm operator population by state, operator demographics and farm parameters: Central States Farm and Ranch Injury Survey, 2011-13

	Farm operators	
	Sample[(1)]	**%[(2)] ($CI_{95\%}$)**
Total	9507	100.0
State		
Iowa	1536	20.0 (19.1-20.9)
Kansas	1422	14.1 (13.4-14.8)
Minnesota	1578	16.9 (16.0-17.6)
Missouri	1374	23.2 (22.2-24.3)
Nebraska	1318	11.5 (10.9-12.1)
North Dakota	994	6.8 (6.5-7.3)
South Dakota	1285	7.4 (7.1-7.9)
Gender		
Male	7610	79.9 (80.4-82.0)
Female	1747	18.5 (18.0-19.6)
Unknown	150	1.5 (-)

Age (years)		
19-35	710	7.7 (6.8-7.9)
35-54	2875	30.1 (29.5-31.5)
55-64	2924	30.6 (30.0-31.9)
≥65	2867	30.8 (30.2-32.2)
Unknown	131	1.3 (-)
Primary Occupation		
Farm/ranch work	5213	53.2 (53.2-55.3)
Other than farming	4127	44.9 (44.7-46.8)
Unknown	167	1.9 (-)
Percentage of time spent working on farm/ranch		
<50%	4291	46.8 (46.8-49.0)
≥50%	5003	50.9 (51.0-53.2)
Unknown	213	2.4 (-)
Type of farm organization		
Individual/Family	8059	85.3 (84.6-86.0)
Partnership operation	759	7.8 (7.2-8.4)
Incorporated under state law	559	5.6 (5.1-6.0)
Other(3)	130	1.3 (-)
Farm size (acres)		
1-179	4013	45.2 (44.2-46.3)
180-999	3465	37.3 (63.2-38.3)
≥1000	2029	17.5 (16.8-18.2)
Gross sales(4)		
<$10,000	2930	33.5 (32.5-34.6)
$10,000-99,999	2730	29.5 (28.5-30.4)
≥$100,000	3847	37.0 (36.0-38.0)
Type of tractor: <40 horsepower(4)		
Yes	4134	43.9 (42.9-45.0)
No	5373	56.1 (55.0-57.1)
Type of tractor: 40-99 horsepower(4)		
Yes	6520	69.6 (68.6-70.5)
No	2987	30.4 (29.5-31.4)
Type of tractor: ≥100 horsepower(4)		

Yes	5494	55.4 (54.4-56.5)
No	4013	44.6 (43.5-45.6)
Types of commodities produced		
Field crop(4)		
Yes	5061	51.2 (50.2-52.2)
No	4446	48.8 (47.8-50.0)
Hay/forage(4)		
Yes	4428	47.0 (46.0-48.1)
No	5079	53.0 (51.9-54.0)
Cattle/calves		
Yes	4366	46.7 (45.7-47.7)
No	5141	53.3 (52.3-54.3)
Horses/ponies		
Yes	1861	19.1 (18.3-19.9)
No	7646	80.9 (80.1-81.7)
Other animals(4, 5)		
Yes	1534	16.7 (16.0-17.5)
No	7973	83.3 (82.5-84.1)
Poultry(4)		
Yes	658	7.0 (6.5-7.6)
No	8849	93.0 (92.4-93.5)
Hogs/pigs		
Yes	399	4.6 (4.1-5.0)
No	9108	95.4 (95.0-95.8)
Sheep/lambs(4)		
Yes	417	4.1 (3.7-4.5)
No	9090	95.9 (95.5-96.3)
Other commodities(4, 6)		
Yes	436	4.6 (3.7-5.5)
No	9071	95.4 (94.8-95.7)

Sample: Number of operators in survey responses for all three years combined.

(1) Raw counts, no weighting applied.
(2) Nonresponse adjusted sampling weights applied.
(3) Other type of organization includes estate or trust, prison farm, grazing association, American Indian Reservation etc.

(4) This variable had >10% missing data, so missing values were imputed using weighted sequential random hot-deck imputation technique.
(5) Other animals include alpacas, llamas, bison, deer in captivity, elk in captivity, live mink, and rabbits.
(6) Other commodities include vegetables, fruits/nuts, berries, nursery/greenhouse crop, woodland crop, bees, and aquaculture.

4.3.2 Farm operator injuries and univariate logic regression analyses

Table 10 displays injury counts and percentage, and effect of each operator and farm attribute on the occurrence of injuries using univariate logistic regression analyses. During 2011-13, about 6% (n=550) of the farm operators in the Central States region indicated they had an injury in the previous calendar year; injury occurrence did not vary state. The majority of injuries occurred in male operators (80%), and individuals between 35 and 64 years of age (69%). Operators on field crop, hay and cattle producing farms accounted for more than half of the injuries (60%, 54%, and 55% respectively). Three-fourths of injuries occurred to operators on farms with 40-99 horsepower tractors, and two-thirds of injuries occurred to operators on farms with tractors of 100 or higher horsepower.

Gender, age, primary occupation, percentage of time spent working on a farm or ranch, farm size, gross sales, having 40-99, and 100 or higher horsepower tractors on farm, and production of field crops, hay or forage, cattle, horse, hogs, and other livestock were associated with occurrence of injury in farm operators. The larger the farm, the higher were the odds of an injury. There was a 50% increase in the risk of injury when the farm size increased from 180-999 acres (OR=1.3) to 1000 acres or more (OR=1.8). Similarly, the higher the sales group of farm, higher was the risk of injury ($OR_{\$10,000\text{-}99,999}$ =1.4, and $OR_{\$100,000 \text{ or more}}$ =1.7). Although injuries were more common in farmers running individual or family-owned operations (85%), the risk of injury on these farms did not vary from other types of farm organizations ($OR_{individual/family}$=2.4, $OR_{partnership}$=2.3, and $OR_{incorporated\ under\ law}$=2.6).

Table 10: Percentage of non-fatal agricultural injuries, and unadjusted odds from univariate logistic regression analysis of injuries by state, operator demographics, farm parameters

	Operators injuries*		**Univariate logistic regression**	
Predictor variables	**Count**[(1)]	**%** [(2)] **($CI_{95\%}$)**	**OR ($CI_{95\%}$)** [(2,3)]	**p-value** [(3)]

Total	550	100.0	-	-
State				
Iowa	85	19.3 (15.6-22.9)	0.9 (0.6-1.2)	0.87
Kansas	87	15.1 (12.2-18.1)	1.0 (0.7-1.3)	0.97
Minnesota	85	16.1 (12.9-19.3)	0.9 (0.6-1.2)	0.86
Missouri	73	21.7 (17.5-26.0)	0.8 (0.6-1.2)	0.84
Nebraska	74	11.6 (9.1-14.1)	0.9 (0.7-1.3)	0.91
North Dakota	65	7.9 (6.0-9.8)	1.0 (0.7-1.5)	1.04
South Dakota	81	8.2 (6.4-10.0)	(ref)	
Gender				
Male	471	86.5 (83.5-89.6)	1.5 (1.1-1.9)	0.004
Female	72	13.5 (10.4-16.5)	(ref)	
Age (years)				
19-35	46	7.8 (5.5-10.2)	1.5 (1.0-2.2)	0.04
35-54	199	37.3 (33.0-41.6)	1.7 (1.4-2.2)	<.0001
55-64	181	32.3 (28.1-36.4)	1.5 (1.1-1.9)	0.003
≥65	120	22.5 (18.8-26.3)	(ref)	
Primary Occupation				
Farm/ranch work	387	69.3 (67.1-71.5)	2.0 (1.6-2.4)	<.0001
Other than farming	157	30.7 (28.5-32.9)	(ref)	
Percentage of time spent working on farm/ranch				<.0001
<50%	170	33.3 (29.0-37.6)	1.9 (1.6-2.3)	
≥50%	372	66.7 (62.4-70.9)	(ref)	
Type of farm organization				
Individual/Family	470	85.6 (82.5-88.7)	2.4 (0.8-6.7)	0.11
Partnership operation	45	7.7 (5.9-10.1)	2.3 (0.8-6.9)	0.13
Incorporated under state law	31	6.0 (3.9-8.2)	2.6 (0.8-7.7)	0.10
Other(4)	4	0.6 (0.02-1.2)	(ref)	
Farm size (acres)				
1-179	184	36.4 (32.1-40.7)	(ref)	
180-999	208	39.3 (34.9-43.6)	1.3 (1.1-1.6)	0.01
≥1000	158	24.3 (20.7-27.9)	1.8 (1.4-2.2)	<.0001
Gross sales(5)				
<$10,000	123	24.6 (20.6-28.5)	(ref)	

$10,000-99,999	161	29.6 (25.6-33.7)	1.4 (1.1-1.8)	0.01
≥$100,000	266	45.8 (41.4-50.2)	1.7 (1.4-2.2)	<.0001
Type of tractor: <40 horsepower[5]				
Yes	244	45.3 (40.9-49.7)	1.1 (0.9-1.3)	0.50
No	306	54.7 (50.3-59.1)	(ref)	
Type of tractor: 40-99 horsepower[5]				
Yes	406	73.7 (69.8-77.6)	1.2 (1.0-1.5)	0.04
No	144	26.3 (22.4-30.2)	(ref)	
Type of tractor: ≥100 horsepower[5]				
Yes	382	67.6 (63.4-71.8)	1.7 (1.4-2.1)	<.0001
No	168	32.4 (28.2-36.6)	(ref)	
Type of commodities produced				
Field crop[5]				
Yes	336	60.2 (55.8-64.6)	1.5 (1.2-1.8)	<.0001
No	214	39.8 (35.4-44.1)	(ref)	
Hay/forage[5]				
Yes	303	54.0 (49.6-58.4)	1.3 (1.1-1.6)	0.002
No	247	46.0 (41.6-50.4)	(ref)	
Cattle/calves				
Yes	309	55.8 (51.4-60.2)	1.5 (1.2-1.8)	<.0001
No	241	44.2 (39.8-48.6)	(ref)	
Horses/ponies				
Yes	123	22.6 (18.3-26.2)	1.3 (1.0-1.6)	0.04
No	418	77.4 (73.8-81.0)	(ref)	
Other animals[5,6]				
Yes	113	20.6 (17.0-24.2)	1.3 (1.1-1.7)	0.02
No	437	79.4 (75.8-83.0)	(ref)	
Poultry[5]				
Yes	45	8.2 (5.8-10.7)	1.2 (0.9-1.7)	0.27
No	505	91.8 (89.3-94.2)	(ref)	
Hogs/pigs				
Yes	42	8.3 (5.8-10.8)	2.0 (1.4-2.8)	0.0001
No	508	91.7 (89.2-94.2)	(ref)	
Sheep/lambs[5]				

Yes	26	4.6 (2.8-6.4)	1.1 (0.7-1.7)	0.56
No	524	95.4 (93.6-97.2)	(ref)	
Other commodities(5,7)				
Yes	17	3.1 (1.3-4.9)	0.7 (0.4-1.1)	0.68
No	533	96.9 (95.1-98.7)	(ref)	

*Operator injuries: An injured operator could have more than one injury, but in this paper, injury variable was dichotomized as injury= yes or injury=no.

(1) Count: Unweighted number of operators who reported an injury. Some variable categories may not add up to total (550) due to missing data.
(2) Nonresponse adjusted sampling weights applied.
(3) Simple logistic regression was performed to obtain crude or unadjusted odds ratios, Wald confidence intervals and Wald Chi-square p-values at alpha=0.05.
(4) Other type of organization includes estate or trust, prison farm, grazing association, American Indian Reservation etc.
(5) This variable had >10% missing data, so missing values were imputed using weighted sequential random hot-deck imputation technique.
(6) Other animals include alpacas, llamas, bison, deer in captivity, elk in captivity, live mink, and rabbits.
(7) Other commodities include vegetables, fruits/nuts, berries, nursery/greenhouse crop, woodland crop, bees, and aquaculture.

4.3.3 Multivariate regression analyses

All predictor variables with p<0.05 in univariate logistic regressions were entered into the main effects multivariate model. Multi-collinearity was identified between variables primary occupation of the operator, and percentage of time spent working on a farm (VIF=5.0, tolerance=0.2 for each variable). Bivariate analysis showed a high correlation between occupation and time spent working on the farm (spearman's rho= -0.93, p<.0001). Because the percentage of time spent working on a farm did not measure actual hours worked, we dropped this variable from the final model to account for multi-collinearity. There was a correlation between farm size and gross sales (spearman's rho= 0.69, p<.0001); but no significant multicollinearity was detected. The final multivariate model retained the variables farm size and gross sales and included an interaction term between farm size and gross sales. The final multivariate model obtained using backward selection process had a max-rescaled R square= 0.964 or 96.4%.

Table 11 presents the results of the multivariate logistic regression analyses of operator demographics and farm parameters. The final adjusted logistic regression model identified the following factors associated with non-fatal agricultural injuries among farm operators: gender, age, primary occupation, gross sales, cattle farming, hog farming. Farmers between 35 and 54 years of age (OR=1.7), and 55 and 64 years of age (OR=1.5) had a higher risk of injury compared to their peers who were 65 years and older. However, the same was not true for comparison between age groups 19-34 and 65 years and older.

Among farm parameters, cattle farming and hog farming were associated with the occurrence of injury. Injury was also associated with gross sales of a farm but farm size i.e. farmland modified the effect of gross sales on incidence of injury. After controlling for all other factors, being an operator on a farm with 180-999 acres of farmland that had gross sales $100,000 or higher, multiplied the risk of injury by 4.3 times compared to an operator on a farm with 180-999 acres of farmland that had gross sales <$10,000.

Table 11: Adjusted odds ratios and confidence intervals from multivariate logistic regression analysis of predictors of non-fatal agricultural injuries

Predictor variables	**Adjusted OR[1,2]**	**95% CI[1,2]**	**p-value[2]**
Gender			
Male	1.4	1.0-1.8	0.03
Female		(ref)	
Age (years)			
19-34	1.4	1.0-2.0	0.08
35-54	1.7	1.3-2.2	<.0001
55-64	1.5	1.2-1.9	0.002
≥65	(ref)		
Primary Occupation			
Farm/ranch work	1.7	1.4-2.2	<.0001
Other than farming	(ref)		
Farm size (acres)			

1-179	(ref)		
180-999	0.60	0.4-1.1	0.12
≥1000	0.30	0.04-2.5	0.28
Gross sales(3)			
<$10,000	(ref)		
$10,000-99,999	1.1	0.8-1.6	0.55
≥$100,000	0.4	0.2-0.8	0.01
Type of tractor: 40-99 horsepower(3)			
Yes	1.0	0.8-1.3	0.86
No	(ref)		
Type of tractor: ≥100 horsepower(3)			
Yes	1.3	1.0-1.6	0.05
No	(ref)		
Type of commodities produced			
Hay/forage(3)			
Yes	1.1	0.9-1.3	0.56
No	(ref)		
Cattle/calves			
Yes	1.3	1.0-1.6	0.04
No	(ref)		
Horses/ponies			
Yes	1.0	0.7-1.5	0.85
No	(ref)		
Hogs/pigs			
Yes	1.5	1.0-2.1	0.03
No	(ref)		
Other animals(3,4)			
Yes	1.3	0.9-1.9	0.19
No	(ref)		
Farm size x gross sales(3) (interaction)			
Farm size:1-179 acres			
Sales category: <$10,000	(ref)		
Sales category: $10,000-99,999	0.6	0.1-5.1	0.65
Sales category: ≥$100,000	0.3	0.01-1.1	0.06

Farm size: 180-999 acres			
Sales category: <$10,000	(ref)		
Sales category: $10,000-99,999	1.3	0.6-2.5	0.50
Sales category: ≥$100,000	4.3	1.7-10.3	0.002
Farm Size: ≥1000 acres			
Sales category: <$10,000	(ref)		
Sales category: $10,000-99,999	1.5	0.2-13.7	0.65
Sales category: ≥$100,000	7.9	0.9-66.8	0.06

(1) Nonresponse adjusted sampling weights applied.
(2) A final multivariable model (R^2= 96.1%) was obtained using backward selection method in multiple logistic regression at alpha=0.05. This table presents the adjusted odds ratios, Wald confidence intervals and Wald Chi-square p-values from the final model. Individual variables and interactions (or effect modifications) which were significant in univariable logistic regression models were included in the multivariable model.
(3) This variable had >10% missing data, so missing values were imputed using weighted sequential random hot-deck imputation technique.
(4) Other animals include alpacas, llamas, bison, deer in captivity, elk in captivity, live mink, and rabbits.

4.4 Discussion

This study identified gender, age, occupation, and livestock farming as significant predictors of farm injuries in the Central States region. The study also revealed an interesting relationship between farm size, gross farm sales, and injury.

Earlier studies conducted in different farm populations also reported gender as an independent risk factor for injury (Dimich-Ward et al., 2004; Gross, Young, Ramirez, Leinenkugel, & Peek-Asa, 2015; Jadhav et al., 2015; Karttunen & Rautiainen, 2013). Men generally tend to perform more physically demanding tasks like operating and maintaining heavy farm machinery, managing large animals and loading/unloading/lifting heavy objects, which are the most common sources of farm injuries (Carlson et al., 2005; Day et al., 2009; Erkal et al., 2008; S. A. McCurdy & Kwan, 2012). However, additional data on types of the task performed, and work hours may help explain the differences in injury risk by gender.

In this study, farm operators in younger age groups (35-54 and 55-64) had an increased risk of injury compared to their peers who were 65 years and older. This was consistent with findings reported in previous research (E. M. Goldcamp, 2010; Hwang et al., 2001a; Karttunen & Rautiainen, 2013; Low et al., 1996; S. McCurdy et al., 2004; Mongin et al., 2007; Viluksela, Louhelainen, & Mäittälä, 2012; Zhou & Roseman, 1994). Younger farmers perform more complex and risky tasks on a farm such as animal handling, or operating heavy farm machinery, have less work experience, and work for longer hours to meet the production demands (DeWit, Pickett, Lawson, Dosman, & for the Saskatchewan Farm Injury, 2015). Also, disability from a prior injury or health issues associated with older age (decreased vision, hearing or musculoskeletal function) may limit older farmers from working long hours, or performing complex tasks (McMillan et al., 2015). Both longer work hours, and history of prior injury are known risk factors for injury (Hwang et al., 2001; Jadhav et al., 2015; S. McCurdy et al., 2004; Viluksela et al., 2012). Although, the risk of non-fatal injuries was higher among younger age groups in this study, injury outcomes can be severe or even fatal in older age groups due to pre-existing medical conditions, or the ability to recover from an injury with increasing age (John R. Myers et al., 2009b; Pransky, Benjamin, Savageau, Currivan, & Fletcher, 2005). Future studies should further examine the effect of age on-farm injuries, specifically looking at differences in farm tasks, use of safety practices, and presence of existing health conditions such as depression, arthritis, balance or gait disorders, and other musculoskeletal disorders, which are known to increase the risk of farm injuries.

Consistent with existing literature, producing livestock commodities like cattle and hogs were associated high risk of injury (Douphrate et al., 2009; Erkal et al., 2008; Jadhav et al., 2015; Karttunen & Rautiainen, 2013). Further evaluation using the number of cattle or hogs per farm, and additional data on work hours and types of tasks may provide a complete picture on exposure-risk association.

Univariate analysis showed that working or living on farms with larger and powerful tractors (100 horsepower or higher) was associated with the occurrence of injury, but this did not true after controlling for other demographic and farm parameters. Instead of just working or living on a farm with large and powerful tractors, data on additional parameters could have better explained the relationship between tractor and injury incidence. Some of this additional parameters include time spent working on a tractor, or whether the tractor had roll-over protection, and shield on power-take-off shaft etc.

Previous studies among farmers in New York (U.S.), Victoria (Australia), and Finland reported the independent effect of farm size, and farm sales on injuries, after controlling for other operator and farm characteristics (Day et al., 2009; Hwang et al., 2001a; Karttunen & Rautiainen, 2013). In this study, the size of a farm modified the effect of farm sales on the injury, which was a unique finding. A cohort study of Saskatchewan farmers in Canada observed that economic worry, and stress associated with production demands varied by farm size (W. Pickett et al., 2011). Although it is not clear from CS-FRIS and Ag Census data, if this may have been the reason for the unique relationship between farm size, gross sales, and injury. The authors warrant further investigation in this direction.

The population-level data from CS-FRIS and Ag Census, and vigorous data analysis methods, allow extrapolation of these results to the farm operator population in the Central States region. Implementation of robust survey weighting and nonresponse adjustments methods (generalized raking using truncated linear methods and weighted sequential hot-deck imputations), minimized the selection and nonresponse bias (Battaglia, Hoaglin, & Frankel, 2013; Crouse, 1999; Deville et al., 1993; Korn & Graubard, 2011; Little & Rubin, 2014; Tutz & Ramzan, 2015). The analysis used sophisticated analysis methods to reduce the nonresponse bias and sampling variability, but there were still other biases in CS-FRIS data. The CS-FRIS was cross-sectional, self-administered survey, which was subject to self-report bias, recall bias, and potential misclassification of information. Therefore, the authors recommend caution when interpreting the results of this study.

In conclusion, a combination of existing (Ag Census) and new data (CS-FRIS) provided a rich database to evaluate risk factors of injury among farm operators in the Central States region. Male gender, younger age, farming occupation, cattle, and hog farming, and working or living on mid-size (180-999 acres) and high sales ($100,000 or more) farms increased the risk of injuries among farm operators in the

Central States region. This study identified high-risk population groups for intervention in the Central States region. Researchers, public health practitioners, and farm safety and health educators can use this information when designing agricultural injury prevention programs for farm operators in the Central States region.

CHAPTER 5

DISCUSSION

This dissertation included three independent studies, and each addressed one specific aim of this research. The first study provided a comprehensive review of survey-based surveillance systems for non-fatal agricultural injuries in the U.S. The second study provided an estimation of incidence of non-fatal agricultural injuries among farm operators in seven Central States - Iowa (IA), Kansas (KS), Minnesota (MN), Missouri (MO), Nebraska (NE), North Dakota (ND), and South Dakota (SD). The third study evaluated risk factors for non-fatal agricultural injuries among farm operators in the Central States region.

The first study used information from peer-reviewed journal articles, reports and other published materials on the websites of the organization operating each system under review, and if required, we contacted program officers managing the surveillance databases. The second and third study were completed using three years of combined data from the annual Central States –Farm and ranch Injury Survey (CS-FRIS), which was linked to the U.S. Census of Agriculture (Ag Census) data.

This final chapter in the dissertation briefly discusses highlights of each study and its implications for agricultural injury surveillance, research, and prevention of injuries. This chapter also includes research limitations, as well as future directions.

5.1 Surveillance systems for non-fatal agricultural injuries in the U.S.

Surveillance is a systematic on-going collection of data, which track conditions of public health significance, define public health priorities, assess the effectiveness of interventions and develop new research. With passing time, health-related conditions under surveillance become amenable to interventions, new issues of public health importance emerge, and information needs change. To accommodate these changes, a public health surveillance systems needs to adapt and evolve. However, some systems designed for a specific purpose may not be able to meet the new information requirements. Periodic evaluation of public health surveillance systems helps determine how well the system operates to meet its intended purpose. Systematic evaluations can help identify critical gaps in system's operation, which if addressed in a timely fashion improve the quality, effectiveness, and usefulness of surveillance data. With the changing landscape of agriculture industry in the U.S., new emerging issues need attention. For example, there is an increase in racial and ethnic diversity in farm workforce; health risks associated with age in older farmers; undocumented and migrant workers; switch from a single commodity farm to production of multiple commodities; boom in agritourism (use of farm for recreation); and growing demand for energy producing farms, etc. These new emerging issues co-exist with high rates of agricultural injury in adults and youth on farms, poor farm safety practices, and challenges in conducting surveillance of injuries in farm populations. There is limited research on Health risks and injury patterns associated with these emerging issues in agriculture. This indicates that in future, existing surveillance data sources will need to incorporate new information on emerging issues. Therefore, a systematic evaluation of existing data systems for agricultural injuries was essential to determine if these systems were flexible enough to meet changing data needs.

The 2008 National Academies review of NIOSH Agriculture, Forestry, and Fishing (AgFF) program stated that current surveillance data for fatal agricultural injuries are adequate, but the same is not true for non-fatal agricultural injuries (Institute of Medicine [IOM] and National Research Council [NRC], 2008). A recent independent panel reviewed NIOSH AgFF program, which emphasized the need to examine NIOSH injury surveys conducted by NASS attributed to low survey response rates (Gunderson, 2012). To date, there are no formal reviews or evaluation reports on existing surveillance data sources for non-fatal agricultural injuries. The dissertation research filled this gap in the literature by systematically reviewing and evaluating six national-level surveys, which are main sources of data for non-fatal agricultural injuries in adults and youth on U.S. farms.

The six national-level survey-based systems reviewed in this dissertation were–Survey of Occupational Injuries and Illnesses (SOII), the National Agricultural Workers Survey (NAWS), Occupational Injury Surveillance of Production Agriculture (OISPA), Minority Farm Operator-Occupational Injury Surveillance of Production Agriculture (M-OISPA), Childhood Agricultural Injury Survey (CAIS), and Minority Farm Operator-Childhood Agricultural Injury Survey (M-CAIS). The data systems evaluated in this research lack interoperability (with each other and with other systems) because of differences in scope, population covered, design and the methods of data collection. Of all the six survey-based systems, SOII had better data quality (higher response rates, verification process in place to check injury data), published annual reports, and was relatively flexible to changing technology and information needs. SOII was also one of the oldest data collection systems for occupational injuries and illness. However, SOII excludes self-employed, unpaid family members and farms with less than 11 employees, and collects data for injuries meeting the Occupational Safety and Health Administration's (OSHA) injury reporting criteria. Leigh et al. (2014) reported that SOII missed about 77% of injuries in agriculture, which is substantial. Other injury surveys reviewed in this dissertation were also unique in terms of their scope, population covered and methods.

Earlier studies using NAWS, OISPA, and CAIS in different farm population groups on U.S. farms reported differences in incidence of injuries by socio-demographic parameters, farming type, and geographic regions of the country (Goldcamp, 2010; Goldcamp et al., 2006; Hendricks & Goldcamp, 2010; Layne et al., 2009; Tonozzi & Layne, 2016). Discontinuing NAWS, OISPA, M-OISPA, CAIS and M-CAIS before replacing them with other systems or identifying appropriate data sources to detect injuries in these populations, resulted in the loss of national-level data for agricultural injuries among children and youth populations on U.S. farms. In the last two decades, the U.S. agriculture observed a declining trend in the number of farms and farm workforce, and surveillance data from different sources indicate a gradual decrease in number of agricultural injuries (Goldcamp, 2010; Goldcamp et al., 2006; Hard, Myers, & Gerberich, 2002; Hendricks & Hendricks, 2010; Rautiainen & Reynolds, 2002; USDA, 2014a). Given this declining trend in agricultural population and the number of injuries (which was a rare event), NIOSH needed larger sample size for all four NIOSH injury surveys and NAWS (injury supplement) to generate statistically reliable injury estimates, which would increase the cost of doing surveys (CDC, 2015a). Besides, an increase in sample size, would not have addressed other data limitations of NIOSH injury surveys which limited its usefulness (NIOSH, 2014b; NIOSH, 2014c; NIOSH, 2014d; NIOSH 2014e).

Several reports using NIOSH injury surveys to examine the injury burden and assess risk factors for injuries in farming populations expressed data quality concerns (Goldcamp, 2010; Goldcamp, Hendricks, Layne, & Myers, 2006; Leigh, Du, & McCurdy, 2014; Mustard, Chambers, McLeod, Bielecky, & Smith, 2012; Rosenman et al., 2006; Stallones, 2012; Wiatrowski, 2014). Use of current case definitions and injury reporting criteria used by both USDOL and NIOSH surveys may result in misclassification and undercount of injuries. Often times it is difficult for the person reporting or recording to differentiate between a non-farm-related and farm-related injury. For example, injuries that occur on farms when transporting farm goods from the operation to the market or other places, or those that may occur at the roadside or on the road are recorded as road traffic injury. Gunderson et al. (1990) and Murphy et al. (1993) expressed the long-standing need to develop clearer case definitions and reporting criteria for farm-related injuries. In addition to data quality concerns, NIOSH injury surveys did provide information on important parameters that can help guide injury prevention and control efforts.

NIOSH surveys did not collect work hour data, which limit calculation of reliable and valid injury rates and extrapolation to the farming population. NIOSH surveys collected little to no information on hazardous work exposure or consequences of injuries. Reliable disability estimates and their impact on the future costs (health care, unemployment) cannot be calculated using data from the surveys reviewed in this dissertation (Deboy, Jones, Field, Metcalf, & Tormoehlen, 2008; Reed & Claunch, 2000). Our review findings suggest that data sharing and dissemination of information based on NIOSH injury surveys was through periodic reports or published tables on aggregate data on system's website. The periodic nature of OISPA, M-OISPA, CAIS, and M-CAIS surveys limited trend analysis. In NAWS, low sample sizes limited usefulness of annual injury data. Lack of availability of accurate, reliable, meaningful, quality, and timely data for public health action reduced the usefulness of OISPAs, CAISs and NAWS (injury supplement) as a surveillance data source. Also, NIOSH surveys were not interoperable and current approaches for data collection showed limited flexibility to changing technology and data needs. Interoperability or ability to integrate with other data systems helps to maintain pace with advancing technology and increasing information needs in a time-efficient and cost-effective way. Discontinuation of an inefficient system and replacing it with a more simple and cost-effective and efficient system helps reduce the burden on public health infrastructure. Surveillance of non-fatal agricultural injuries in the U.S. has evolved over time, and one system has replaced the other because of methodologic, cost and sustainability concerns.

The U.S. National Safety Council (NSC) developed the very first system (during the 1970s) to collect information on non-fatal occupational injuries in agriculture through personal interviews with farm operators (three interviews in one year). By mid-1980s, 34 states in the U.S.participated in this system, but the system was no longer sustainable as it relied on volunteers (in Ag extension) for data collection and was discontinued. Soon after that, Minnesota initiated the Olmsted Agricultural Trauma Survey (OATS) of farm operators which collected fatal and non-fatal agricultural injury data through telephone interviews. Based on the success on OATS and availability of reliable, valid and timely data for injuries, this survey was expanded to five Midwestern states (Minnesota, Nebraska, North Dakota, South Dakota, and Wisconsin) and called as Regional Rural Injury Study-I or the RRIS-I (in 1990). The CDC refunded this survey and was again implemented in 1999 (RRS-II). The RRIS-II used unique methods for data collection to collect data on both injuries and risk factors of injuries. The RRIS-II consisted of a cohort of approximately 4000 farm operators spread across the five-state region. Around the same time as RRIS-I and RRIS-II, the National Safety Council initiated the NIOSH Traumatic Injury

Survey of Farmers (TISF). TISF was a mail-based survey of farmers across all 50 states and conducted between 1994 and 1996. Findings from RRIS-I and TISF pointed towards the need to develop a national agricultural injury surveillance program. Besides RRIS-I, II, and TISF, several state-base surveillance efforts existed (Hard et al., 2002; Institute of Medicine [IOM] and National Research Council [NRC], 2008; Stallones, 2012).

The Farm Family Health Hazard Survey (FFHHS) in the 1990s collected basic health information, and injury data from farm families in six states – Colorado, Iowa, Kentucky, New York, Ohio, and California. However, this survey too was discontinued because of inconsistencies in data collection methods and survey instrument, which limited state-level comparisons and meaningful use of data. With the initiative of Childhood Agricultural Injury Prevention Initiative in 1997, the CAISs and OISPAs replaced older surveys like TISF and FFHHS at the beginning of the year 2000 (Hard et al., 2002; IOM-NRC, 2008; Stallones, 2012). Now again, due to inconsistencies in data, and cost of maintaining national-level surveys, both CAISs and OISPAs were discontinued. Discontinuation of inefficient systems and emerged data gap further the need to identify new, stronger, simpler, cost-effective and sustainable methods for surveillance of non-fatal agricultural injuries.

Use of data from existing surveys or administrative data sets such as Workers' Compensation Claims system, hospital discharge data, trauma registries, and pre-hospital or ambulance records are potential alternatives to NIOSH injury surveys. However, using existing systems not designed for surveillance of agricultural injuries, pose unique challenges. For example, state-based medical records can provide data for adults and children simultaneously and available to states at minimal or no cost, and are not subject to survey or sampling biases. Although, data in medical records are not self-reported there can inaccuracies in identifying farm injuries using the limited options in the external cause of injury codes (E-codes). Work-related or employment information (includes industry and occupation) are often incomplete in the administrative medical database because these are optional data fields. The Health Insurance Portability and Accountability Act (HIPAA) may pose a challenge to access record-level data for population for surveillance and research. Medical databases vary from state-to-state, which makes it difficult to combine these datasets and generate national injury estimates. Hospital discharge databases and other medical records database are managed my data vendors who may be located out a state. In any case, changes are needed in the system (addition or removal of data files), it may require involvement from multiple organizations within and across states and a substantial lag time.

Recent advances in information technology make management and operation of large datasets more cost-effective and time-efficient. The advances in information technology allow management of large medical databases, which are potential sources of data for public health surveillance. There are two large medical databases in the U.S., which can provide surveillance data for non-fatal agricultural injuries. One of the two databases is the National Trauma Data Bank (NTDB), which is an aggregation of data from all state trauma registries. The second database is the National Emergency Medical Services Information Systems (NEMSIS), a database of all EMS records from all states in the U.S. Currently, researchers at the National Children's Center for Rural and Agricultural Health and Safety (NCCRAHS) are examining the feasibility and usefulness of NTDB and NEMSIS for agricultural injury surveillance in youth (NCCRAHS, 2016). The Northeast Center for Agricultural Safety and Health is exploring the feasibility, usefulness, and cost of using multiple medical records databases for surveillance of agricultural injuries (NEC, 2015). In addition to administrative datasets, there are national surveys that collect data for public health surveillance activities. Some of these surveys also collect data on non-fatal injuries and include employment details.

The Behavioral Risk Factor Surveillance System (BRFSS) is the largest random-digit dial survey in the U.S., which collects data on general health conditions and injuries, health-related risk factors, use of preventive health services, respondent demographics, etc. States participating in BRFSS can add optional modules that contain a set of questions for topics relevant to the state. In 2014, 24 out of 50 states in the U.S. implemented the industry and occupation (I/O) module (CDC, 2016). Using data from a set of core questions and I/O module, we can assess the risk factors for health such as smoking, alcohol, physical activity, existing co-morbidity, shift work, and sleep habits by industry and occupation, which are not available in administrative data sets. Similarly, the National Health Interview Survey (NHIS) a household sample survey collects data for physical and mental health status, chronic conditions, access to and use of health care services, measures of functioning etc. Periodically NHIS core questionnaire include additional questions on employment history, and work-related injuries and illnesses (occupational supplement) (NIOSH, 2015b). Although, BRFSS and NHIS are among most commonly used sources for public health surveillance data, they may underrepresent farmers. In addition to this, about 50% of states (26) do not implement I/O model with BRFSS. Both BRFSS and NHIS are useful for describing overall health and injuries by industry/occupation groups, but may not be the best data sources for surveillance of agricultural injuries in farm populations. With the current sampling methods, survey instruments, case definition and reporting criteria in BRFSS and NHIS, we may not capture farm-related injuries in some of the hard-to-reach agricultural populations such as migrant and seasonal farmworkers, and therefore may underestimate injuries.

There are three major surveys collecting national-level data from healthcare facilities across the U.S. The three major surveys are – National Hospital Ambulatory Medical Care Survey (NHAMCS), National Ambulatory Medical Care Survey (NAMCS), and National Hospital Care Survey (NCDS) that may have data on agricultural injuries. The NHAMCS, NAMCS, and NCDS collect nationally representative data on health care utilization patterns, consequences of injuries and illnesses, and cost associated with it for ambulatory and inpatient care as well as care delivered in emergency departments across health care facilities in the U.S. (CDC, 2015b; CDC 2015c). The three medical care use surveys (listed here) are subject to similar concerns when using administrative data sources, i.e. not all farm-related injuries may require hospitalization or medical care. For severe farm-related injuries requiring medical care, it may be difficult to capture them attributed to limited work or industry or occupation data in medical records. The three health care surveys health care are designed to capture utilization in the general population, and hence, may underrepresent farm populations. Undocumented workers and farm workers, who have no health care insurance coverage, might be missing in these medical record based datasets.

To summarize, none of the existing surveillance data sources administrative datasets or the national surveys provide a comprehensive data for non-fatal agricultural injuries and risk factors of injuries in adult and youth on U.S. farms. The evaluations of surveillance systems found that system attributes are inter-linked. For example, the system was more acceptable by users and stakeholders, if it is simple, flexible, and provides timely and better quality of data. Researchers, practitioners, and policymakers should consider using results from the review study to make informed decisions while using data from national surveys for surveillance of non-fatal agricultural injuries. Surveillance epidemiologists and agricultural safety and health experts interested in designing new or identifying potential databases for surveillance activities in a state or region or entire nation should consider information on pros and cons of each system.

5.2 Lessons learned from surveillance of non-fatal agricultural injuries among farm operators in the Central States region

Five out of six national surveys reviewed in this dissertation research did not provide state-level estimates on non-fatal agricultural injuries. All six national surveys reviewed in the dissertation underestimated injuries in farm populations. The evaluation findings suggest a lack of accurate and reliable population-level data on injuries, and risk factors of injuries among farm populations, especially in self-employed operators, farm owners, and unpaid family members that constitute two-thirds of farm workforce (BLS, 2016b). About 20% of the U.S. farm operator population including self-employed, farm owners and unpaid family members live or work on farms and ranches in seven Midwestern states- Iowa (IA), Kansas (KS). Minnesota (MN), Missouri (MO), Nebraska (NE), North Dakota (ND), and South Dakota (SD) (USDA, 2014a). These seven Midwestern states also called as the Central region in this research have a higher concentration of farms, mainly large-size and high sales farms compared to other regions in the U.S. (USDA, 2014a). Independent research studies using data from national and regional surveys, and state-based administrative datasets documented high rates of non-fatal injuries among farmers in some of these Midwestern or Central States (Goldcamp, 2010; Landsteiner et al., 2015; Missikpode et al., 2015; Mongin et al., 2007; Myers et al., 2009). However, there is limited population-level surveillance data for agricultural injuries and risk factors of injuries among farm operators in this seven-state region.

The Central States- Center for Agricultural Safety and Health (CS-CASH) at the University of Nebraska Medical Center in Omaha, Nebraska is one of the ten NIOSH-funded Ag Centers in the U.S., and conducts surveillance, research and injury prevention activities among farm populations in the seven Central States (IA, KS, MN, MO, NE, ND, and SD). As a part of on-going surveillance efforts, CS-CASH designed an annual mail-based self-administered injury survey (the Central States Farm and Ranch Injury Surveyor CS-FRIS) which collects demographic and injury data for up to 3 operators and 3 children/youth on farms in the Central States region. The linkage between the injury survey responses and existing data from the most recent Census of Agriculture (Ag Census) provided population-level data on injuries, operator demographics, farm characteristics and farm production activities. The CS-CASH non-fatal injury surveillance model is a good example of using existing data, and supplementing it with some new information through structured surveys for population-level surveillance data on non-fatal agricultural injuries. This research study used three years (2011-13) of data from this unique population-level dataset to determine the incidence of injuries, injury rates and evaluate risk factors of injuries among farm operators in the Central States region.

The CS-CASH meticulously designed and pilot-tested the injury survey, and used probabilistic stratified sampling to select an unbiased sample of farm operators from the seven Central States. During the design and pilot-testing phase, CS-FRIS team ensured that the questionnaire was in plain language, readable, and formatted to resemble the Ag Census form. A cover letter explaining the purpose and the use of the survey accompanied the injury survey. In a case of nonresponse, reminder postcards and a second survey was sent. Despite the measures taken in design and implementation phase, the response rates for CS-FRIS ranged from 33% to 37% during 2011-13. Conventionally survey methodologists consider it a low response rate (Fowler F.J., 2014). However, one must consider that farm population is some of the hard-to-reach populations due to their remote locations, type of workforce (e.g. undocumented or migrant workers), and seasonal nature of farm work.

In the past, independent research groups who administered surveys to collect injury and other health and safety data from different farm population groups in the U.S. and other countries achieved response rates ranging from 33% to 87%. Does that mean farmers were more responsive to a personal contact? (Browning, Truszczynska, Reed, & McKnight, 1998; Chae et al., 2014; Hwang et al., 2001; Nilsson, Pinzke, & Lundqvist, 2010; Taattola et al., 2012; Lewis et al., 1998; Marcum, Browning, Reed, & Charnigo, 2011; S. McCurdy et al., 2004; McCurdy et al., 2013; Mongin et al., 2007; Nonnenmann, Anton, Gerr, Merlino, & Donham, 2008; William Pickett et al., 2008; Shipp, Cooper, del Junco, Cooper, & Whitworth, 2013; Stallones & Beseler, 2003; Svendsen, Aas, & Hilt, 2014; Zhou & Roseman, 1994). Some of these surveys with high response rates were administered through telephone or face-to-face interviews (Chae et al., 2014; Hwang et al., 2001; S. McCurdy et al., 2004; McCurdy et al., 2013; Mongin et al., 2007; Stallones & Beseler, 2003) surveying team/organization versus sending them a postal questionnaire? In general, often the mode of administering the surveys determine the response rates and the data quality. Face-to-face interviews tend to have higher survey response rates and survey completion rates compared to telephone interviews and self-administered postal mail surveys (Bowling, 2005). However, face-to-face interviewers are time-consuming and costly, subject to interviewer bias, and less desirable for surveys on sensitive topics or population groups (in this case undocumented workers). In such scenarios, telephone interviews and self-administered surveys work well compared to face-to-face interviews (Bowling, 2005; Fowler, 2014).

Pennings et al. (2002) conducted a study among farmers to understand farmers' behavior to self-administered mail surveys. The authors found that the time of the year for administering a survey is one of the key factors affecting the willingness of farmers to participate in any kind of survey. Other factors affecting response rates among farmers included type and amou..nt of compensation, the organization conducting the survey, and the length of the questionnaire. The survey researchers at the USDA's National Agricultural Statistics Service (NASS) examined survey responses and response patterns for recurring NASS surveys among different farm population groups collecting data on different agricultural topics such as farm labor, farm production practices and economics. The researchers at NASS found that there was no pattern in survey participation/refusal for repeated contacts, but the survey taker's feelings towards the sponsoring agency of the survey, and the farmer's perception on the topic and use of the survey influences survey response rates (McCarthy, Beckler, & Qualey, 2007). Another group of researchers at NASS examined the effect and feasibility of using incentives to increase response rates among farmers to mail surveys. Beckler & Ott (2007) found that indirect monetary incentives ($20) increased response rates to the NASS's Agricultural Resource Management Survey (ARMS) that collects data on farm production practices, earnings, and expenses. The National Agricultural Workers Survey (NAWS) used similar approach to collect data from migrant and seasonal crop workers and had an average response rate of 90% from workers. However, in NAWS workers are not directly contacted, first, their employer is contacted which had an average response rate of 60% (USDOL, 2014). This tells us that survey response rates may also depend on who is the primary sampling unit- an employer or a worker, and often a farm owner or self-employed operator. Researchers must consider several parameters (discussed here) when designing and implementing surveys to farmers to achieve a high survey participation/response rates.

It is possible that a survey has a good response rate but may have substantial missing responses to items in the questionnaire. For example, the NIOSH injury surveys OISPAs and CAISs had an average participation rate of 80%, but only 50% of the interview responses were complete. In contrast, to that the Central States-Farm and Ranch Injury Survey (CS-FRIS) overall had minimal missing data (<3%). However, variables from Ag Census had considerable missing data (5-18%), but use of imputation for missing values in variables with more five percent missing data, adjusted for item nonresponse. The length and complexity of Ag Census questionnaire could be a potential reason why select Ag Census variables had missing data. The Ag Census is a 24-page questionnaire with 37 sections. Evidence suggests that the language, the format, and the length of questionnaire not only influence the response rate but also the data quality (Bowling, 2005; Fowler, 2014; Lohr, 2010). Future surveys collecting safety or health data among farmers must attempt to develop simpler and shorter surveys for higher response rates and better data quality.

This research used three years of CS-FRIS data linked with Ag Census data and estimated an average 44,887 injuries per year, i.e. an average annual injury rate of 6.8 injuries per 100 farm operators in the Central States region during 2011-13. Although, North Dakota (8.5) and South Dakota (8.0) had higher rates of injuries, the difference in injury rates among seven Central States was statistically non-significant. The addition of more years of CS-FRIS data may help detect variations by state and examine trends in injury incidence over time. The rates of injuries among farm operators in the Central States region differed by gender, age group, primary occupation, the percentage of time spent working on a farm, size and sales group of farms, types of tractors used on a farm, and type of commodities produced by a farm, which was as expected. This explained why it is not only important to obtain information on basic demographics (age, gender, occupation, etc.), but also on farm attributes, which help us understand the complete picture.

Being a male farmer, farmer between 35-64 years of age, and farming as the main occupation were significant risk factors of injury, and these demographic groups had high rates of injuries. This suggests that males, farmers between 35-64 years of age, and those with farming as a primary occupation are high-risk populations and hence, the target audience for farm safety outreach and education programs.

The risk factor study in this dissertation also identified a relationship between farm sizes, gross sales of a farm, and injury, which was novel. The study identified that the farm size modified the effect of gross sales (an indicator of farm productivity) on injury incidence. Although, it is not clear whether farm size was a true effect modifier or this relationship is limited to the data in this study. This is because the variable farm size here indicated total acres of land owned and rented or leased from others by farm operators. It was possible that someone owned or rented a farm, but had land under the Conservation Reservation Program (CRP) or a Wetlands Reserve Program (WRP), land not used for crop production, or land used for the non-farming purpose. Future investigations should further investigate the relationship between farm size and sales while incorporating the information on actual land used for farm production activities. Future research should examine relationships among other covariates, and the effect of these relationships on injuries, which in this data was statistically non-significant.

The CS-FRIS data showed that 60% of farm operators who reported a farm-related injury during 2011-13 required a doctor/clinic visit, 12.2% required hospitalizations. About 66% of injured farm operators in CS-FRIS data reported that the farm-related injury resulted in a lost farm work time ranging from less than half a day to 30 days or more. Severe non-fatal farm-related injuries incur substantial medical and other direct costs, and may result in temporary to permanent disability affecting functionality at work and overall poor quality of life (Deboy, 2008) Recent studies looking at farm-related injuries requiring medical care in Iowa, and Minnesota indicated that most of these injuries were work-related (Gross et al., 2015; Landsteiner et al., 2016). For non-work-related injuries, and some work-related injuries not receiving workers' compensation, the cost is borne by the private insurer, Medicaid, Medicare and some out-of-pocket (Costich, 2010). With rising cost of medical care and expansion of health care coverage, it is essential to understand the channels of payment for management of agricultural injuries; specifically for children/youth, or unpaid family worker injuries that do not qualify for workers' compensation. Hence, it is important that surveillance systems capture information on consequences of injuries including the cost of injuries. Based the findings from the CS-FRIS data and existing literature, it is recommended that future surveillance efforts focus on injuries requiring any form of professional medical care and identify vulnerable groups for interventions.

To sum up, together second and third paper analysis provided a comprehensive report on non-fatal agricultural injury incidence and risk factors of injuries among farm operators in the Central States region. This study filled the gap in knowledge by calculating regional as well as state-level injury estimates and injury rates. It also explored a unique relationship between farm sizes, gross sales of a farm and injury. Although researchers have identified risk factors for agriculture injuries in several settings, but the availability of data on several operator and farm characteristics gave an insight into risk factors that were specific to the Central States farm operator population. Researchers, agricultural safety and health practitioners including extension educators, health care providers, public health agencies, and farming communities should consider from the CS-FRIS data analysis project when developing farm injury prevention and control program for farm operators in the Central States region.

5.3 Limitations in dissertation research

5.3.1 Review and evaluation of existing survey-based systems for surveillance of non-fatal agricultural injuries

The study used standardized CDC guidelines for surveillance systems for evaluating the national-level survey-based systems for non-fatal agricultural injuries in the U.S. The assessment of attributes such as stability and data quality was limited because of lack of information available on the system. This research did not evaluate the positive predictive value (systems attribute in CDC guidelines) of a system because there is no reference data or gold standard to compare the injury incidence data from systems reviewed here. The CDC guidelines are subjective and so, the measurements used in the study are also subjective and based on the author's interpretation of information on each system. The review excluded three systems not meeting the study inclusion criteria - 1) National Electronic Injury Surveillance System (NEISS), and 2) Behavioral Risk Factor Surveillance System (BRFSS), and 3)National Health Interview Survey (NHIS). The BRFSS, the NHIS, and the NEISS provide information on non-fatal injuries for both adults and children. This research excluded the NEISS from the evaluation because it is not a survey-based system. BRFSS is a national survey, but not all states participating in BRFSS collect industry and occupation data; therefore, this study excluded BRFSS. The review study excluded NHIS because it does not specifically collect data for work-related injuries and illness, to date NHIS collected occupational health in 1988, 2010 and 2015. NHIS is, therefore, not commonly used as the source of data for non-fatal agricultural injuries. Lastly, this review excluded local, state-based, and regional injury surveys for farmers and farm workers conducted by the NIOSH-funded agricultural safety and health centers (Ag-centers) periodically because they did not meet the study inclusion criteria. These Ag-centers either use existing administrative databases or conduct surveys locally to determine the burden of injury and its risk factors in the population served.

5.3.2 Incidence of non-fatal agricultural injuries, and risk factors of injuries among farm operators in the Central States region

The secondary data analyses used data from a cross-sectional injury survey- CS-FRIS. The CS-FRIS used stratified random sampling method and the selected sample from the most recent Ag Census respondent list to minimize selection bias and ensure representativeness of the sample to actual farm operator population in the seven Central States during the study period. Stratified random sampling uses probabilistic methods to select a statistically representative sample from each stratum, which allows us to obtain sufficient observations for each stratum. In addition, stratified random sampling often requires a small sample that provides greater precision than a simple random sample of the same size, thereby, reducing the cost and increasing the efficiency of the survey (Lohr, 2010).

Between 2007 and 2012, there was a 3.2 percent decline in operator population in the Central States region (USDA, 2014a). If an operator retired from farming or sold out the farm after 2007, they still appeared in the 2011 sample because the sampling frame was 2007 Ag Census respondent list. The data analysis attempted to calculate a representative denominator for injury rate calculation, such that rates were generalizable. The first step in injury rate calculation was an estimation of the average annual number of farms and operators during the study period using 2007 and 2012 Ag Census data. The second step was benchmarking estimates for operator characteristics and injuries based on CS-FRIS to match the average annual number of farms and operators during 2011-2013. The estimated average annual number of operators in the Central States region during 2011-2013 presented in the study matched with the population counts published in 2012 Ag Census report (USDA, 2014a). These two steps allowed calculation of reliable injury rates for farm operator population in the Central States region.

The CS-FRIS did not collect demographic and injury data for hired workers. Therefore, this research recommends caution when extrapolation findings to farm owners and operators in the Central States region. The survey was designed to elicit demographic and injury information only for up to three adult farm operators, so it is possible that we missed injuries on farms with more than three operators. The responding operator filled information on other two operators, resulting in a proxy bias. It is possible that the respondents missed to report less severe injuries without consequences. In addition, CS-FRIS was administered within 90 to 120 days (between March and April), after the end of the reference year for which data was collected. Failure to recall because they were less severe injuries or due time lag between occurrence and reporting of an injury may have resulted in an undercount of injuries.

Despite, attempts to increase participation in the survey, the response rate for CS-FRIS during study period remained low (33.1%, 33.5%, and 36.8%). Due to feasibility reasons, it was difficult to contact the nonresponse and determine if they were different from the responders. First, the stratum-specific initial (base) weights were calibrated using the raking procedure. Then the raked weights were rescaled such that the sum of weights was equal to the average annual number of operators during 2011-13. This dissertation also used weighted hot deck imputation (nearest neighbor method) to impute missing values in variables with more than five percent of missing data. Both raking and imputation methods implemented here are being used by large sample surveys like the (California Health Interview Survey (2014), the National Health and Nutrition Examination Survey, and the Behavioral Risk Factor Surveillance System (Pierannunzi et al., 2012; Mirel et al., 2013). The robust sample weighting and imputation methods reduced the potential selection or sampling bias, and nonresponse bias attributed to low response rate and missing data.

This research did not calculate true injury rates or hour-based injury rates because information on hours of exposure at work was not available in the current CS-FRIS data. This study recommends further research to explore methods to calculate reliable estimates of working population, and hours worked using a combination of existing datasets like Ag Census, CPS, ACS, etc., similar to the approach used by Leigh et al., (2014) and Landsteiner et al., (2015).

Further, CS-FRIS was also subject to non-differential misclassification. For example, an individual may not exactly remember if the amount of lost farm work time was less than half day or half day to one day for less severe injuries, and hence, misclassify the lost farm work time. If an operator reported more than one injury, he/she could describe only the most severe injury; resulting in some amount of information loss about the type of injury despite, counting it as an injury. The injury survey did not collect information on nature of the injury, which could help determine the severity of the injury. However, we cannot address these issues in data, as this was a secondary data. This research did not evaluate other potential factors known to be associated with non-fatal agricultural injury incidence such as operator socio-economic status, sleep deprivation, fatigue, medication use, and history of a previous injury because these data were not available.

The Ag-census variables farm size, farm sales, commodities produced, type of farm organization, and type of tractors on the farm were farm-level information, rather than individual-level. Therefore, when assessing the influence of these variables on injury incidence, there could have been potential misclassification of exposure. The direction and magnitude of such misclassification is unknown, but we expect it to have a minor effect on the current injury estimates obtained using CS-FRIS data. To address this limitation, we could individual data, but it was beyond the scope of dissertation work.

5.4 Future directions

Surveillance is an applied science, where the information collected is used to track the health status in communities, define public health priorities, and to formulate strategies for data-guided interventions. However, lack of valid and reliable information can limit the usability of a surveillance system for these purposes.

Currently, surveillance data for non-fatal agricultural injuries in different farm populations in the U.S. mainly comes from various types of surveys (national or regional). All these surveys have some common deficiencies- low response rates, missing data, data subject to recall bias and misclassification errors etc. Some of these deficiencies in survey data can be addressed in design, implementation, and data analysis phase. Responder education and awareness about purpose and utility of the survey data and tailoring the design and mode of administering the survey that fits the preferences of survey population can help reduce survey nonresponse. For example, plan to administer the survey early in the calendar year (January or February), when it is not the peak season for farming activities, so the farmer would not need to specially take out time from their farm routine to fill out the survey. This would also reduce the recall period for surveys collecting data on injuries in the previous calendar year. If we were to collect data from young adults or adolescents who are more tech-savvy, we might consider using both mail-based and online or internet-based surveys (i.e. mixed-mode surveys). If we were to survey special populations like minority farm operators or migrant and seasonal workers, it would be important to consider some of the cultural issues. For example, designing the survey in a language and using lay terms that they are most familiar with. In a case where face-to-face interviews are required, it is best to recruit interviewers from their community or at least someone who knows the culture and language, so the interviewee-interviewer interaction is comfortable. Besides, the design of the survey it is important to select an unbiased and representative sample for the survey.

Current databases still undercount the employment in agriculture. Therefore, it is important to choose an appropriate sampling frame that provides a represents the farm population. For example, if we were to survey farm operators or farm children, using the Census of Agriculture respondent list is a good option to identify an actual number of farm families or farm operators. If we were to survey hired or migrant workers, we need to use the USDAs Farm Labor Survey, Agricultural Resource Management

Survey, or USDOL's Quarterly Census of Employment and Wages that provide details on hired farm workforce. Another option is collaborating with labor management companies, or farm labor association to obtain information on hard-to-reach populations like migrant or seasonal workers often employed by farm labor contractors not directly by the farm owner. Despite the measures taken during survey design, conduct and analysis phase, there is still some residual sampling and measurement error. Besides, operating and maintaining large annual population-based surveys can be resource intensive, and so relying solely on surveys for surveillance activities may not be the best approach.

Digitalization of health records made data sharing, merger, and storage easier. Health records contain substantial information other than injury or health conditions, like E-codes for external causes of injury, treatment taken and cost associated with the injury, medication use, any specific history related to previous injury etc. Researchers identified limited or no industry and occupation information as a major drawback in using health records for surveillance of work-related injuries. However, the addition of industry and occupation data fields to the health records in nearing future will address the former data gap. In addition to work information, farm-related cases in health records are identified using external cause of injury codes (E-codes), but there are limited options in the current E-codes to classify a farm injury. Even if all these limitations are addressed administrative datasets like Workers' Compensation and health care records do not include information on risk factors or exposures such as the type of farming (crop vs. livestock) and types of tasks performed on a farm. Information on these parameters can be useful to designing appropriate injury prevention interventions. In future, short surveys can collect data on specific hazards or exposures of interest or safety practices that are not present in administrative datasets.

Because of feasibility and cost reasons, it is difficult to have one system that capture the entire farm population and collect all the relevant data. One approach to address the challenge of establishing a comprehensive system for surveillance of non-fatal injury is to use a combination of data sources. The combination approach would include – 1) routine surveillance using data from multiple administrative sources, and 2) periodic population-based surveys to collect additional information (e.g. type of farming-crop vs. livestock, farm hazards and other farm work exposures, etc.), or obtain data on vulnerable groups (e.g. migrant and undocumented workers, children/youth) that are underrepresented in administrative sources.

For example, we can track severe farm-related injuries requiring professional medical care using information from ambulance reports, emergency department, and hospital records, and examine for patterns – in age groups, geographic locations, the specific causes, or injury type. Because these data are state-level data, Ag Centers can collaborate with state health agencies to identify injuries that are most frequently occurring and administer more specific surveys to obtain further information on hazards, safety practices, and any other emerging farm safety issues in that region. Also, this kind of approach would enhance partnerships between multiple stakeholders (state health agencies, public health practitioners, medical care providers, Ag Centers, and farm community of interest) who can work together to address specific farm safety issues, ultimately reducing the burden of injuries in their states/region. It would also make it possible to involve the local farming communities in this process who can help identify high-priority or specific issues that need attention. The surveys can be designed using approach used by the Central States- Center for Agricultural Safety Health. Collecting new data and using some information from existing data on the same population can help reduce the burden on survey takes. Besides, regional level surveys would not require sample sizes as for national surveys reducing the cost of conducting and maintaining surveys. Regional surveys may require smaller sample sizes compared to national surveys, so multi-modal surveys (online, mail, and telephone interviews) may not be resource intensive as for national surveys. Multiple modes of data collection, specific and shorter surveys may help improve the response rates and obtain better quality data useful for public health action.

Some of the hard-to-reach populations in U.S. agriculture, which include undocumented and migrant workers, and farmers from racial and ethnic minorities make data collection challenging. The

Workers' Compensation Claims records or hospital discharge records may not capture data on many of the hard-to-reach population groups because many of them might not directly use these resources attributed lack of insurance coverage. These hard-to-reach population groups may have social, economic and health issues unique to them, and may need special attention in terms of education and awareness on reporting and preventing injuries, and worker rights. Considering the challenges in conducting surveillance and implementing injury prevention interventions in hard-to-reach population, it is vital to first address the gaps in data for population employed in agriculture. Under the new health reform (Affordable Care Act) there might be opportunities to expand and improve health care insurance, which might allow better utilization of health care services for injuries and other ailments in farming populations, and capture data for injuries that were missed in health records earlier. A health insurance scheme will also help promote other health prevention programs for chronic conditions in the aging farming population.

When improving surveillance efforts for agricultural injuries, it is important to remember the audience of interest- farming communities. To many farmers, farming is their way of life that has continued for generations in their families. For others, it is a sense of pride to be involved in a noble profession, which feeds the world's population. This culture among farmers to an extent influence their perceptions of farm safety and injury prevention.To many farmers, it is the risk of doing a business (Donham & Thelin, 2006; Reed, 2004). Previous studies reported behavioral, cultural, social and economic issues influence the decision of a farmer to adopt safe farming practices (Arcury, Estrada, & Quandt, 2010; Beseler & Stallones, 2011; Calvert & Higgins, 2010; Jenkins et al., 2012; Kaustell, Mattila, & Rautiainen, 2011; Viveros-Guzmán & Gertler, 2015). Most farm safety programs are educational in nature and intended to increase the knowledge and awareness regarding hazards on a farm and prevention measures (DeRoo & Rautiainen, 2000). Often researchers investigate the barriers to adopting a safety intervention, which is mainly education. Although it is important to understand the barriers to a successful intervention, it is even more critical to identify the motivators of adopting a particular farm safety practices. A way surveillance can help in this area is through providing data on what influences a farmer's decision to incorporate safety measures on a farm. Finally, short and specific surveys can be useful to collect data on specific farm hazards and exposures of interest.

Besides farmers, it is also important to educate and involve the health care providers, local public health practitioners, extension educators, farm bureaus, farm labor unions, and workers' compensation and insurance providers in the process developing and implementing agricultural injury prevention strategies, including surveillance. Agricultural injuries are a public health problem, which has health, social and economic consequences to the person injured, their families and the society as a whole. Similar to other public health problems, agricultural injury prevention too, needs a holistic approach that involves members from each level- farmers and their families, employers, insurance providers, health care practitioners, extension educators, public health agencies and policymakers.

In conclusion, estimating the incidence of mortality, morbidity, and disability, and examining trends over time is quintessential. Systematic and ongoing surveillance data will not only help determine the magnitude of agricultural injury burden, but also to inform resource allocation, guide development and track the progress of injury prevention and control strategies.

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Appendix 1

Central States- Farm and Ranch Injury Survey (Only variables used in this project presented here)

SECTION 1 OPERATORS

1. Is your operation a farm or a ranch? 1 ☐ Farm 2 ☐ Ranch

2. Answer the following questions for up to three operators of this operation as of December 31, 2011.

	Principal Operator	Operator 2	Operator 3
a. What was the operator's age on December 31, 2011?	☐ Years	☐ Years	☐ Years
b. Sex of operator	1 ☐ Male 2 ☐ Fem.	1 ☐ Male 2 ☐ Fem.	1 ☐ Male 2 ☐ Fem.
c. At which occupation did the operator spend the majority (50 percent or more) of his/her worktime in 2011? (Mark only one.)	1 ☐ Farm/ranch work 2 ☐ Other	1 ☐ Farm/ranch work 2 ☐ Other	1 ☐ Farm/ranch work 2 ☐ Other
d. What percentage of this operator's time was spent working on the farm / ranch in 2011? (Mark only one.)	1 ☐ 100% 2 ☐ 75-99% 3 ☐ 50-74% 4 ☐ 25-49% 5 ☐ 0-24%	1 ☐ 100% 2 ☐ 75-99% 3 ☐ 50-74% 4 ☐ 25-49% 5 ☐ 0-24%	1 ☐ 100% 2 ☐ 75-99% 3 ☐ 50-74% 4 ☐ 25-49% 5 ☐ 0-24%

SECTION 4 INJURIES TO OPERATORS

Definitions: "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. "Farm-related" includes work and leisure activities on this operation, plus commuting, transport, and business trips for this operation.

	Principal Operator	Operator 2	Operator 3
5. How many farm-related injuries occurred to each operator during 2011?	0 ☐ None 1 ☐ One 2 ☐ Two 3 ☐ Three or more	0 ☐ None 1 ☐ One 2 ☐ Two 3 ☐ Three or more	0 ☐ None 1 ☐ One 2 ☐ Two 3 ☐ Three or more
The following questions are about the most serious injury to each operator. (If no injuries occurred in 2011, skip to 13.)			
6. Did the most serious injury happen during work or leisure?	1 ☐ While working 2 ☐ Leisure	1 ☐ While working 2 ☐ Leisure	1 ☐ While working 2 ☐ Leisure
7. Where did this injury occur? (Mark only one.)	1 ☐ Home/office 2 ☐ Farm building 3 ☐ Farm yard 4 ☐ Field/pasture 5 ☐ Road/off-farm	1 ☐ Home/office 2 ☐ Farm building 3 ☐ Farm yard 4 ☐ Field/pasture 5 ☐ Road/off-farm	1 ☐ Home/office 2 ☐ Farm building 3 ☐ Farm yard 4 ☐ Field/pasture 5 ☐ Road/off-farm

8. Object or substance which caused this injury: (Mark all that apply.)	a ☐ Tractor	a ☐ Tractor	a ☐ Tractor
	b ☐ ATV	b ☐ ATV	b ☐ ATV
	c ☐ Machinery	c ☐ Machinery	c ☐ Machinery
	d ☐ Livestock	d ☐ Livestock	d ☐ Livestock
	e ☐ Hand tool	e ☐ Hand tool	e ☐ Hand tool
	f ☐ Power tool	f ☐ Power tool	f ☐ Power tool
	g ☐ Chemical/Pesticide	g ☐ Chemical/Pesticide	g ☐ Chemical/Pesticide
	h ☐ Working surface	i ☐ Working surface	i ☐ Working surface
	i ☐ Truck/automobile	j ☐ Truck/automobile	j ☐ Truck/automobile
	j ☐ Other vehicle	k ☐ Other vehicle	k ☐ Other vehicle
	k ☐ Water	l ☐ Water	l ☐ Water
	l ☐ Other, specify: ________________	m ☐ Other, specify: ________________	m ☐ Other, specify: ________________
9. What body part was injured? (Mark all that apply.)	a ☐ Head/neck	a ☐ Head/neck	a ☐ Head/neck
	b ☐ Eye	b ☐ Eye	b ☐ Eye
	c ☐ Chest/trunk	c ☐ Chest/trunk	c ☐ Chest/trunk
	d ☐ Back	d ☐ Back	d ☐ Back
	e ☐ Arm/shoulder	e ☐ Arm/shoulder	e ☐ Arm/shoulder
	f ☐ Finger	f ☐ Finger	f ☐ Finger
	g ☐ Hand/wrist	g ☐ Hand/wrist	g ☐ Hand/wrist
	h ☐ Leg/knee/hip	h ☐ Leg/knee/hip	h ☐ Leg/knee/hip
	i ☐ Toe	i ☐ Toe	i ☐ Toe
	j ☐ Foot	j ☐ Foot	j ☐ Foot
	k ☐ Other, specify: ________________	k ☐ Other, specify: ________________	k ☐ Other, specify: ________________

	Principal Operator	Operator 2	Operator 3
10. What professional medical care did this injury require? (Mark all that apply.)	0 ☐ None	0 ☐ None	0 ☐ None
	1 ☐ Doctor/clinic visit	1 ☐ Doctor/clinic visit	1 ☐ Doctor/clinic visit
	2 ☐ Hospitalization	2 ☐ Hospitalization	2 ☐ Hospitalization
11. How much lost farm work time resulted from this injury? (Mark only one.)	0 ☐ No lost time	0 ☐ No lost time	0 ☐ No lost time
	1 ☐ Less than 1/2 day	1 ☐ Less than 1/2 day	1 ☐ Less than 1/2 day
	2 ☐ 1/2 to 1 day	2 ☐ 1/2 to 1 day	2 ☐ 1/2 to 1 day
	3 ☐ 2 to 6 days	3 ☐ 2 to 6 days	3 ☐ 2 to 6 days
	4 ☐ 7-29 days	4 ☐ 7-29 days	4 ☐ 7-29 days
	5 ☐ 30 days or more	5 ☐ 30 days or more	5 ☐ 30 days or more

Appendix 2

List of variables from 2007 and 2012 Census of Agriculture used in this project

Variable in Census form	Label
State	State
K46	Total land in operation
K683	Land under conservation
K803	Total number cattle & calves
K815	Total number hogs & pigs
K830	Horses and ponies
K946	Tractor < 40 horsepower
K948	Tractor 40-99 horsepower
K962	Tractor >=100 horsepower
K1011	Field crops
K1032	Nursery
K1041	Berries
K1047	Fruits/nuts
K1101	Vegetables/melons
K1103	Sheep
K1104	Bees
K1152	Hay/forage
K1153	Woodland crops
K1157	Aquaculture
K1217	Poultry
K1237	Other livestock
K1671	Type of organization-Family owned
K1347	Total sales (in USD)
K926	Principal operator Gender
K927	Principal operator Hispanics

2007 Census of Agriculture form link

http://www.agcensus.usda.gov/Help/Report_Form_&_Instructions/2007_Report_Form/Full_Report_Form/2007_RFG.pdf

2012 Census of Agriculture form link

https://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_US/usappxb.pdf