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REVIEW

Risk Factors for Agricultural Injury: A Systematic Review and Meta-analysis

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

KEYWORDS. Agricultural injury, farm injury, meta-analysis, risk factor, systematic review

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BACKGROUND

Agriculture is one of the most hazardous industries, globally. Knowledge of injury rates, characteristics, sources, and risk factors is essential for reducing the burden of injury. Research in all of these areas is developing, although many gaps still exist, and a complete evidence-based picture is difficult to obtain.

Injury rates provide an indication of the magnitude of the problem. Statistics and studies from developed countries show that injury is a major contributor to mortality and morbidity in farmers and agricultural workers.[1,2] Fatal injury rates have ranged from 11.5 to 30.6 fatalities per 100,000 workers,[3–6] whereas nonfatal injury rates have ranged from 3.5 to 16 injuries per 100 workers annually.[7–11] In the developing world, knowledge of agricultural injury is scarce. Studies from India, Tanzania, and China reported 0.13–13.1 injuries per 100 agricultural workers.[12–14] The great variation in injury rates may be due to differences in working conditions, injury definitions, data collection methods, cultural differences, knowledge, attitudes, and other factors. Although the rates vary, agriculture consistently ranks among the most hazardous industries in most countries and data sources.

Understanding injury characteristics helps describe the nature of the problem and develop an appropriate response. Injuries have been characterized by type of injury (sprain, strain, fracture, laceration, etc.),[15–18] medical treatment (no care, outpatient care, hospitalization),[19–21] severity (disability duration and cost),[8,22,23] prognosis (complete recovery, impairment),[22] work activity (lifting, operating machinery, handling livestock, etc.),[22,24,25] time (day, week, month, season),[22,24,25] place (home, road, field, pasture, building, etc.),[22,24,26] situation (working alone, accompanied by others),[27] as well as other aspects.

Understanding *injury sources* (or causes) helps identify specific actions needed to prevent similar incidents in the future. Common sources addressed in statistics and studies include machinery (tractors, power take-off drivelines, augers, all-terrain vehicles, etc.),[1,15,16,19,24,28,29] animals (horses, bulls, boars, etc.),[1,20,21,30,31] and working surfaces (leading to slips/trips/falls).[32] Other sources include water, poisonous gases, electricity, transportation vehicles, and (struck by, struck against) objects.[1,14,16,17] In-depth incident investigations are needed to identify more specific sources/causes, such as design flaws, missing safety features, or unsafe actions of the worker. Multiple factors typically contribute to injury incidents, providing alternative options for prevention.

This study focuses on injury risk factors. According to the World Health Organization, a risk factor is any attribute, characteristic, or exposure of an individual that increases the likelihood of developing a disease or injury.[33] Prior research has identified many risk factors for agricultural injury; however, the results vary and individual studies are often contradictory. Considering all available studies is necessary for evidence-based evaluation of risk factors. No such information is available to date. To address this gap, we conducted the first systematic review and meta-analysis of commonly reported risk factors for agricultural injury. In this report we present the weight of evidence[34] for male gender, full-time farming, farm owner/operator status, regular medication use, history of prior injury, health problems, stress/depression, and hearing loss as risk factors for agricultural injury.

Several interventions to reduce agricultural injury have been implemented, but little success has been shown to date.[35,36] It is imperative to enhance the efficiency of injury prevention efforts. Evidence-based understanding of risk factors is essential to achieving this goal.[37]

METHODS

With a growing body of literature, it is common that the point estimates for risk factors vary from study to study. For example, some studies have identified health problems as a risk factor for injury,[38–40] whereas other studies reported them as a protective factor.[41,42] Systematic review and meta-analysis provide the weight of evidence from all available findings, leading to a more precise estimation of the effect of a risk factor, compared with using individual studies.[43]

We used a common systematic review process, which includes defining the question, preparation, systematic research of the literature, selection of studies, quality assessment of studies, analysis and synthesis of the data, and interpretation of the results.[35,36,44] In this systematic review process, we found point estimates for 34 different injury risk factors. In this report, we report on eight risk factors. These risk factors were chosen because they had the following characteristics: (1) reported multiple times in the literature, (2) evaluated in multivariable regression models adjusting for potential confounders, (3) proximal to farmers regardless of the geographic location or type of farming, and (4) classified in a way that enabled their inclusion in meta-analysis. The remaining 26 factors will be discussed in other reports in the future.

Definitions

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

The selected risk factors were defined and prepared for meta-analysis. Table 1 shows the list of risk factors, levels, and definitions used in the analyses.

Identification of Studies

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

TABLE 1. Risk Factors, Levels and Definitions Used in the Analyses

Risk factor	Level	Definition
Gender	Male vs. female	
Work time	Full-time vs. part-time	Full-time defined as 5–7 days weekly or 40 or more hours weekly.
Worker status	Owner/operator vs. other	Other defined as family member or hired worker. Some studies included only one principal (primary) operator. Other studies considered both spouses equally as farmers or primary operators. Children were excluded.
Regular medication use	Yes vs. no	Taken regularly or taken in combination with another medication vs. not taken. Definitions for regular included: once per week over 30 days, once per week during most weeks over 3 months.
Prior injury	Yes vs. no	One or more injuries prior to the study period vs. none.
Health problems	Yes vs. no	Self-reported or diagnosed by a physician including musculoskeletal conditions, heart disease, high blood pressure, diabetes, and chronic respiratory conditions such as bronchitis and asthma.
Stress or depression	Yes vs. no	Self-reported or identified using validated instruments such as Center for Epidemiologic Studies Depression Scale.
Hearing loss	Yes vs. no	Self-reported or diagnosed difficulty in hearing, deafness or use of a hearing aid in one or both ears.

163 and 122 relevant studies were identified, respectively.

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

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

As the final step, references cited in the selected studies were checked to identify additional studies, but no further eligible studies were found for the review. The steps for selection of studies are illustrated in Figure 1.

Quality Assessment

The quality of the 32 selected studies was assessed by employing the Newcastle-Ottawa Scale (NOS) checklist, which is designed for assessing the quality of evidence of nonrandomized studies.[45,46] The NOS considers selection of study participants, comparability of study groups, and the ascertainment of exposure and outcome data, and it generates a score for study quality.[46] We used commonly applied cutoff scores[47,48] for eligibility: score of 6 out of 9 for case-control, 6 out of 10 for cross-sectional, and 5 out of 9 for cohort studies. One of the 32 selected studies did not pass NOS quality criteria, leaving 31 studies to be included in the meta-analysis.

Sensitivity Analyses

Of the 31 included studies, 16 scored at least 1 point higher than the set cutoff points. These were termed as "high-ranking" studies, and the rest were "low-ranking." Among the 16 high-ranking studies, 14 were cross-sectional, one was case-control, and one was a cohort study. We conducted sensitivity analyses of the pooled OR for each of the eight risk factors to examine the stability of the measured associations. These sensitivity analyses were conducted by calculating the pooled ORs (see data analysis) and confidence intervals (CIs), first with and then without low-ranking studies. For risk factors where all studies were either high-ranking or low-ranking, pooled estimates were calculated with and without studies that reported point estimates with statistically nonsignificant confidence limits ($P > .05$).

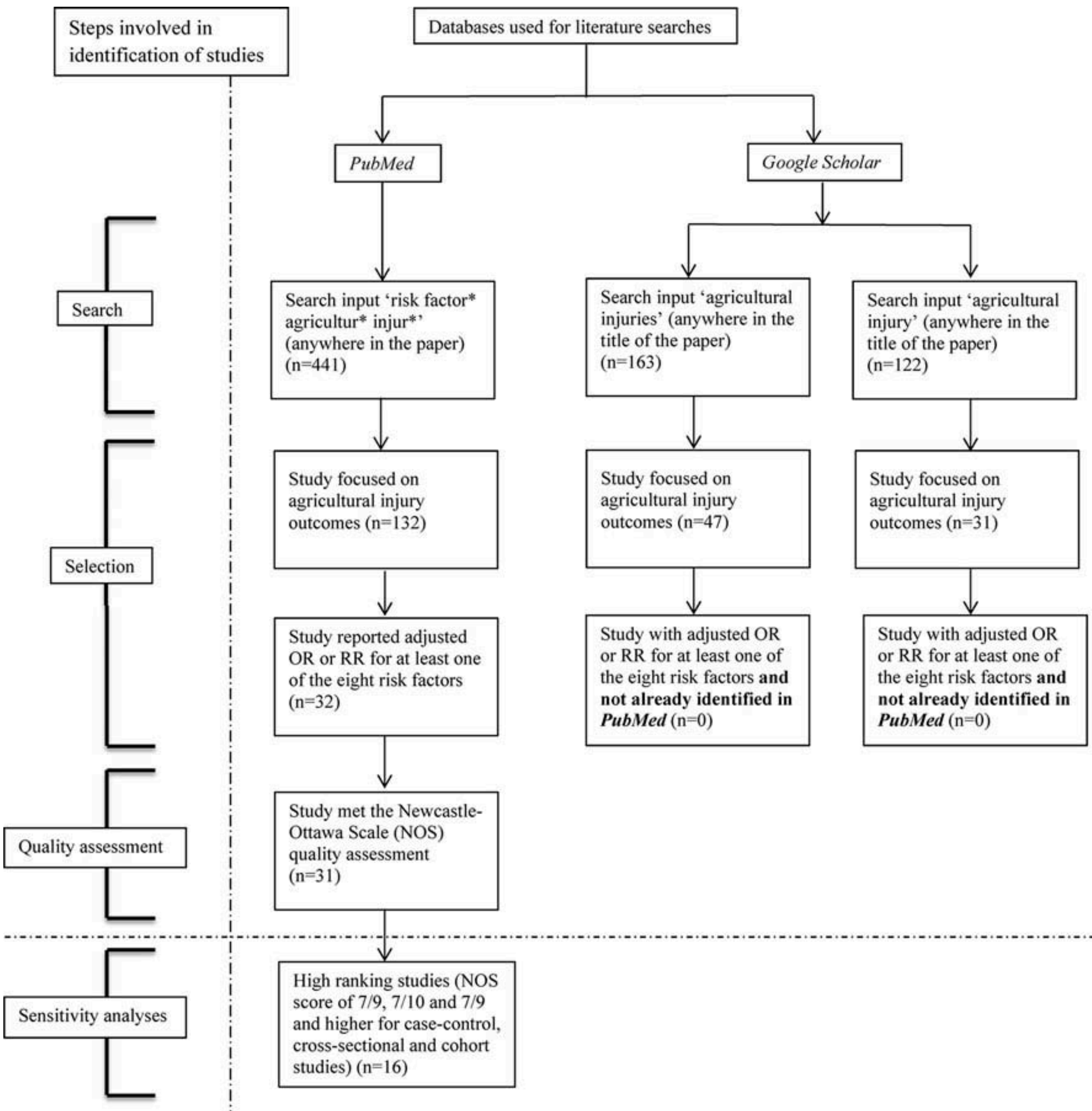
Data Analysis

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

$\mathrm{OR} = (1 - P_o) \times \mathrm{RR}/(1 - P_o \times \mathrm{RR})$ where P_o is the incidence of agricultural injury in the nonexposed individuals (without the risk factor).[49]

P_o varies in workers without risk factors from study to study. It also varies within a study depending on comparison populations used to assess a specific risk factor. It is not possible to construct the exact P_o for each conversion from research reports. Hence, we set P_o at 0.05 or 5 injuries per 100 workers for all conversions, which is a fairly representative injury rate across agricultural injury studies and statistics. Point estimates were converted for studies that used opposite referent groups by using the reciprocal of the point estimate and confidence limits. In studies where authors reported point estimates for more than two levels of the risk factor, the categories were dichotomized and then compared in case and control or comparison groups separately. For instance, in one

FIGURE 1. Schematic for identifying studies for systematic review and meta-analysis.



study the authors reported ORs for three categories of regular medication use (medication not taken regularly, medication taken alone, taken in combination).[50] In this case, the two categories "medication taken alone" and "medication taken in combination" were combined and compared against the category "medication not taken regularly."

The meta-analysis was conducted using the Comprehensive Meta-analysis (CMA) program.[51] Pooled ORs and 95% confidence intervals (CIs) were calculated using the inverse variance method for each of the eight risk factors. We utilized both fixed and random effects for the meta-analysis depending on the anticipated heterogeneity among the studies. The studies were also balanced by weighting using the CMA software. Weighting is vital for obtaining an unbiased estimated pooled OR. Variances within studies (V_r) and/or between studies (T^2) were used to obtain the weight of a study (W_i). For the fixed-effects model, the weight of a study was calculated by taking the inverse of variance within studies/between studies:

$$W_i = \frac{1}{V_r}$$

where W_i = weight of a study and V_r = variance within studies.

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

$$W_i = V_r + T^2$$

where W_i = weight of a study and T^2 = variance between studies.

The pooled OR was calculated by dividing the summation of the product of the weights of the studies and the natural log of given odds ratios by summation of the weights of the studies. The results were considered statistically significant at $P \leq .05$ level.

$$M = \frac{\sum_{i=1}^{k} W_i Y_i}{\sum_{i=1}^{k} W_i}$$

where M = pooled odds ratio, W_i = weight of the ith study, and Y_i = natural log of the odds ratio of the ith study.[51]

RESULTS

Characteristics of Studies Included in the Systematic Review and Meta-analysis

Location and sample size. The majority of the selected studies (n = 20) represented agricultural populations in the United States. Others (n = 11) represented populations from Australia, China, Poland, Finland, and Canada. The sample sizes varied from 113 in the smallest to 274,797 in the largest study. Eleven studies had less than 1,000 participants, 12 had 1,000–3,999 participants, and 7 had 4,000–99,000 participants. An appendix with details (study, location, design, sample size, target population, injury type, significant risk factors found, and confounders adjusted in multivariable model) on the included studies is available from the corresponding author by request.

Population. The proportion of participants drawn from the source populations varied with the sampling scheme used. In four studies, the researchers used records of all participants in their defined population. Insurance records were used in two of these studies. In other studies, samples were derived from their corresponding populations by employing random or nonrandom sampling. Agricultural census records were used to identify participants in the majority of the studies (12) that used random sampling. Among studies where random sampling was not used, six studies used stratified sampling (equal probability or systematic), two studies used hospital records, and three studies had insufficient information on the sampling strategy. The populations were engaged in agricultural production work, similar to what is described in the North American Industrial Classification System, codes 111 (Crop production) and 112 (Animal production), including subcategories under these codes.[52] The participants were defined as principal owners/operators, regular or seasonal workers, full-time farmers, part-time farmers, male farmers, female farmers, farmers who were young, middle, and older age, and farmers who had their principal source of income from farming. The vast majority of participants were white in all but two studies. Studies of children and youth were excluded, as their injuries and preventive strategies differ in many respects from working adults.

Injury outcome. Self-reporting was used for data collection in most studies. The injury outcome was mostly assessed by asking farmers if they had an injury (or injuries) in the past 12 months. Further definitions included "injury that required medical care (other than first aid) and/or lost work for half a day or more." In two studies, administrative insurance records were used. In two studies,[42,53] the severity of the injury was assessed by the Injury Severity Scale (ISS), which scores the outcome by medical characteristics of the injury. One study presented risk factors separately for serious and nonserious injuries based on the amount of compensation in insurance claims (serious = €2,000 and more).[8] Most studies provided information on injury characteristics. Common sources/causes included machinery, animals, and falls. Injury locations included fields and animal facilities. Work tasks included transport of agricultural goods, operation and repair of machinery, mounting and dismounting of tractors, tractor overturns, fieldwork, and animal-related tasks such as feeding, milking, herding, moving, and riding animals.

Estimated Effect of Risk Factors on Agricultural Injury

Pooled risk estimates were calculated in eight separate meta-analyses for the selected eight risk factors using adjusted point estimates in the source studies. Different studies adjusted for a different set of confounders. The most common confounders included in the multivariable models were age ($n = 17$), education ($n = 15$), gender ($n = 13$), work hours ($n = 12$), marital status ($n = 9$), health- and safety-related factors ($n = 18$), and farm-related factors ($n = 18$). The results for the eight risk factors are illustrated in Table 2. The short descriptions are as following.

Male gender. We used OR estimates from 10 studies where point estimates of injury for males (vs. females) were reported. The probability of injury was higher in males in nine studies and nearly equal in one study. The RR estimates from four studies were approximated to OR estimates. The pooled OR estimate for male gender was 1.68 (95% CI: 1.63–1.73).

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

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

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

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

Health problems. Five studies with OR estimates of injury for farmers with health problems (vs. without) were used for the meta-analysis. In three studies, the authors reported an increased risk of injury from health problems. In two studies, they reported that having health problems was protective. The pooled OR estimate for health problems was 1.21 (95% CI: 0.96–1.53). The difference was not significant ($P = .09$).

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

Hearing loss. In seven studies, OR estimates of injury were reported in farmers who suffered from hearing loss or wore hearing aid devices compared with farmers who did not have conditions pertaining to hearing. In seven studies,

TABLE 2. Results of the Meta-analyses for Selected Risk Factors

Risk factor	Studies	OR (95% CI)	Pooled OR (95% CI)
Male gender (vs. female)	Erkal et al., 2008[20]	1.90 (1.64 – 2.20)	1.68 (1.63 – 1.73)
	Nogalski et al., 2007[53]	1.27 (1.06 – 1.51)	
	Rautiainen et al., 2009[8]	1.77 (1.65 – 1.88)	
	Erkal et al., 2009[21]	1.10 (0.70 – 1.60)	
	Tiesman et al., 2006[26]	1.34 (1.10 – 1.63)	
	Karttunen and Rautiainen, 2013[37]	1.75 (1.68 – 1.82)	
	Moshiro et al., 2005[14]	1.75 (1.46 – 2.12)	
	Maltais, 2007[9]	1.44 (1.33 – 1.56)	
	Gerberich et al., 1998[19]	4.44 (1.89 – 12.45)	
	Taattola et al., 2012[7]	1.43 (1.00 – 2.12)	
Full-time farming (vs. part-time)	Carruth et al., 2002[38]	3.10 (1.52 – 6.30)	2.17 (1.12 – 4.21)
	Pickett et al., 1996[50]	1.68 (0.95 – 2.96)	
	Sprince et al., 2002[16]	2.02 (1.38 – 2.94)	
	Zhou and Roseman, 1994[22]	5.25 (1.24 – 22.18)	
	Lee et al., 1996[24]	6.56 (3.60 – 11.94)	
	Crawford et al., 1998[71]	2.01 (1.00 – 4.05)	
	McGwin et al., 2000[56]	0.48 (0.38 – 0.79)	
Owner/operator (vs. family member/hired worker/other)	Broucke and Colemont, 2011[57]	1.96 (0.14 – 27.73)	1.64 (1.13 – 2.38)
	Zhou and Roseman, 1994[22]	3.36 (1.00 – 11.34)	
	Pickett et al., 1996[50]	0.58 (0.28 – 3.33)	
	Xiang et al., 1999[41]	1.63 (0.61 – 4.35)	
	Hwang et al., 2001[39]	1.60 (1.03 – 2.50)	
Regular medication use (vs. no regular medication)	Pickett et al., 1996[50]	1.51 (0.81 – 2.80)	1.57 (1.23 – 2.00)
	Xiang et al., 1999[41]	3.02 (1.05 – 8.64)	
	Sprince et al., 2003[58]	1.80 (1.01 – 3.17)	
	Sprince et al., 2003[17]	1.44 (1.04 – 1.96)	
History of prior injury (vs. no prior injury)	Zhou and Roseman, 1994[22]	3.71 (1.83 – 7.52)	1.75 (1.58 – 1.94)
	Erkal et al., 2009[21]	3.80 (2.36 – 6.20)	
	Day et al., 2009[42]	0.54 (0.33 – 0.91)	
	Erkal et al., 2008[20]	3.20 (2.61 – 3.91)	
	McGwin et al., 2000[56]	1.54 (1.00 – 2.22)	
	Tiesman et al.,2006[26]	1.36 (1.19 – 1.56)	
Having health problems (vs. no health problems)	Sprince et al., 2003 (Arthritis)[b30]	3.00 (1.71 – 5.24)	1.21 (0.96 – 1.53)[a]
	Day et al., 2009 (Chronic medical condition)[b42]	0.65 (0.45 – 0.92)	
	Xiang et al., 1999 (High BP)[b41]	0.20 (0.06 – 0.69)	
	Xiang et al., 1999 (Heart disease)[b41]	0.47 (0.15 – 1.49)	
	Hwang et al., 2001 (Arthritis)[b39]	2.56 (1.52 – 4.32)	
	Carruth et al., 2002 (Back pain)[b38]	2.05 (1.11 – 3.80)	
Having stress/depression (vs. no stress/depression)	Park et al., 2001[25]	3.22 (1.04 – 9.99)	1.86 (1.60 – 2.16)
	Xiang et al., 1999[59]	4.91 (1.93 – 12.6)	
	Simpson et al., 2004[70]	1.27 (0.93 – 1.71)	
	Thu et al., 1997[61]	1.70 (1.17 – 2.34)	
	Tiesman et al., 2006[26]	1.44 (1.10 – 1.87)	
	Taattola et al., 2012[7]	2.06 (1.41 – 3.00)	
	Xiang et al., 2000[72]	6.28 (4.05 – 9.75)	
Having hearing loss (vs. no hearing loss)	Crawford et al., 1998[71]	1.90 (0.82 – 4.40)	2.01 (1.57 – 2.57)
	Xiang et al., 1999 [41]	1.88 (0.67 – 5.26)	
	Hwang et al., 2001[39]	1.86 (1.22 – 2.83)	
	Sprince et al., 2007[40]	1.98 (1.02 – 3.80)	
	Sprince et al., 2002[16]	4.37 (1.55 – 12.25)	
	Sprince et al., 2003[17]	2.36 (1.07 – 5.20)	
	Sprince et al., 2003[58]	1.82 (1.07 – 3.08)	

[a]Pooled estimate not significant ($P > .05$).
[b]Specific health condition addressed.

the probability of injury was higher in individuals with hearing impairment or those that used hearing aid devices. The pooled OR for hearing loss was 2.01 (95% CI: 1.57–2.57).

Sensitivity Analyses of Measured Associations

As illustrated in Table 3, all measured associations remained relatively stable after the implementation of the sensitivity analyses. The change in the strength of associations (OR) was minimal, i.e., within the range of 0.01–0.52. There was no change in the direction of the association in all but one case; for health problems, the pooled OR estimate changed from 1.21 to 0.86, but both pooled estimates were statistically insignificant.

DISCUSSION

Reported Reasons for Risk Differences

This study presents findings for commonly reported risk factors for agricultural injury based on the evidence from all studies identified in a systematic review of the literature. To our knowledge, no similar review studies have been conducted to date. Seven of the eight evaluated risk factors were associated with an increased risk of injury, pooled ORs ranging from 1.57 to 2.17. Based on the P value of the pooled OR estimates, full-time farming is significant ($P < .05$), and history of prior injury, male gender, hearing loss, regular medication use, stress/depression, and farm owner/operator status are very significant ($P < .01$) risk factors for injury. These risk factors can be used for targeting interventions. Although information on populations with elevated risk is important in itself, understanding reasons behind the elevated risk may point to specific interventions for the target populations at risk. Some explanations were offered in the source studies, and they are discussed briefly in the following for each of the identified risk factors.

Male gender. Males have a higher risk of agricultural injury compared with females. Rather than gender itself, the difference may be based on the division of work tasks between the genders. This is reflected in findings where males have a higher risk of injury from machinery, whereas females have a higher risk of animal-related injuries.[7] In contrast, Erkal et al.[20,21] found a higher risk of animal-related

TABLE 3. Sensitivity Analysis Results; Pooled Risk Factor Estimates for Agricultural Injury Calculated From All Studies and High-Ranking Studies

Risk factor	Pooled OR, all studies (95% CI)	*P* value*	Pooled OR (95% CI) high-ranking studies	*P* value*
Male gender (vs. female)	1.68 (1.63–1.73)	.00	1.67 (1.62–1.72)	.00
Full-time farming (vs. part-time)	2.17 (1.12–4.21)	.02	2.69 (1.68–4.31)	.00
Owner/operators (vs. others/family members)	1.64 (1.13–2.38)	.00	2.15 (1.03–4.48)	.04
Regular medication use (vs. no regular medication)	1.57 (1.23–2.00)	.00	1.58 (1.21–2.06)[a]	.00
History of prior injury (vs. no prior injury)	1.75 (1.58–1.94)	.00	1.42 (1.25–1.60)	.00
Having health problems (vs. no health problems)	1.21 (0.96–1.53)	.09	0.86 (0.63–1.17)	.34
Having stress/depression (vs. no stress/depression)	1.86 (1.60–2.16)	.00	1.87 (1.59–2.20)	.00
Having hearing loss (vs. no hearing loss)	2.01 (1.57–2.57)	.00	2.03 (1.55–2.65)[a]	.00

*P value of .00 reflected very small, undetermined value.
[a]Only low-ranking studies were available for the meta-analysis. Pooled estimate was calculated without studies that had a nonsignificant confidence interval for this risk factor ($P > .05$).

injuries in males, but the difference was reduced after controlling for working hours in associated tasks. Also contrary to common findings, males had a lower risk of injury than females in crop production work after controlling for task-based exposure.[54] Further, in a Tanzanian study, the risk of transportation-related injuries was 1.75 times greater in males, but transportation-related work was also more frequent in males.[14] One study reported a higher risk of hospital admissions due to farm injury in males regardless of the amount of hours spent on farm work.[53] The differences in the duration and ways by which men and women are exposed during agricultural activities are not well-known. Although such data are difficult to obtain, future research should explore task-based working hours and differences in work exposures and injuries by gender. Overall, our results showed that male farmers had 1.68 times greater odds of agricultural injury compared with female farmers.

Full-time farming. The risk of injury increases with the amount of hours spent in farm-related tasks such as machinery, animal handling, and transportation.[16,19] Machinery-related injuries largely occur during busy spring planting and fall harvesting seasons.[19] Carruth et al.[38] showed that women who worked full-time had 3 times greater risk of injury than women who worked part-time on the farm. However, in two studies, part-time farmers had a higher risk compared with full-time farmers. This could be due to part-time farmers with off-farm employment being tired when performing farm-related tasks during evenings and weekends.[48] Further, Mongin et al.[55] suggested that full-time farmers may avoid injuries based on their greater experience in farm work. In some cases, full-time farmers may also have hired workers to perform hazardous tasks.[56] However, in summary, working full-time on the farm was a risk factor increasing the odds of injury by 2.17 times compared with working part-time.

Farm owner/operator status. Social and economic pressures to enhance productivity can make farm owners/operators perform dangerous tasks and put themselves at risk in spite of their knowledge of safety.[22] Hwang et al.[39] suggested a similar effect from psychological stress, social pressure, and financial constraints, which can increase work exposure time and risk of injuries. The responsibility that comes with owning the farm, making it more productive, and passing it to the next generation may make owners/operators perform more demanding and risky tasks in comparison with family members and hired workers.[39] Van De Broucke and Colemont[57] also reported a higher risk of injury in owners/operators compared with other workers. However, when stratified by tasks, the differences in safety behavior scores (Likert 1–5 scale) became insignificant reflecting different risk levels in different tasks. Overall, the odds of injury were 1.64 times higher in owners/operators compared with non-owners/operators.

Regular medication use. Certain common medications such as narcotic analgesics, tranquilizers, sleeping pills, and antidepressant drugs can sedate the central nervous system. This can cause changes in farmers' behavior, which may result in an increased risk of injury. Side effects of medication can affect the alertness and compromise judgment, which is required to perform complex farm-related tasks.[50] The lack of alertness may lead to failure in maintaining an upright posture, which can result in fall-related injuries.[58] The likelihood of regular medication use for adverse health conditions increases with age.[50] Xiang et al.[41] reported increased odds of injury from medication use in older (60 years and older) farmers. Overall, regular use of medication is a risk factor for injury, and farmers who used medications regularly had 1.57 times higher odds of injury compared with those who did not use medication regularly.

History of prior injury. Zhou and Roseman[22] reported a 3-fold risk of injury in farmers who had residual injury (history of injury in a lifetime prior to the reporting period). Erkal et al.[20,21] reported similar findings for the risk of animal-related injury. McGwin et al.[56] suggested that the residual health effects of prior injuries can contribute to the occurrence of subsequent injuries. In addition, farmers with prior injury may work in more hazardous environments, take more risks, and be less conscious of safety.[56] A possible synergistic effect from history of prior injury and regular medication use for depression was also reported. In contrast, Day et al.[42] reported a protective effect of prior injury. They suggested that farmers who had serious injury in the past may be more proactive in developing safety measures compared with farmers with no history of serious injury. Overall, the result of the meta-analysis shows that farmers with history of prior injury have 1.75 times higher odds of injury in comparison with farmers with no prior injury.

Health problems. According to Hwang et al.,[39] the risk of injury was higher in farmers who had joint trouble of the shoulder, wrist, knee, or spine at the lower back. Sprince et al.[30] reported increased odds of injury from animals for farmers who had arthritis. They explained that arthritis limits the movements of upper and lower extremities, and this situation can result in diminished ability to control large animals, resulting in loss of ability to maintain proper balance on the ground, which may lead to fall-related injury.[58] Marcum et al.[54] reported increased odds of injury in farmers with bronchitis and emphysema. These chronic respiratory conditions can affect breathing, and that can result in increased fatigue, which may contribute to the risk of injury at work.[54] In contrast, Day et al.[42] reported reduced odds of injury in farmers with back pain and chronic medical conditions. Also, Xiang et al.[41] reported lower odds of injury in older farmers with high blood pressure. It is possible that farmers who had chronic medical conditions such as high blood pressure or a chronic respiratory condition may restrict their tasks and exposures to farm-related activities.[42] The risk of injury can vary with the health problems experienced. Future studies should look at different health problems separately. In summary, the result of the meta-analysis showed that farmers with health problems had 1.21 times higher probability of injury compared with farmers without health problems, but this difference was not statistically significant.

Stress or depression. Depression and the side effects of depression medication can cause inattention and cognitive changes, which can put farmers at a risk of injury.[25] Xiang et al.[59] reported 4 times greater risk of injury in women with depression compared with women without depression. Work overload as well as underload can cause depression symptoms.[59] Work overload commonly occurs when the help is limited during busy times of the year. Work underload occurs when performing repetitive tasks while working in solitude. Low decision latitudes (limited decision-making) during overload situations can lead to increased mental strain.[60] Thu et al.[61] concluded that the risk of injury was higher in farmers who reported having high levels of stress (vs. no high level of stress). From most studies, it is not possible to determine to what extent stress and depression are risk factors for injury or consequences of injury. Prospective studies can help explain the temporality of depression/stress and injury. Tiesman et al.[26] and Park et al.[25] showed prospectively that depression is a risk factor for injury, and that injury can also be followed by depression or stress. The overall result of the meta-analysis showed that farmers with stress or depression had 1.86 times higher probability of injury than farmers who did not experience depression or stress.

Hearing loss. The diminishing hearing capability can make farmers insensitive to warning signals from machinery, animals, and other exposures. One might think that hearing aid devices may overcome poor hearing. However, Sprince et al.[40] reported increased odds of injury in farmers who had difficulty in hearing even when they wore hearing aid devices. According to Choi et al.,[62] hearing aid devices alter the hearing sensation, and using an inadequate device may not improve hearing adequately. They also showed that hearing loss and hearing asymmetry were significantly associated with farm injury. The farm environment usually has many noise sources, such as machinery, equipment, and animals. Working in such an environment with compromised hearing can contribute to the risk of injury.[62] Overall, our results showed that the odds of injury increased

2-fold in farmers who had hearing loss or who wore hearing aid devices compared with farmers with normal hearing.

Strengths

A growing number of studies have reported on risk factors for agricultural injury. In many cases, these studies show similar results, but some results are inconsistent or contradictory. Systematic review brings together all available studies and quantifies the evidence from all studies in meta-analysis. In the agricultural safety and health field, systematic reviews have been done to evaluate the effectiveness of interventions to reduce injury.[35,36,44,63] Other reviews have provided descriptive information on agricultural injury rates, characteristics, sources, risk factors, and vulnerable populations.[1,2,64,65] To our knowledge, no systematic reviews have been done to evaluate risk factors for agricultural injury. With the relatively large number of existing studies, this review is timely and has the capability to produce relatively stable estimates based on multiple studies.

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

Several methods can be used for assessing the quality of research studies, including Critical Appraisal Skills Program,[66] Strobe checklist,[67] and the Downs and Black checklist.[68] The Newcastle-Ottawa Scale (NOS)[46] was used in this review. It is suitable for quality assessment of nonrandomized studies, and it produces a score that can be used for study selection. None of the studies received a full score on NOS. All studies failed to explain the characteristics of nonrespondents. Many studies interviewed nonrespondents and enrolled them into the study as respondents. All selected studies used multivariate modeling for adjustment of confounders, which were selected from the univariate analyses in most cases. Overall, all but one of the selected studies met the predetermined quality score and were used to estimate risk factors.

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

Limitations

The study had several limitations. The strengths and limitations of systematic reviews have been discussed in numerous textbooks and studies. The limitations include reliance on the quality of source studies. Measures are taken in the systematic review process to select high-quality studies and reducing biases. However, publication bias in particular is difficult to overcome. Studies with negative or nonsignificant findings are more difficult to publish than studies with positive findings.[69] This applies to intervention studies, but could affect risk factor studies as well.

Although some studies used secondary data such as hospital or insurance records, many studies used self-reporting. This can introduce a recall bias. For instance, Mongin et al.[55] suggested that farmers who had injuries in the past may remember their injuries better than those without injuries in the past. Further, participants with severe injury may remember the exposures better than those with nonsevere injury. In some instances, participants may not be able to interpret the survey questions, which can result in information bias. The studies selected for this systematic review employed measures to control recall and information bias, such as using insurance data, structured questionnaires, and computer-assisted interviews for data collection. Therefore, the recall and information bias may not have a large effect on our results.

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

None of the studies provided estimates for interaction effects between risk factor variables, which can distort results. For example, without controlling for tasks, the risk of injury was higher in males, but after controlling for tasks, the effect of gender greatly diminished.[54] Therefore, controlling for tasks is important, but calculating interaction terms for task and gender could reveal further information on specific tasks that are particularly hazardous for one gender or the other. Future research should explore interactions among covariates for agricultural injury.

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

Future Directions

This study provides evidence that male gender, full-time farming, farm owner/operator status, regular medication use, history of prior injury, stress/depression, and hearing loss are risk factors for agricultural injury. Health problems did not emerge as a significant risk factor. These findings provide several implications for research. Investigators may consider the identified risk factors as potential confounders when designing new intervention studies. Even with significant evidence from existing studies to date, it is important to update information on these risk factors. As agricultural populations, practices, and environments change, injury sources and risk factors may change as well. Some risk factors, particularly health problems, require further study. Work time should be assessed in a greater detail than full-time vs. part-time, including seasonal variation in work time. The effects of gender require further study. Work exposure time by task would improve the understanding of risks to each gender. Use of the term "principal operator" in the US Census of Agriculture, and studies based on it, may lead to an undercount of women owner/operators. Other data sources consider all owner/operators (usually spouses) as equal partners rather than principal and secondary operators. This provides a better representation of women farmers.

This study also provides implications for practice. Knowledge of risk factors can be used by health and safety professionals and educators to identify target groups for prevention. Risk factor information alone is not sufficient, however. It is also important to understand the nature of injuries and prevention needs for each population at risk. Information on the identified risk factors should be disseminated, not only to agricultural health and safety practitioners, but farmers, ranchers, and hired workers as well. Each individual can consider his/her own risk factors. Knowledge of having a particular risk factor can be important for an individual for his/her own decision-making regarding safety.

CONCLUSION

Agriculture is a hazardous industry. Farmers and agricultural workers deal with numerous risks and exposures in their daily lives. In this study, we quantified the effect of eight common risk factors increasing the risk of injury, based on the available literature. The results of the meta-analysis show evidence that male gender, owners/operator status, injury in the past, regular medication use, full-time work, hearing loss, and stress or depression are significant risk factors for injury. The evidence of health problems as a risk factor was inconclusive. Further research and prevention efforts should be directed to populations with these risk factors, including those with several co-occurring risk factors. The identified risk factors can also be considered as potential confounders in future intervention studies.

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