# Tractor-Related Injuries: A Population-Based Study of a Five-State Region in the Midwest

**Kathleen Ferguson Carlson, MS,[1] Susan Goodwin Gerberich, PhD,[1]* Timothy R. Church, PhD,[1] Andrew D. Ryan, MS,[1] Bruce H. Alexander, PhD,[1] Steven J. Mongin, MS,[1] Colleen M. Renier, BS,[2] Xueying Zhang, MS,[1] L. Ronald French, PhD,[3] and Ann Masten, PhD[4]**

**Background** *Tractor-related injuries are among the most severe of agricultural injuries. This study identifies the incidence, consequences, and potential risk factors for tractor injuries among 3,765 agricultural households in a five-state region.*
**Methods** *Demographic, injury, and exposure data were collected for two 6-month recall periods in 1999 using computer assisted telephone interviews. A causal model served as a basis for survey design, data analysis, and interpretation of results; associated directed acyclic graphs guided development of multivariate models.*
**Results** *The overall injury rate was 9.6 events per 1,000 persons per year. Increased personal risk was observed for males and prior agricultural injury experience. Compared with ages 35–44, decreased risks were identified for those less than 5, 5–9, 10–14, 15–19, and 20–24.*
**Conclusions** *Risk of tractor injury among agricultural household members varied by gender, age, and prior injury experience.* Am. J. Ind. Med. 47:254–264, 2005.
*© 2005 Wiley-Liss, Inc.*

***KEY WORDS: occupational injury; agricultural injury; tractor-related injury; injury surveillance; agricultural workers; tractors***

## INTRODUCTION

Agriculture ranks among the highest of United States (U.S.) industries for work-related fatal injuries. Although estimates vary by region and data sources used [Myers and Hard, 1995], the U.S. agriculture-related fatality rate of 21.3 deaths per 100,000 workers in 2001 was 5.5 times greater than the rate for all occupations combined [National Safety Council, 2002]. It has been shown that tractors and machinery are the principal sources of agricultural fatalities [Etherton et al., 1991; Myers and Hard, 1995; Rivara, 1997; Day, 1999; Pickett et al., 1999]. Of the work-related fatalities identified for the agriculture, forestry, and fishing sector in 2001 (excluding agricultural operations with fewer than 11 employees), tractors were identified as the primary source of injury in approximately one-fourth of all fatal events [United States Department of Labor, Bureau of Labor Statistics, 2002].

Tractors are also associated with a large number of non-fatal agricultural injuries [Cordes and Foster, 1988; Fuortes

[1]Regional Injury Prevention Research Center, Division of Environmental Health Sciences, School of Public Health, University of Minnesota, Minneapolis, Minnesota
[2]Division of Education and Research, St. Mary's Duluth Clinic Health System, Duluth, Minnesota
[3]Chronic Disease and Environmental Epidemiology, Health Promotion and Chronic Disease Division, Minnesota Department of Health, Minneapolis, Minnesota
[4]Institute of Child Development, University of Minnesota, Minneapolis, Minnesota
Institution: School of Public Health, University of Minnesota
Contract grant sponsor: National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention, Department of Health and Human Services; Contract grant number: R01 CCR514375; Contract grant sponsor: Occupational Injury Epidemiology and Control Program, Occupational Injury Prevention Research Training Program, and the National Occupational Research Agenda Program, Midwest Center for Occupational Health and Safety, University of Minnesota (NIOSH); Contract grant number: T42/CCT510-422; Regional Injury Prevention Research Center and Center for Violence Prevention and Control, Division of Environmental Health Sciences, School of Public Health, University of Minnesota, Minneapolis, Minnesota.
*Correspondence to: Susan Goodwin Gerberich, Regional Injury Prevention Research Center, Division of Environmental Health Sciences, School of Public Health, University of Minnesota, MMC 807, 420 Delaware St. S.E., Minneapolis, MN 55455.
E-mail: gerbe001@umn.edu

Accepted 28 October 2004
DOI 10.1002/ajim.20135. Published online in Wiley InterScience (www.interscience.wiley.com)

et al., 1990; May, 1990; Gerberich et al., 1991, 1993, 1998, 2003; Brison and Pickett, 1992; Layde et al., 1995; Lee et al., 1996; Bancej and Arbuckle, 2000]. In 2001, a rate of 2.6 non-fatal, days-away-from-work tractor injuries per 10,000 full-time workers was reported for the agriculture, forestry, and fishing industry [United States Department of Labor, Bureau of Labor Statistics, 2003]. This rate is based on injuries that are recognized, diagnosed, and reported for operations with 11 or more employees, and is likely a considerable underestimate of all tractor injuries among the agricultural population.

Although tractors are consistently identified as a major source of injury, many studies present tractors and machinery as one category, impeding adequate examination of risk factors specific to tractors. Also, with few exceptions [Layde et al., 1995; Lee et al., 1996], studies concentrating on tractor-related injuries have relied on hospital and case-based data, even though it has been found that only 18%–46% of people who sustain an agricultural injury are treated in the emergency department, and only 3%–6% are hospitalized [Brison and Pickett, 1992; Gerberich et al., 1993, 2003]. In addition multiple risk factors and potential confounders are rarely assessed through multivariate modeling.

The objectives of this study were to determine: the rate of occurrence, the consequences of, and the potential risk factors for, tractor-related injuries among a population of agricultural households in a five-state region of the Midwest.

## METHODS

### Study Design and Population

Data for this study were extracted from the 1999 Regional Rural Injury Study-II (RRIS-II) cohort database, which is described in detail elsewhere [Gerberich et al., 2003]. In brief, the RRIS-II was a comprehensive, population-based study of all injuries, agriculture-related and not, involving agricultural operation households with children in Minnesota, Wisconsin, North Dakota, South Dakota, and Nebraska. The study utilized a telephone-based injury surveillance methodology that expanded upon the RRIS-I [Gerberich et al., 1993] and the Olmstead Agricultural Trauma Study [OATS; Gerberich et al., 1991]. A sample of 16,000 farming and ranching operations (3,200 from each state), identified from the U.S. Department of Agriculture's National Agricultural Statistics Service (NASS) Master List Frame of Agricultural Operations, was selected. Letters from the investigators and the respective state NASS offices describing the study were mailed to each operation to invite participation in the study. Follow-up telephone interviews were conducted by NASS interviewers specifically trained for the RRIS-II. These interviews obtained informed consent, established eligibility, and enrolled eligible households that agreed to participate.

Approval for the conduct of this study was obtained from the Institutional Review Board, Human Subjects Committee of the University of Minnesota.

Households were eligible to participate in the RRIS-II if they met all of the following criteria: were associated with the agricultural operation; included children younger than 20 years of age (<20) in residence as of January 1, 1999; produced at least $1,000 of agricultural goods in the previous year, or were involved in a Conservation Reserve Program (CRP); and were actively farming or ranching as of January 1, 1999. Participation in the study required that the eligible households be willing to complete two additional telephone interviews at 6-month intervals.

Subsequently, enrolled households received comprehensive packets containing a letter describing the forthcoming full-length interview, along with informational cards to be used to facilitate the data collection. A comparable packet was also mailed before the second full interview. As an incentive for participation, all sampled operations were eligible to enter a drawing that provided at least a 1 in 32 probability of receiving a $100 U.S. savings bond; justification for use of this incentive was based on past research reports [Woodward et al., 1985; Elkington, 1990; Boyle, 1995].

An *a priori* causal model guided development of the data collection instruments, and subsequent data analyses and interpretation. Interviews were conducted by NASS for each 6-month period of 1999, using a computer-assisted telephone interview (CATI) instrument. The interviews collected information on demographics, injury occurrence, and some exposures for each member of the household. Non-respondents for whom eligibility status was not established were sent a cover letter, one-page survey, and postage-paid return envelope to ascertain the eligibility of the household. Copies of the interview instruments, and all materials sent to the agricultural operations, are available for review [Regional Injury Prevention Research Center (RIPRC), 2004].

An injury was defined as any event resulting in one or more of the following: restriction from normal activities for 4 hr or more; loss of consciousness, loss of awareness, or amnesia for any length of time; use of professional health care. An event was classified as a tractor-related injury if the participant identified a tractor (including those with 20 horsepower (HP) or greater, those with less than 20 HP, and skid-steer loaders; based on similar mechanisms of non-fatal injury) as a source of injury associated with either agricultural or non-agricultural activities. Agriculture-related injuries were those that transpired as a result of any activity relating to an agricultural operation, or as a result of standing or playing in areas where agricultural work occurred. Based on this definition, no distinction could be made between work-related and non-work-related injuries.

Information on the injury events, including sources, mechanisms, and outcomes, was recorded in narrative form.

The injury event descriptions were coded by the research team using a simplified coding structure that was used in the OATS [Gerberich et al., 1991] and RRIS-I [Gerberich et al., 1993] studies, in combination with the International Classification of Diseases-Ninth Revision, External Cause Codes (ICD-9-CM E-Codes, 800–999; United States Department of Health and Human Services, 1989). Multiple responses were recorded for variables such as source/vehicle of injury, body part injured, type of injury, and ICD-9 E-code. For the purposes of this analysis, children were defined as persons <20 years of age as of January 1, 1999.

## Data Analysis

All injuries coded as tractor-related in the RRIS-II database were used for this analysis. Initially, the data were described by sources of injury (if additional sources were identified in combination with tractors), ICD-9 E-codes, anatomical locations and types/diagnoses of injuries, time and location of the injury events, measures of injury severity, and the activities in which the injured persons were involved at the time of the injury. Annualized injury rates were calculated for the cohort using logistic and Poisson regression. Additionally, annualized rates were identified for categories of sociodemographic variables (age, gender, state of residence, race, educational status, and marital status) and available exposure information (number of hours worked per week on one's own operation and history of prior agricultural injury).

Hours worked per week on one's own operation were categorized to reflect patterns of part-time (1–20; 21–40), full-time (41–60), and over-time (61–80; >80) work. To assess the potential trend between categories of hours worked and rates of injury, univariate and multivariate trend contrasts were used. Hours worked were not used as an exposure time denominator due to the inclusion of an unknown number of non-work related injuries in the numerator.

Rates were adjusted for within-household correlation using generalized estimating equations [GEEs; Liang and Zeger, 1986]. Item non-response was generally too low to estimate a rate for the group whose exposure could not be determined. To address non-response at the level of entire households (unit non-response), potential selection bias was partially accounted for by inversely weighting observed responses with probabilities of response [Horvitz and Thompson, 1952], estimated as a function of these characteristics from the NASS Master List Frame of Agricultural Operations: state in which the operation was located; the type of operation; and annual revenue by quintile. To account for unknown eligibility among non-respondents, probability of eligibility was estimated for these same characteristics [Mongin, 2001].

Multivariate analyses were guided by the *a priori* causal model (Fig. 1), which included known and hypothesized associations between the available sociodemographic and exposure variables of primary interest for the analyses. Odds ratios (ORs) and 95% confidence intervals (CI) were calculated for risk of injury using logistic regression. Selection of confounders for multiple logistic regression, using the principles in Maldonado and Greenland [2002], was based on directed acyclic graphs (DAGs), derived from the causal model. The use of DAGs is described by Greenland et al. [1999] and illustrated by Hernan et al. [2002]. These methods identify minimal confounder sets, leading to parsimonious models, and help identify covariates that may introduce bias if entered into the regression.

The computed ORs, based on the DAGs, identify the net causal effect of each particular exposure of interest on risk of tractor injury. Some studies have attempted to estimate the effect of an exposure conditional on hours worked per week (‘‘conditional effect’’). It should be noted, however, that the true conditional effect of these exposures is unidentifiable in non-experimental studies [Greenland and Robins, 1986; Pearl, 2000]. To provide a result for comparison with other studies, the ‘‘hours worked per week’’ variable was included in additional multivariate analyses. These analyses included the following exposures of interest: age, gender, and history of prior agricultural injury. Estimates from such analyses must be interpreted cautiously, since there is no clear interpretation of these estimated effect measures unless an alternative causal model can be reasoned. For example, an alternative model might be hypothesized for prior agricultural injury, in which the association between prior injury and hours worked is driven by a common, unmeasured ancestor (e.g., prior hours worked, at time 0), rather than using the causal arrow from prior injury to hours worked at time 1.

To address some of the uncertainty stemming from the observational nature of the study, sensitivity analyses were employed. This technique helped assess the magnitude and direction of bias that might result from the differential prevalence of an unmeasured confounder within levels of exposures identified as potential risk factors [Rothman and Greenland, 1998]. Upper and lower bounds for risk estimates were estimated under different plausible scenarios of association between the exposure of interest and an unmeasured confounder. For this computation, the prevalence of the potential confounder among the exposed versus unexposed population was allowed to differ between 10% and 60%, and the ORs for the association between the potential confounder and tractor injury were set at 5.0, 10.0, and 15.0.

# RESULTS

## Response

Among the 16,000 operations sampled, 12,677 households were successfully screened, of which 8,288 (51.8%) were ineligible and 4,402 (27.5%) were eligible. Of the

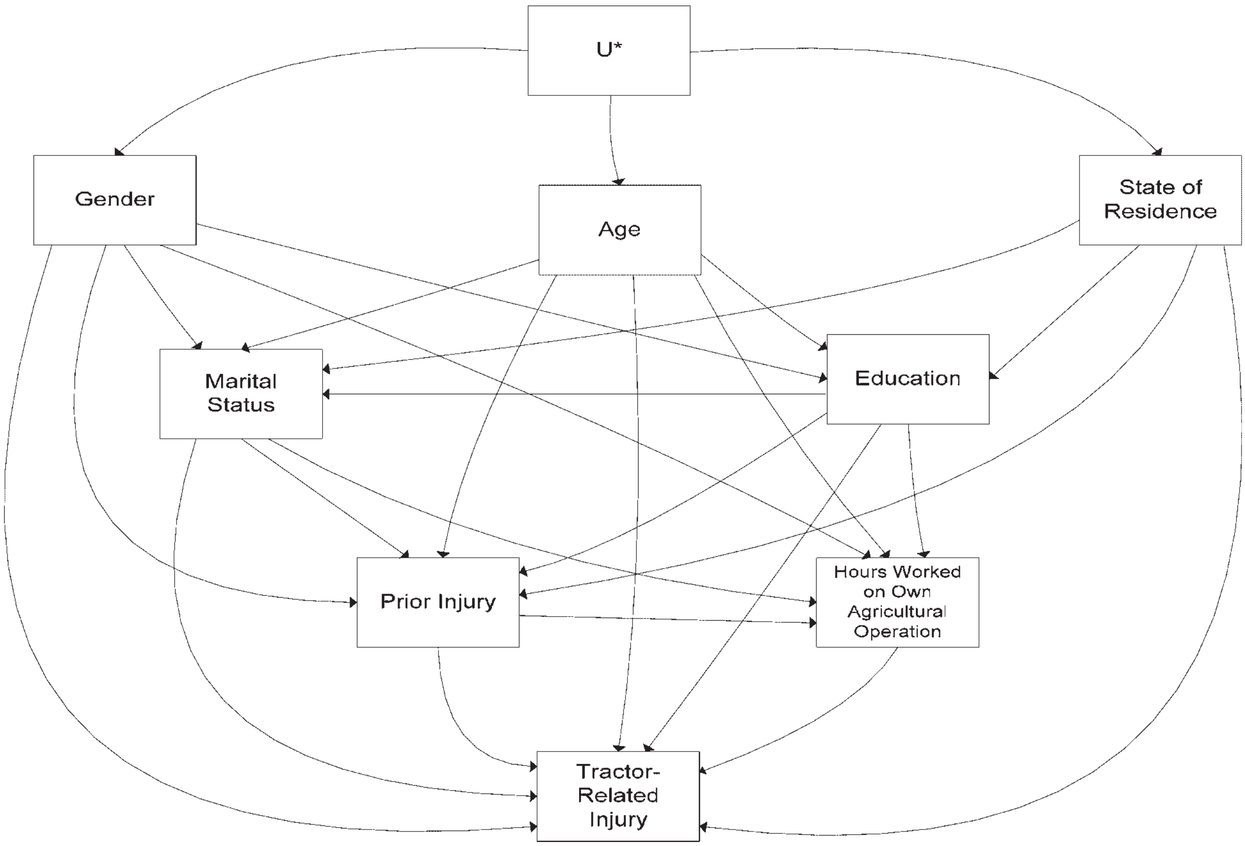


**FIGURE 1.** Causal Model: Basis for directed acyclic graph (DAG) used to select confounders for multivariate modeling of tractor-related injuries (n = 146) occurring on one's own agricultural operation: Regional Rural Injury Study-II, 1999. *U: Unidentified association between variables.

eligible operations, 3,765 (85.5%) participated in the first 6-month interview and 3,677 (83.5%) participated in both full interviews. Data were collected for 16,537 operation household members.

## Event Descriptions

Of 2,557 injuries reported by the cohort, a total of 156 injury events (6%), involving 144 people, were associated with tractors. The majority (n = 146) occurred on the participants' own agricultural operations, while only a few took place on someone else's operation (n = 5) or were not associated with activities considered to be agriculture-related (n = 5). Only one injury event occurred on a public or private roadway. Most injuries for which tractor type was known (n = 140) involved tractors with greater than 20 HP (n = 118; 76%), with only 7% each associated with tractors of 20 HP or less (n = 11) or with skid-steer loaders (n = 11). The highest percentage of tractor-related injuries was reported in North Dakota (n = 38; 27%) while the lowest was in Wisconsin (n = 17; 12%). A power take-off (PTO) was implicated in eight (5%) events; two were reportedly not shielded. Three events involved tractor rollovers and one involved a run-over. No fatal tractor-related injuries were reported for the cohort during the 1-year study period.

A small proportion of the study population (1.3%) self-identified with a race other than Caucasian; these participants reported no tractor-related injury events. Males were involved in most (n = 120; 77%) of the events. Among the 19 events (12%) that involved children, 16 occurred among males, and 3 among females. Most (78%) of the children's injuries involved tractors with greater than 20 HP; none were injured by skid-steer loaders.

More than half (58%) of the tractor-related injury cases reported having incurred an agricultural injury prior to 1999. Of these, nearly one-fourth (24%) reported some type of resultant disability at the time of the interview.

## Personal Injury Rates

### *Univariate analyses*

Univariate rates for tractor-related injury events, and injured persons, are reported in Table I. The total tractor-related injury rate (9.6 injury events per 1,000 persons per year) was higher among males (16.2) than among females

**TABLE I.** Person and Event Injury Rates* per 1,000 Persons per Year Among Farm or Ranch Household Members: Regional Rural Injury Study-II, 1999

| Exposure | Number exposed[a] | Agriculture-related; one's own operation rate (95% CI): Number of injury events | Agriculture-related; one's own operation rate (95% CI): Injured persons per 1,000 persons | Agriculture-related; one's own operation rate (95% CI): Injury events per 1,000 persons[b] | Total rate (95% CI): Number of injury events | Total rate (95% CI): Injured persons per 1,000 persons | Total rate (95% CI): Injury events per 1,000 persons[b] |
|---|---|---|---|---|---|---|---|
| Total population | 16,537 | 146 | 8.3 (7.0, 9.9) | 9.0 (7.5, 10.7) | 156 | 8.9 (7.5, 10.5) | 9.6 (8.0, 11.4) |
| Gender | | | | | | | |
| Males | 8,539 | 128 | 14.3 (11.9, 17.2) | 15.3 (12.6, 18.5) | 136 | 15.2 (12.8, 18.2) | 16.2 (13.5, 19.5) |
| Females | 7,998 | 18 | 2.0 (1.2, 3.3) | 2.3 (1.3, 3.9) | 20 | 2.1 (1.3, 3.4) | 2.5 (1.4, 4.4) |
| Age by gender | | | | | | | |
| Males ≤19 | 4,410 | 15 | 3.5 (2.1, 5.8) | 3.5 (2.1, 5.8) | 16 | 3.7 (2.3, 6.1) | 3.7 (2.3, 6.0) |
| Males 20+ | 4,124 | 113 | 25.9 (21.3, 31.4) | 27.9 (22.8, 34.2) | 120 | 27.6 (22.9, 33.3) | 29.6 (24.4, 36.0) |
| Females ≤19 | 4,077 | 3 | 0.8 (0.3, 2.6) | 0.8 (0.3, 2.6) | 3 | 0.8 (0.3, 2.6) | 0.8 (0.3, 2.6) |
| Females 20+ | 3,917 | 15 | 3.3 (1.9, 5.6) | 3.8 (2.1, 6.9) | 17 | 3.5 (2.1, 5.9) | 4.2 (2.3, 8.0) |
| Age groups | | | | | | | |
| ≤4 | 1,108 | 3 | 2.6 (0.8, 8.1) | 2.6 (0.8, 8.1) | 3 | 2.6 (0.8, 8.1) | 2.6 (0.8, 8.1) |
| 5–9 | 1,917 | 2 | 1.1 (0.3, 4.4) | 1.1 (0.3, 4.4) | 2 | 1.1 (0.3, 4.4) | 1.1 (0.3, 4.4) |
| 10–14 | 2,643 | 6 | 2.3 (1.0, 5.2) | 2.3 (1.1, 5.1) | 7 | 2.7 (1.3, 5.6) | 2.6 (1.3, 5.6) |
| 15–19 | 2,819 | 7 | 2.7 (1.3, 5.8) | 2.7 (1.3, 5.8) | 7 | 2.7 (1.3, 5.8) | 2.7 (1.3, 5.8) |
| 20–24 | 553 | 3 | 5.4 (1.8, 16.4) | 5.7 (1.9, 17.4) | 5 | 9.2 (3.9, 21.9) | 9.8 (4.1, 23.3) |
| 25–34 | 1,059 | 14 | 12.3 (7.1, 21.0) | 13.2 (7.5, 23.2) | 16 | 14.1 (8.5, 23.3) | 15.0 (8.9, 25.3) |
| 35–44 | 3,721 | 69 | 17.0 (13.3, 21.7) | 18.5 (14.3, 23.8) | 71 | 17.6 (13.8, 22.4) | 19.0 (14.8, 24.5) |
| 45–54 | 2,277 | 34 | 13.0 (9.0, 18.8) | 14.6 (9.8, 21.8) | 36 | 13.4 (9.4, 19.3) | 15.5 (10.3, 23.3) |
| 55+ | 431 | 8 | 24.0 (10.5, 54.3) | 23.7 (10.4, 54.0) | 9 | 26.3 (12.1, 56.3) | 25.9 (12.0, 56.0) |
| State of residence | | | | | | | |
| Minnesota | 3,178 | 24 | 7.5 (4.7, 11.8) | 8.1 (5.0, 13.0) | 25 | 7.8 (5.0, 12.1) | 8.4 (5.3, 13.3) |
| Nebraska | 3,381 | 34 | 9.1 (6.3, 12.9) | 9.9 (6.8, 14.3) | 35 | 9.3 (6.6, 13.3) | 10.2 (7.1, 14.6) |
| North Dakota | 3,498 | 42 | 11.7 (8.6, 16.0) | 12.2 (8.9, 16.7) | 45 | 12.6 (9.3, 16.9) | 13.0 (9.6, 17.7) |
| South Dakota | 3,527 | 28 | 7.2 (4.9, 10.6) | 8.1 (5.3, 12.4) | 31 | 7.8 (5.3, 11.3) | 9.0 (5.9, 13.9) |
| Wisconsin | 2,953 | 18 | 5.8 (3.6, 9.3) | 6.1 (3.7, 9.9) | 20 | 6.5 (4.2, 10.2) | 6.8 (4.3, 10.8) |
| Educational status | | | | | | | |
| Incomplete (<20 years of age) | 8,487 | 18 | 2.2 (1.4, 3.5) | 2.2 (1.4, 3.5) | 19 | 2.3 (1.5, 3.7) | 2.3 (1.5, 3.6) |
| Less than high-school graduate | 266 | 5 | 15.0 (5.5, 39.8) | 18.7 (6.4, 54.3) | 6 | 19.5 (8.0, 46.5) | 23.1 (9.0, 58.9) |
| High school graduate or equivalency | 3,222 | 63 | 17.7 (13.7, 22.9) | 19.4 (14.7, 25.5) | 67 | 18.6 (14.5, 23.9) | 20.6 (15.6, 27.1) |
| Technical school or some college | 2,897 | 37 | 13.1 (9.2, 18.6) | 13.4 (9.5, 19.1) | 39 | 13.9 (9.9, 19.5) | 14.2 (10.1, 19.9) |
| College graduate/post graduate | 1,652 | 23 | 12.2 (7.9, 18.9) | 14.1 (8.9, 22.5) | 25 | 13.4 (8.8, 20.2) | 15.2 (9.8, 23.7) |
| Marital status | | | | | | | |
| Incomplete (<16 years of age) | 6,308 | 13 | 2.1 (1.2, 3.6) | 2.1 (1.2, 3.6) | 14 | 2.2 (1.3, 3.8) | 2.2 (1.3, 3.7) |
| Married/living as married | 7,255 | 121 | 15.5 (12.8, 18.8) | 16.9 (13.8, 20.6) | 128 | 16.3 (13.6, 19.7) | 17.8 (14.7, 21.7) |
| Never married | 2,770 | 9 | 3.5 (1.8, 6.7) | 3.5 (1.8, 6.8) | 11 | 4.3 (2.4, 7.7) | 4.3 (2.4, 7.8) |
| Separated/divorced/ widowed | 187 | 3 | 14.2 (4.6, 43.4) | 14.0 (4.5, 43.4) | 3 | 14.2 (4.6, 43.4) | 14.0 (4.5, 43.4) |
| Hours worked on own operation (weekly average)[c] | | | | | | | |
| 0 | 2,765 | 3 | 1.1 (0.4, 3.4) | 1.1 (0.4, 3.5) | 3 | 1.1 (0.4, 3.4) | 1.1 (0.4, 3.5) |
| 1–20 | 7,715 | 27 | 3.1 (2.1, 4.6) | 3.5 (2.3, 5.4) | 31 | 3.5 (2.4, 5.1) | 4.0 (2.6, 6.2) |
| 21–40 | 2,287 | 19 | 8.5 (5.0, 14.3) | 9.3 (5.5, 16.0) | 24 | 10.6 (6.7, 16.7) | 11.5 (7.2, 18.3) |
| 41–60 | 1,446 | 34 | 21.4 (15.1, 30.1) | 22.7 (16.0, 32.3) | 35 | 22.1 (15.7, 30.9) | 23.4 (16.5, 33.1) |
| 61–80 | 1,290 | 40 | 29.2 (21.3, 39.9) | 30.8 (22.3, 42.5) | 40 | 29.2 (21.3, 39.9) | 30.8 (22.3, 42.5) |
| >80 | 481 | 16 | 29.4 (17.5, 49.0) | 33.9 (19.6, 58.6) | 16 | 29.4 (17.5, 49.1) | 33.9 (19.6, 58.6) |
| Prior agricultural injury | | | | | | | |
| No | 13,387 | 70 | 5.0 (3.9, 6.4) | 5.3 (4.1, 6.8) | 76 | 5.4 (4.2, 6.8) | 5.7 (4.4, 7.3) |
| Yes | 3,144 | 76 | 22.6 (17.6, 28.8) | 24.7 (19.1, 31.8) | 80 | 23.8 (18.8, 30.2) | 25.9 (20.3, 33.2) |

*Adjusted for within-household correlation using GEEs [Liang and Zeger, 1986] and weighted for non-response [Horvitz and Thompson, 1952; Mongin, 2001].
[a]Number responded/injured corresponding to total injuries.
[b]Sum of all injury counts based on person time in half-years; annualized rate adjusted for within-household correlation using GEEs [Liang and Zeger, 1986], and weighted for non-response [Horvitz and Thompson, 1952; Mongin, 2001].
[c]Results of a Cochran–Armitage test indicate a significant trend of increasing injury rates across categories ($P < 0.0001$).

(2.5). Rates were also increased among males and females aged 20 years or older (20+) compared with those <20. While no injuries were reported for persons 65 years or older, the rate for those older than 55 was the highest among all age groups. Rates of injury corresponded positively with hours of agricultural work per week, from 1.1 among those with 0 hr per week to 33.9 for those who worked more than 80 hr per week. Results of the univariate trend contrast indicated that this increase was statistically significant ($P = 0.0002$) with a slope of 0.6545.

### Multivariate analyses

In Table II, results are shown for the multivariate analyses including potential risk factors, as identified by the a priori causal model (Fig. 1); the covariates included in each model are indicated in the subheadings. Increased risks for tractor injury were observed for males and those with prior agricultural injury experience. Decreased risks were identified for ages less than 5, 5–9, 10–14, 15–19, and 20–24 years, compared with participants aged 35–44. Although no effect was observed for individual categories of hours worked per week on one's own operation, when controlling for potential confounders, the ORs increased across categories of increasing work hours per week. Similar to the univariate analysis, results of the trend contrast indicated this rise was significant ($P = 0.0347$) although smaller in slope (0.1778).

Based on sensitivity analyses results of the multivariate analyses appeared to be stable. Males remained at a greater risk of injury than females even in the presence of a theorized unmeasured confounder with differential prevalence among males and females. Similarly, participants with a prior agricultural injury remained more likely to incur a tractor-related injury in the presence of an unmeasured confounder; the effect of this exposure could only be reversed in examples where the prevalence of the confounder was at least 40% greater among those with prior injury than those without. Through comparable analyses of age, the ORs for younger age groups remained decreased in the presence of an unmeasured confounder with differential prevalence among exposure groups.

Results of multivariate analyses that included the "hours worked per week" variable in the models (gender, age, and prior agricultural injury) were similar to those conducted without this variable. Males had a higher risk of incurring a tractor injury (OR = 5.3; CI = 2.9, 9.9) as did participants with a prior agricultural injury (OR = 1.9; CI = 1.3, 2.7). Decreased risks were observed for the age groups of 5–9 (OR = 0.11; CI = 0.03, 0.46), 10–14 (0.17; CI = 0.07, 0.45), and 15–19 (OR = 0.24; CI = 0.10, 0.55) compared to those aged 35–44 years. While those less than 5 or 20–24 years of age were also at a decreased risk in the aforementioned model, the effect was not observed when controlling for hours worked.

## Characteristics and Consequences

In Table III, frequencies of additional injury sources/vehicles associated with the tractor-related injury events, activities at the time of the injury, and relevant ICD-9 E-codes are presented. Over half of the injury events involved a source/vehicle of injury in addition to tractors; the most frequent were falls, large machinery/equipment, and hand tools. One-third of all reported injury events occurred while mounting or dismounting a tractor. Among the injured children (results not shown), activities commonly associated with the injury events included driving a tractor (17%), or riding on a tractor (22%). In addition to agricultural machinery (E919; 35%), nearly one-third of all events were associated with an ICD-9 E-Code of E927, representing injuries related to overexertion and strenuous movements.

The highest proportion of injuries (32%) occurred during April, May, and June while the smallest proportion (17%) occurred during the months of January, February, and March. Of the injuries incurred by children, 58% occurred during months typically associated with school vacation (June, July, and August); in comparison, only 26% of adult injuries occurred during these months. Most injuries (82%) occurred between the hours of 6:00 AM and 5:59 PM while a few occurred between the evening hours of 6:00 PM and 11:59 PM (14%) or nighttime hours of 12:00 AM and 5:59 AM (4%).

By anatomical location, almost one-fourth of the injuries occurred to the back (24%). Fingers and/or thumbs, and the spinal cord and spine, were involved in 19% and 9% of the injuries, respectively. The resulting types of injuries/diagnoses included sprains and strains (41%), bruises and contusions (23%), and fractures and dislocations (23%). Concussions occurred in nine (6%) of the injury events. Of the injuries to children, 37% involved fractures and dislocations. Among all cases involving backs, sprains and strains were identified for 83% of the injuries; the spinal cord and spine injuries were most commonly classified as fractures and dislocations (73%).

In Table IV, the measures of severity assessed in the RRIS-II are identified. Of the 130 (83%) cases that required health care, 19% were treated in a hospital emergency department while 3% were admitted as hospital in-patients (due to fractures, burns, and amputations). Treatment was more commonly received in doctors' offices or chiropractic clinics. More than one-fourth (26%) of children's injuries were seen in hospital emergency departments, and nearly one-half (47%) were seen in doctors' offices; by comparison 18% and 29% of adults' injuries were treated in these locations. Treatment for 73% of all spinal cord and spine injuries, and for 62% of back injuries, was received from a chiropractor. More than one-fourth (26%) of cases treated by health care providers incurred costs that were not covered by health insurance.

**TABLE II.** Multivariate Analyses: Personal Risk of Tractor-Related Injuries Incurred on One's Own Agricultural Operation (n = 146): Regional Rural Injury Study-II, 1999

| Exposure | Responded (n) | Events (n) | Personal risk odds ratio[a] | 95% CI |
|---|---|---|---|---|
| Gender[b] | | | | |
| Male | 8,335 | 119 | 7.23 | (4.27, 12.26) |
| Female | 7,803 | 16 | Referent | (—) |
| Age (years)[c] | | | | |
| ≤4 | 1,092 | 3 | 0.14 | (0.04, 0.45) |
| 5–9 | 1,891 | 2 | 0.06 | (0.02, 0.24) |
| 10–14 | 2,575 | 6 | 0.12 | (0.05, 0.29) |
| 15–19 | 2,739 | 7 | 0.15 | (0.07, 0.33) |
| 20–24 | 542 | 3 | 0.29 | (0.09, 0.92) |
| 25–34 | 1,037 | 13 | 0.81 | (0.44, 1.49) |
| 35–44 | 3,627 | 63 | Referent | (—) |
| 45–54 | 2,218 | 30 | 0.66 | (0.42, 1.04) |
| 55+ | 417 | 8 | 1.13 | (0.47, 2.73) |
| State of residence[d] | | | | |
| Minnesota | 3,111 | 22 | Referent | (—) |
| Nebraska | 3,326 | 31 | 1.19 | (0.66, 2.14) |
| North Dakota | 3,370 | 40 | 1.52 | (0.87, 2.67) |
| South Dakota | 3,482 | 25 | 0.94 | (0.51, 1.73) |
| Wisconsin | 2,849 | 17 | 0.76 | (0.39, 1.49) |
| Educational status[e] | | | | |
| Incomplete (age <20) | 8,297 | 18 | 0.51 | (0.15, 1.71) |
| <High school graduate | 253 | 4 | 1.10 | (0.36, 3.36) |
| High school graduate or equivalency | 3,147 | 57 | 1.26 | (0.74, 2.13) |
| Technical school or some college | 2,832 | 36 | 1.05 | (0.58, 1.89) |
| College graduate/post graduate | 1,605 | 20 | Referent | (—) |
| Marital status[f] | | | | |
| Incomplete (age <16) | 6,174 | 13 | 0.83 | (0.12, 5.78) |
| Married/living as married | 7,077 | 110 | Referent | (—) |
| Never married | 2,770 | 9 | 0.59 | (0.17, 2.11) |
| Separated/divorced/widowed | 178 | 3 | 0.71 | (0.22, 2.29) |
| Hours worked/week on their own operation[g] | | | | |
| 0 | 2,759 | 3 | 0.63 | (0.18, 2.27) |
| 1–20 | 7,699 | 24 | Referent | (—) |
| 21–40 | 2,282 | 17 | 1.20 | (0.64, 2.26) |
| 41–60 | 1,441 | 32 | 1.67 | (0.88, 3.15) |
| 61–80 | 1,284 | 38 | 1.88 | (1.00, 3.53) |
| >80 | 475 | 14 | 1.85 | (0.85, 4.04) |
| Prior injury[h] | | | | |
| No | 13,039 | 66 | Referent | (—) |
| Yes | 3,081 | 69 | 2.02 | (1.39, 2.94) |

[a]Adjusted for within-household correlation using GEEs [Liang and Zeger, 1986], excluding level for missing values, and weighted for non-response [Horvitz and Thompson, 1952; Mongin, 2001].
[b]Adjusted for age and state.
[c]Adjusted for gender and state.
[d]Adjusted for age and gender.
[e]Adjusted for age, gender, and state.
[f]Adjusted for age, gender, state, and education.
[g]Adjusted for age, gender, education, marital status, and prior injury status.
[h]Adjusted for age, gender, state, education, and marital status.

**TABLE III.** Sources, Activities/Vehicles, and ICD-9 E-codes Associated With Tractor-Related Injuries (n = 156): Regional Rural Injury Study-II, 1999

| Characteristic | n | % |
|---|---|---|
| Additional source of injury, identified in combination with tractors | | |
| Slips, trips, and falls | 42 | 26.9 |
| Large machinery/equipment | 18 | 11.5 |
| Small equipment/hand tools | 7 | 4.5 |
| Physical object | 6 | 3.8 |
| Motor vehicle | 5 | 3.2 |
| Other | 4 | 2.6 |
| All additional sources | 82 | 52.5 |
| No additional source | 74 | 47.4 |
| Reported activities at time of injury event[a] | | |
| Mounting/dismounting | 51 | 33.1 |
| General repairs | 18 | 11.7 |
| Driving tractor | 16 | 10.4 |
| Riding on tractor | 14 | 9.1 |
| Adjusting machinery | 14 | 9.1 |
| Hitching/adjusting load | 12 | 7.8 |
| Feeding | 4 | 2.6 |
| Handling/transporting equipment | 4 | 2.6 |
| Handling/transporting feed/grain | 4 | 2.6 |
| Other | 18 | 11.7 |
| Unknown | 2 | 1.3 |
| ICD-9 E-code[a] | | |
| E919.00: Caused by agricultural machinery | 54 | 34.6 |
| E927: Overexertion and strenuous movements | 52 | 33.3 |
| E880–E885: Falls | 21 | 13.3 |
| E918: Caught accidentally in or between objects | 11 | 7.1 |
| E917: Struck against or by objects or persons | 9 | 5.8 |
| E916: Struck by falling object | 7 | 4.5 |
| Other | 10 | 6.4 |

[a]Multiple responses included.

**TABLE IV.** Measures of Severity Relating to Tractor-Related Injuries (n = 156): Regional Rural Injury Study-II, 1999

| Severity measure | n | % |
|---|---|---|
| Types of healthcare sources used | | |
| None | 26 | 16.7 |
| Doctor's office | 49 | 31.4 |
| Hospital emergency room | 30 | 19.2 |
| Hospital in-patient | 4 | 2.6 |
| Chiropractor's office | 41 | 26.3 |
| At scene of accident | 3 | 1.9 |
| Other health care facility | 3 | 1.9 |
| Work time lost on their own agricultural operation | | |
| No time lost | 81 | 52.6 |
| >0–<4 hr | 13 | 8.4 |
| 4 hr–<1 day | 15 | 9.7 |
| 1–< 7 days | 20 | 13.0 |
| 7–< 14 days | 7 | 4.5 |
| 14 days–< 1 month | 5 | 3.2 |
| 1–< 3 months | 6 | 3.9 |
| 3 months+ | 7 | 4.5 |
| Other work time lost | | |
| No time lost | 142 | 91.0 |
| >0 hr–<1 day | 1 | 0.6 |
| 1+days | 13 | 8.3 |
| Length of restricted activity | | |
| No restriction | 23 | 15.5 |
| >0–<4 hr | 16 | 10.8 |
| 4 hr–<1 day | 27 | 18.2 |
| 1–<7 days | 43 | 29.1 |
| 7–<14 days | 12 | 8.1 |
| 14 days–<1 month | 15 | 10.1 |
| 1–<3 months | 11 | 7.4 |

Nearly half of the injuries resulted in lost work time on the agricultural operation; 18% resulted in 1 day or less, 29% in 1 or more days, and 16% in 1 or more weeks. A large proportion of injuries resulted in long periods of restricted general activity; 29% resulted in more than a day but less than a week, and 26% resulted in 1 week or more. Of those that resulted in a week or more of restricted activity, fractures and dislocations (39%) and sprains and strains (31%) were the most common injury types. Of injuries among children, 71% involved a day or more and 29% resulted in a week or more of restricted activity.

## DISCUSSION

This study provides important information on the magnitude and consequences of, and potential risk factors for, tractor-related injuries among agricultural households with children in a five-state Midwest region. Although tractor-related injuries have been described frequently as an important problem among agricultural populations, studies have infrequently been population-based or have analyzed particular risk factors. However, despite differences in methods, some comparisons can be made across studies, specific to characteristics, consequences, and potential risk factors.

The overall rate of tractor-related injury identified in this analysis was higher than the rate reported by Lee et al. [1996] from the 1990 RRIS-I (8.9 vs. 5.1 injured persons per 1,000 persons, respectively). In both the current study and the RRIS-I, males had a higher rate of injury (15.2 and 8.1) than females (2.1 and 1.2 per 1,000 persons). However, rates by gender are not entirely comparable as the RRIS-I data did not include injuries related to skid-steer tractors and only included in the denominator operations known to have tractors. Based on the fact that so few events in the current study were reported to have involved skid-steer tractors (n = 11), the overall and gender-based rates of tractor injury appear to have increased.

No tractor deaths were reported for this cohort. As these data were from a population-based study of 16,537 agricultural household members, this was not surprising. While tractors are a leading source of agricultural fatality, less than 200 tractor-related deaths were reported for the agriculture, forestry, and fishing industry in 2001 [United States Department of Labor, Bureau of Labor Statistics, 2002], out of an estimated 3,209,000 workers (NSC, 2002; data exclude operations with fewer than 11 employees).

Potential risk factors identified in the current study were similar to findings from prior research efforts. Males compared with females were at a higher risk of tractor injury, even after adjusting for pertinent exposures using multivariate modeling and assessing the potential impact of an unmeasured confounder with sensitivity analyses. Consistent with this finding, males have previously been identified as being at greater risk of agricultural injury in general [Gerberich et al., 1993; McCurdy and Carroll, 2000], and specifically for tractor-related injuries [Lee et al., 1996]. Though data on specific tractor exposures were not obtained in this study, males may be at greater risk of tractor-related injury due to increased exposure time or involvement with more hazardous tasks.

In addition to gender, prior injury has also been identified as a risk factor for agricultural injury [Elkington, 1990; Boyle, 1995, 1997]. In the current effort, participants who reported prior agriculture-related injuries were twice as likely to have incurred a tractor-related injury during the study period than those without an injury history, even after controlling for several potentially confounding variables including age. Sensitivity analyses supported this result; the effect diminished only if the prevalence of the potential confounder differed by at least 40% between those who reported prior injury and those who did not. This finding of prior injury as a risk factor may be explained, in part, by persistent physical limitations or disabilities resulting from the injury; almost one-fourth of those reporting a prior agricultural injury had some permanent disability from that injury.

Increasing hours of work on one's own agricultural operation were associated with an increased rate of tractor-related injury in univariate analyses; the test for trend indicated this increase was significant. While there was also a significant trend when controlling for age, gender, marital status, and history of prior agricultural injury, those working more hours per week were not at a substantially increased risk of injury. This finding indicates that much of the effect of hours worked on tractor injury risk was mediated through these other variables.

Tractors and falls have been described separately as important causes of injury on agricultural operations [Brison and Pickett, 1992; Gerberich et al., 1993; Layde et al., 1995; Nordstrom et al., 1996; Pickett et al., 1999; Bancej and Arbuckle, 2000]. Falls from tractors have also been identified as being associated with a notable proportion of injuries [Lee et al., 1996; Day, 1999; Pickett et al., 1999]. Elkington [1990] reported that falls were associated with 11%–19% of machinery-related injury events in a Southeastern Minnesota county; tractors were included in this study. Frequent injury occurrence has also been reported to be associated with mounting and dismounting tractors [Juha, 1992; Lee et al., 1996]. In the current study, falls on or from tractors were reported for more than one-fourth of the tractor-related injury events, and one-third of the injuries occurred while the person was mounting or dismounting. The need to further investigate tractor design and safety, especially relevant to mounting and dismounting tractors, has been discussed previously [Gerberich et al., 1991, 1998; Waller, 1992; Lee et al., 1996]; the findings from the current study further support this need.

In this study, sprains and strains were found to be the most common types of injury, while the back, fingers and/or thumbs, and spinal cord or spine were the most frequently injured body parts. A large proportion of injuries to the back were identified as sprains or strains, while injuries to the spinal cord or spine were commonly identified as fractures and dislocations. These findings are mirrored by results of the RRIS-I, pertaining to tractors [Lee et al., 1996]. Similarly, the proportions of tractor injuries requiring health care (83%) and hospitalization (3%) paralleled those from population-based studies of agricultural injury, in general [Gerberich et al., 1991, 1993], and those specific to tractors [Lee et al., 1996].

It has been reported previously that the physical and financial burdens of non-fatal tractor-related injuries, when measured by health care costs and/or lost productivity, are substantial [Gerberich et al., 1991, 1993, 1998; Lee et al., 1996; Hartling et al., 1997]. Data from the current study confirm this. Nearly 30% of the injuries resulted in a day or more of lost work on the operation, with 16% involving a week or more of lost work. In addition, the length of restricted activity is noteworthy: 29% of injuries resulted in more than 1 day, but less than a week, of restricted general activity; 26% of the injuries resulted in a week or more; and 7% resulted in a month, or more, of restricted activity. Findings from severity measures such as these, compared with the number of injuries treated in a hospital, emphasize the importance of collecting population-based data rather than relying on hospital surveillance or case-based data.

The overall proportion of tractor-related injuries incurred by children was fairly low (12% of tractor-related injury events); this was similar to the findings by Lee et al. [1996] where children were associated with only 6% of tractor-related injuries. It is believed that this is a corollary of lower numbers of hours that children are directly exposed to tractors, relative to the hours of tractor exposure among adults. However, tractor-specific exposure hours were not available for the current study; therefore, the effects of differential exposure levels between children and adults could not be assessed. It was evident, though, that the consequences of injuries incurred by children were substantial. More than one-fourth of the injuries among children required care in hospital emergency departments and nearly half were treated in doctors' offices; this compared with 18% and 29%, respectively, among adults. The consequences of children's injuries also appeared to be considerable; 71% involved a day or more and 29% resulted in a week or more of restricted activity. These findings may be associated with the fact that a substantial proportion of injuries incurred by children (37%) involved fractures and dislocations.

Some limitations of this study should be considered when interpreting these data. Although the response rate was relatively high (86%), the potential for some selection bias from non-participation exists. To minimize this potential bias, adjustments for non-response based on data from the NASS Master List Frame of Agricultural Operations were made using the methods of Horvitz and Thompson [1952]. Participants may have been more likely to remember and report the most severe or most recent tractor-related injuries at the time of the interview. To address this potential recall bias, the reporting periods involved 6-month windows, which has been shown to improve reporting reliability [Gerberich et al., 1991; Braun et al., 1994]. In addition, the use of informational packets and forms on which participants could record information on their injury events throughout the study period would also be expected to decrease recall bias. To minimize misclassification the data collection instruments were subjected to rigorous development and testing and interviewers participated in thorough training before each interview period. The use of a causal model provided an additional foundation for designing the interview instruments; this model also enabled the application of directed acyclic graphs, thus, facilitating selection of potential confounders in the multivariate analyses.

In general, tractor injury rates based on exposure time are lacking in the agricultural health literature. Though it would have been useful to analyze injury rates based on an exposure time denominator (i.e., agricultural hours worked per week) for the current study, such rates would have been biased, based on the inclusion of non-work related tractor injuries in the numerator. The number of non-work related injuries was unquantifiable due to the nature of the data, limiting the ability to adequately estimate exposure-time rates. For future studies, a clear division between work and non-work injuries would facilitate computation of exposure time rates and contribute further to the literature. Additionally, a study such as this would benefit from additional information on tractor-specific, or tractor-type specific, exposure hours, as well as a distinction among types of agricultural operations.

The target population for this study included agricultural operations with associated households that included children less than 20 years of age. These households were in a five-state, Upper Midwest region of the U.S. As such, results are theoretically generalizable only to this specific population, though they may be useful as a basis for studies involving other agricultural target populations. Analyses were also limited by the number of tractor-related injuries sustained by the cohort. Specifically, the overall number of reported injuries may have been too low to detect differences for some categories within exposures of interest. Also, the presence of an unknown and/or unmeasured confounder may have affected the results of these analyses. Although sensitivity analyses were conducted using postulated data, specific data to support such an analysis were not available.

Despite these limitations, this study provided data on the magnitude of problems associated with tractor-related injuries and the potential risk factors in a Midwest agricultural population. The findings from this effort indicated that these injuries represent a significant problem among agricultural households based on injury rates, consequences of injury, and potential risk factors. These results provide a picture of tractor-related injuries occurring among a five-state agricultural population that includes a broader spectrum of events than are represented by hospital or case-based studies. Most importantly, the results serve as the basis for an analytical case-control study that may further identify specific risk factors and help facilitate development of appropriate prevention and control efforts.

## ACKNOWLEDGMENTS

The authors are grateful for the collaboration with, and assistance from, the United States Department of Agriculture's NASS and for thoughtful comments on the manuscript from Todd Rockwood, PhD, Department of Health Services Research and Policy and James Gurney, PhD, Department of Pediatrics, University of Minnesota. Much appreciation is also due to the households that participated in the RRIS-II.

## REFERENCES

Bancej C, Arbuckle T. 2000. Injuries in Ontario farm children: A population based study. Inj Prev 6:135–140.

Boyle D. 1995. Case-control study of dairy cattle operation injuries. Dissertation. Minneapolis: University of Minnesota.

Boyle D, Gerberich SG, Gibson RW, Maldonado G, Robinson A, Martin F, Renier CM. 1997. Case-control study of dairy-operation related injuries: Rate ratios associated with dairy activities. Epidemiology 8:37–41.

Braun BL, Gerberich SG, Sidney S. 1994. Injury events: Utility of self-report in retrospective identification in the USA. J Epidemiol Community Health 49:604–605.

Brison RJ, Pickett CWL. 1992. Non-fatal farm injuries on 117 Eastern Ontario beef and dairy farms: A one-year study. Am J Ind Med 21: 623–636.

Cordes DH, Foster RD. 1988. Health hazards of farming. Am Fam Physician 38(4):233–244.

Day LM. 1999. Farm work related fatalities among adults in Victoria, Australia. The human cost of agriculture. Accid Anal Prev 31:153–159.

Elkington JM. 1990. A case-control study of farmwork-related injuries in Olmsted County, Minnesota. Dissertation. Minneapolis: University of Minnesota.

Etherton JR, Myers JR, Jensen RC, Russell JC, Braddee RW. 1991. Agricultural machine-related deaths. Am J Public Health 81:766–768.

Fuortes LJ, Merchant JA, Van Lier SF, Burmeister LF, Muldoon J. 1990. 1983 occupational injury hospital admissions in Iowa: A comparison of the agricultural and non-agricultural sectors. Am J Ind Med 18: 211–222.

Gerberich SG, Gibson RW, Gunderson PD, French LR, Melton LJ, III, Erdman A, Smith P, True JA, Carr WP, Elkington J, Renier CM, Andreassen LR. 1991. The Olmsted Agricultural Trauma Study (OATS): A population-based effort. A report to the Centers for Disease Control. Minneapolis: Regional Injury Prevention Center, University of Minnesota.

Gerberich SG, Gibson RW, Gunderson PD, French LR, Martin F, True JA, Shutske J, Renier CM, Carr WP. 1993. Regional Rural Injury Study (RRIS): A population-based effort. A report to the Centers for Disease Control. Minneapolis: Regional Injury Prevention Center, University of Minnesota.

Gerberich SG, Gibson RW, French LR, Lee T-Y, Carr WP, Kochevar L, Renier CM, Shutske J. 1998. Machinery-related injuries: Regional Rural Injury Study-I (RRIS-I). Accid Anal Prev 30(6):793–804.

Gerberich SG, Gibson RW, French LR, Church TR, Alexander BH, Shutske J, Masten AS, Renier CM, Mongin SJ, Ryan A, Ferguson KR, Zhang X, Jensen KE. 2003. Etiology and consequences of injuries among children in farm households: A regional rural injury study. A report to the Centers for Disease Control and Prevention Minneapolis: Regional Injury Prevention Center, University of Minnesota.

Greenland S, Robins J. 1986. Identifiability, exchangeability, and epidemiologic confounding. Int J Epidemiol 16(3):413–419.

Greenland S, Pearl J, Robins J. 1999. Causal diagrams for epidemiologic research. Epidemiology 10(1):37–48.

Hartling L, Pickett W, Dorland J, Brison RJ. 1997. Hospital costs associated with agricultural machinery injuries in Ontario. Am J Ind Med 32:502–509.

Hernan MA, Hernandez-Diaz S, Werler MM, Mitchell AA. 2002. Causal knowledge as a prerequisite for confounding evaluation: An application to birth defects epidemiology. Am J Epid 155(2):176–184.

Horvitz DG, Thompson DJ. 1952. A generalization of sampling without replacement from a finite universe. Am Stat Assoc J 47:663–685.

Juha S. 1992. Tractor accidents and their prevention. Int J Ind Ergon 10:321–329.

Layde PM, Nordstrom DL, Stueland D, Brand L, Olson KA. 1995. Machine-related occupational injuries in farm residents. Ann Epidemiol 5(6):419–426.

Lee T, Gerberich SG, Gibson RW, Carr WP, Shutske J, Renier CM. 1996. A population-based study of tractor-related injuries: Regional Rural Injury Study-I (RRIS-I). J Occup Environ Med 38(8):782–793.

Liang KY, Zeger SL. 1986. Longitudinal data analysis using generalized linear models. Biometrics 73:45–51.

Maldonado G, Greenland S. 2002. Estimating causal effects. Int J Epid 31:422–429.

May JJ. 1990. Issues in agricultural health and safety. Am J Ind Med 18:121–131.

McCurdy SA, Carroll DJ. 2000. Agricultural injury. Am J Ind Med 38:463–480.

Mongin SJ. 2001. Adjustment for non-response in the Minnesota Nurses Study. Health Studies Research Report (http://www1.umn.edu/eoh/NewFiles/resreports.html), Division of Environmental Health Sciences, School of Public Health, University of Minnesota, Minneapolis.

Myers JR, Hard DL. 1995. Work-related fatalities in the agricultural production and services sectors, 1980–1989. Am J Ind Med 27:51–63.

National Safety Council. 2002. Injury facts, 2002 edition. Itasca, IL: National Safety Council.

Nordstrom DL, Layde PM, Olson KA, Stueland D, Follen MA, Brand L. 1996. Fall-related occupational injuries on farms. Am J Ind Med 29:509–515.

Pearl J. 2000. Causality: Models, reasoning, and inference. New York: Cambridge University Press.

Pickett W, Hartling L, Brison RJ, Guernsey JR. 1999. Fatal work-related farm injuries in Canada, 1991–1995. Can Med Assoc J 160(13):1843–1848.

Regional Injury Prevention Research Center (RIPRC). 2004. (http://enhs.umn.edu/riprc/riprc.html). Division of Environmental Health Sciences, School of Public Health, University of Minnesota, Minneapolis.

Rivara RF. 1997. Fatal and nonfatal farm injuries to children and adolescents in the U.S. Pediatrics 76:567–573.

Rothman KJ, Greenland S. 1998. Modern epidemiology. Second edition. Philadelphia: Lippincott-Raven.

United States Department of Health and Human Services. 1989. The International Classification of Diseases. 9th Revision. Pub. No. (PHS) 89–1260.

United States Department of Labor, Bureau of Labor Statistics. 2002. Census of Fatal Occupational Injuries. Fatal occupational injuries by primary and secondary source of injury by major private industry division, All Unites States, 2001. Retrieved July 15, 2004, from http://www.bls.gov/iif/oshwc/cfoi/cftb0154.pdf.

United States Department of Labor, Bureau of Labor Statistics. 2003. Occupational injuries and illnesses: Counts, rates, and characteristics, 2001. US DOL, BLS, Bulletin 2560.

Waller JA. 1992. Injuries to farmers and farm families in a dairy state. J Occup Med 34:414–421.

Woodward A, Douglas B, Miles H. 1985. Chance of free dinner increases response to a mail questionnaire. Int J Epidemiol 14(4): 641–642.