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Hospitalized head injuries in agricultural settings: Who are the vulnerable groups?

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ABSTRACT

Objectives: The goal of this study was to identify subgroups of the farm population that are particularly vulnerable to head injury.
Methods: A retrospective case series of hospitalized head injuries was assembled from a national registry of agricultural injuries. Vulnerable subgroups were identified based on a priori criteria and the causes and consequences of their injuries were profiled.
Results: Three distinct subgroups of farm people were identified as being vulnerable: (1) farm children under the age of 10, injured most frequently by a fall from a structural height (42.5%); (2) females 10–19 years, injured most frequently by large animals (68.8%), mainly horses, and (3) men over age 60 years, who were injured by a diversity of mechanized and animal-related external causes.
Conclusion: This identification of vulnerable groups provides foundational information from which to develop and direct prevention efforts.

1. Introduction

Head injuries with brain involvement present a devastating form of physical trauma that can have lifelong physical, cognitive, behavioral, and emotional consequences (Langlois et al., 2006). Thus, head injuries are considered one of the most disabling injuries and are reported to be the leading cause of disability in children (Centers for Disease Control, 2000). In the general population, leading external causes of these serious forms of head injury include falls and motor vehicle traffic collisions (Langlois et al., 2006; Pickett et al., 2004). Populations at higher risk include preschool-aged children, adolescents, and the elderly (Langlois et al., 2006). Other than these general observations, few existing analyses have characterized population subgroups that are most vulnerable to major head injury.

Farm populations experience extremely high risks for traumatic injury (Pickett et al., 1999), and thus the concept of differential *vulnerability* is particularly relevant to farm populations. Farming is a unique industry in that there is the potential for people of all ages, from infancy through old age, to be routinely exposed to a variety of injury-producing physical hazards. Some groups on farms are vulnerable due to the nature of their work. Others, such as young children, are vulnerable simply because they live in a dangerous and sometimes unpredictable environment. Farms remain relatively unregulated and there is a consequent reliance on voluntary occupational health and safety standards that have questionable efficacy (Kelsey, 1994). On some farms, little distinction is made between residential and worksite areas. This combination of circumstances leaves people on farms vulnerable to many causes of traumatic injury over and above the typical experiences of the general population.

No studies exist which profile the occurrence of major head injuries in the farm population and evaluate whether subgroups in this population are especially vulnerable. We had the opportunity to address this void in the biomedical literature. Using an existing national registry of hospitalized traumatic farm injuries (Pickett et al., 2001), we conducted a novel analysis in order to: (1) identify subgroups of the farm population that are particularly vulnerable to head injury and (2) compare the leading external causes and consequences of farm-related head injuries among these vulnerable groups. Our hope was that this analysis would provide foundational information on this important and disabling form of injury. This in turn could be used to critically examine the content and targeting of farm injury prevention strategies towards those at highest risk.

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2. Methods

The study involved primary review of 1245 injury records contained in a national registry of agricultural injuries. Included are all known cases of head injury from 1990 to 2000 that happened during farm work and/or occurred in the farm production environment in Canada and resulted in an admission to any Canadian hospital. Ethics approval was obtained from the Queen's University Health Sciences Research Ethics Board.

2.1. Data source

Individual records of injury events were obtained from the Canadian Agricultural Injury Surveillance Project (CAISP) (Hartling and Pickett, 1998). CAISP has maintained a national registry of hospitalized agricultural injury cases since 1990. For the study period involved, records of potential agricultural injuries are identified using International Classification of Diseases, Ninth Revision Clinical Modification (ICD-9-CM) E-code (National Center for Health Statistics, 1989) searches of electronic hospital discharge databases accessed from each Canadian province. The medical records departments of individual hospitals reporting one or more cases are then contacted by mail. A standard data abstraction form is completed and returned to the national CAISP offices for each case record. Each hospital medical records office is asked to verify key information contained in the electronic record, the circumstances surrounding the injury event, and the mechanisms leading to injury. Information contained in the electronic hospital discharge record is also abstracted and analyzed. The additional abstracted information contains up to five diagnostic fields describing the nature and anatomic sites of injuries sustained, based upon ICD-9-CM N-codes (National Center for Health Statistics, 1989; Pickett et al., 2001). CAISP hospitalization data have been used in the past to profile patterns and causes of injuries in the Canadian farm population, e.g. (Lim et al., 2004; Locker et al., 2002; Pickett et al., 2001) to study agricultural injuries sustained by subpopulations including children (Lim et al., 2004) and the elderly (Pickett et al., 2001), and to highlight specific external causes of injury, such as runovers (Pickett et al., 2005) and falls (Pickett et al., 2007). Participation of Canadian hospitals in this program is very high, with response rates exceeding 95% in all provinces when calculated on a per record basis (Pickett et al., 2001).

2.2. Definitions of head injuries

Injury records were included in this analysis if they met each of the following criteria: (1) patient presented to a hospital in any Canadian province during the fiscal years 1990–2000, (2) the patient was subsequently admitted to the hospital as an inpatient with a recorded length of stay, (3) the patient hospital record included an ICD-9-E-code of E919.0 (injuries caused by agricultural machines) and/or E849.1 (injuries that occurred on a farm), (4) attending staff provided a diagnosis of at least one head injury (ICD-9-CM N-codes 800.0–804.9 and 850.0–854.1, inclusive), and (5) the case was verified as an agricultural injury by the medical records personnel and the national CAISP office. In cases where more than one head injury was diagnosed, the primary injury code (the diagnosis that led to hospital admission) was used in subsequent analyses. Agricultural injuries were defined as hospitalized injury events that occurred on a Canadian farm or that involved any farm production hazard, including those occurring on public roadways. Fatal injury events were included if there was record of an inpatient hospital admission associated with the acute injury prior to pronouncement of death.

2.3. Instrument and data verification

The CAISP data collection instrument contains specific items that are abstracted for research purposes. Variables used in this particular analysis included demographic characteristics (age, gender) and nature of injury (ICD-9-CM codes), as well as closed-ended questions and an open-ended narrative used to describe the external causes of injury. These data were subsequently coded and verified using standard CAISP rules and procedures. Codes available to describe circumstances leading to injury include the mechanism involved, with specific categories being animals, machinery, falls, and struck by objects. Verification occurs at two levels: (1) key diagnostic and length of stay variables from the hospital discharge record are checked by hospital-based medical records technicians, and (2) each external cause of injury code is verified by at least two coders against the narrative text supplied as part of the data abstraction process.

2.4. Coding of injury severity

Standard measures of anatomic injury severity employed included the abbreviated injury severity (AIS) score for the head region (Sacco et al., 1999), as well as the injury severity score (ISS) consisting of the sum of the squares of the maximum AIS scores for the three most severely injured body regions (Baker and O'Neill, 1976). These scores were not available directly from the hospital discharge records. ICDMAP-90 software (Johns Hopkins/Tri-Analytics Inc.) was therefore used to convert available ICD9-CM diagnoses to ICD/AIS and then to ICD/ISS scores. ICDMAP-90 computes the maximum ICD/AIS score for each injured body region and uses these to calculate the summary ICD/ISS value. Where the ICD-9-CM diagnostic code was insufficient to directly assign an AIS value, no loss of consciousness was conservatively assumed in the generation of the AIS and ISS scores.

Valid AIS scores are: 1 (mild), 2 (moderate), 3 (serious), 4 (severe), 5 (critical), and 6 (non-survivable) (Sacco et al., 1999). Valid ISS scores range from 1 (one reported minor injury) to 75 (high risk of mortality) (Baker and O'Neill, 1976). An ISS score ≥12 is classified as major trauma (Ball et al., 2007).

2.5. Coding of injury diagnoses

Major diagnostic categories of head injury available from ICD-9-CM N-codes used in this analysis included concussion (ICD 850), intracranial contusion/bleeds (ICD 851–853), skull and other head fractures (ICD 801–804), and unspecified intracranial injuries (ICD 854).

3. Data analysis

We profiled the occurrence of head injuries in this agricultural injury case series according to age group and gender, and then estimated the rate of hospitalized head injuries per 100,000 person years as extrapolated from the Canada Census of Agriculture (Statistics Canada, 1996) at the midpoint of the study period (1996). Confidence intervals for the rates were calculated based upon exact inference for a Poisson distribution. The age groups used for children and adolescents in the analysis were 0–4, 5–9, 10–14, 15–19 years and then 0–19 years (the standard definition of a child in Canada (Choinière and Robitaille, 1997)). Age groups used for adults were 20–39, 40–59, and 60+ years. The wide age ranges used for adult age groups reflect the consistency of injury patterns observed within those same age groups, as informed by preliminary analyses.

All analyses were descriptive and involved calculation of measures of central tendency, frequencies and cross-tabulations. The primary emphasis involved comparison of patterns of head injury observed among these vulnerable groups on the farm.

3.1. Identification of vulnerable groups

The process used to identify groups that were vulnerable to head injury involved several steps. First, we subdivided the patient population by gender. Then, we calculated rates of head injury by gender, both overall and within specific age groups (Table 1). For each gender, the point estimates for the age-specific rates that exceeded the overall gender-specific rates were highlighted. This indicated those age groups most vulnerable to head injury. Some vulnerable age groups were combined for subsequent analyses.

4. Results

Between 1990 and 2000, a total of 1245 people met our case definition following admission to a Canadian hospital. There were 1329 diagnoses of head injuries reported in the five available diagnostic fields for these 1245 cases. A head injury diagnosis was the primary code leading to hospital admission in 1138/1245 (91.4%) of the cases. In 7% of cases, more than one head injury diagnosis was recorded. Overall, males had more than twice the rate of hospitalized head injuries compared to females (Table 1). The most vulnerable groups identified were: (1) children younger than 10 years for both genders, (2) men 60 years and older, and (3) preadolescent and adolescent females 10–19 years (Table 1).

The leading mechanisms of head injury varied for the three vulnerable groups (Table 2). For children younger than 10 years, the leading mechanism of injury was fall/jump from heights (108/254, 42.5%). For females 10–19 years, animals were the leading mechanism of head injury (53/77, 68.8%) and for men 60 years and older, the leading mechanism of head injury was machinery (76/205, 37.1%). When examining animal-related injuries, children younger than 10 years and females 10–19 had higher proportions of head injuries involving horses, and men over 60 years had a higher

Table 1
Distribution of hospitalized head injuries by gender and age

Age (years)	Male farm-related head injuries			Male farm population 1996 (CAN), *N*	Female farm-related head injuries			Female farm population 1996 (CAN), *N*
	N	Event rate[a]	95% CI		*N*	Event rate[a]	95% CI	
0–19	308	18.7	16.7–20.9	149,620	151	9.9	8.4–11.7	138,020
0–4	87	**29.3**	23.4–36.1	27,020	36	**13.0**	9.1–18.0	25,105
5–9	93	**23.2**	18.7–28.4	36,420	38	**10.0**	7.1–13.7	34,615
10–14	63	13.2	10.1–16.9	43,425	36	**8.1**	5.6–11.2	40,600
15–19	65	13.8	10.7–17.6	42,755	41	**9.9**	7.1–13.4	37,700
20–39	194	16.6	14.3–19.1	106,555	65	6.2	4.8–7.9	95,450
40–59	217	15.1	13.1–17.2	130,780	82	6.3	5.0–7.8	118,785
60+	205	**28.4**	24.6–32.6	65,650	23	4.5	2.8–6.7	46,545
All ages	924	18.6	17.4–19.8	452,595	321	7.3	6.5–8.2	398,805

Vulnerable groups are in boldface type. CAN: Canada; CI: confidence interval.

[a] Estimated rate of hospitalized head injuries per 100,000 person years as extrapolated from the 1996 farm population. This assumes that the 1996 figures approximate the average population size over the study years 1990–2000.

Table 2
Distribution of hospitalized head injuries by circumstance for three vulnerable groups on the farm

	Vulnerable group					
	Children <10		Females 10–19		Men 60+	
	N	%	*N*	%	*N*	%
Circumstances of injury						
Animal-related	57	22.4	53	68.8	43	21.0
Machine-related	67	26.4	10	13.0	76	37.1
Fall same level	8	3.1	2	2.6	20	9.8
Fall/jump from height	108	42.5	9	11.7	31	15.1
Struck by/against	11	4.3	2	2.6	31	15.1
Other/unknown	3	1.2	1	1.3	4	2.0
Total	254		77		205	
Animal-related						
Cow, calf or bull	6	10.5	2	3.8	26	60.5
Horse	50	87.7	51	96.2	15	34.9
Other/unknown animal	1	1.8	0	–	2	4.7
Total	57		53		43	
Machine-related						
Balers	0	–	0	–	3	3.9
Harvesters	7	10.4	1	10.0	12	15.8
Hay elevators/conveyers	3	4.5	0	–	4	5.3
Motor vehicles	7	10.4	1	10.0	7	9.2
Off road vehicles	8	11.9	3	30.0	2	2.6
Powered tools	1	1.5	0	–	4	5.3
Tractors	26	38.8	3	30.0	32	42.1
Trailed implements	13	19.4	2	20.0	11	14.5
Other/unknown	2	3.0	0	–	1	1.3
Total	67		10		76	

Table 3
Nature of head injury in three vulnerable groups on the farm

Nature of injury	Vulnerable group					
	Children <10		Females 10–19		Men 60+	
	N	%	*N*	%	*N*	%
All intracranial injury	125	49.2	31	40.3	105	51.2
Concussion	91	35.8	45	58.4	88	42.9
Skull fracture	38	15.0	1	1.3	12	5.9
Total	254		77		205	

Table 4
Head injury severity scores for three vulnerable groups on the farm

Injury severity	Vulnerable group					
	Children <10		Females 10–19		Men 60+	
	N	%	*N*	%	*N*	%
ICD/ISS 12+ (major trauma)						
Yes	46	21.8	7	10.4	35	19.7
No	165	78.2	60	89.6	143	80.3
Total	211		67		178	
ICD/AIS mild (1)*	65	25.6	15	19.5	45	22.0
ICD/AIS moderate (2)†	123	48.4	50	64.9	109	53.2
ICD/AIS serious (3)‡	24	9.4	5	6.5	22	10.7
ICD/AIS severe to non-survivable (4, 5, 6)δ	42	16.5	7	9.1	29	14.1
Total	254		77		205	

Examples—**Mild*: intracranial injury of other and unspecified nature without open intracranial wound with no loss of consciousness; †*Moderate*: intracranial injury of other and unspecified nature without open intracranial wound with brief (less than 1 h) loss of consciousness; ‡*Serious*: subarachnoid, subdural, and extradural hemorrhage following injury; δ*Severe*: closed fracture of base of skull with cerebral laceration and contusion.

proportion of head injuries involving cows and bulls (Table 2). Tractors were the predominant cause of machinery-related injury in all three vulnerable groups.

The leading diagnosis related to head injury among children younger than 10 years (125/254, 49.2%) and men 60 years and older (105/205, 51.2%) was intracranial injury (Table 3). The leading diagnosis for females 10–19 years was concussion (45/77, 58.4%). By severity of injury (Table 4), the majority of head injuries across the three vulnerable groups were ICD/AIS moderate, with many injuries rated ICD/AIS serious or severe. Children younger than 10 years and men 60 years of age and older had the highest proportions of ICD/AIS serious or severe injuries.

5. Discussion

The constellation of physical hazards and associated injury patterns observed on farms cannot be found in any other occupational setting. The diversity of causes of major head injury makes the planning of a unified prevention strategy difficult. For this reason, it is helpful to identify the vulnerable groups and use the injury patterns observed with each to identify factors that might contribute to head injury occurrence.

5.1. Vulnerable group 1—pediatric falls to children younger than 10 years

5.1.1. Interpretation of pattern

Consistent with other studies (Hendricks et al., 2004; Pickett et al., 2007), falls to young children were a recurrent external cause of injury leading to major head injuries on farms. Falls are a leading cause of traumatic injury in non-agricultural settings (Langlois et al., 2006), although farms contain a number of unique height-related hazards. Major external causes leading to pediatric head injury in the farm environment include falls from haylofts and other farm structures and falls from vehicles and operating machinery. The unpredictable natures of both child behavior and the farm occupational environment contribute to these events (Morrongiello et al., 2007), as does the practice of adults bringing children into the farm worksite when they are engaged in farm work (Brison et al., 2006; Morrongiello et al., 2008).

5.1.2. Prevention

In terms of protecting this vulnerable group, it is clear that farm children less than 10 years of age are exposed to many unforgiving hazards due to their ready access to the farm worksite. Children and farm worksites are both unpredictable, and this interaction has been shown to differentially affect risks for injury among the very young, especially when supervision is not continuous, proximal and attentive (Morrongiello et al., 2007, 2008). Supervision of young children by adults who are simultaneously engaged in farm chores places children at risk. This suggests a need to limit children from gaining access to the farm worksite as a primary strategy to prevent injuries in this vulnerable group. The provision of childcare away from the worksite is a second preventive need.

Classic approaches to injury prevention also include the installation of passive barriers that prevent people from being exposed to unwanted physical forces. Such approaches include strategies that minimize the impact of a force once an injury event has been initiated. In the farm context, this would include provision of fences and barriers to prevent falls, and installation of ground surfaces that cushion the impact of fall events. We are unaware of any injury control strategy that has emphasized the installation of passive safety barriers on farm worksites, save the provision of safety cages around ladders and the fencing of large animals and drowning hazards.

5.2. Vulnerable group 2—horse-related injuries to pre-adolescent and adolescent females

5.2.1. Interpretation of pattern

Injuries caused by large animals were the leading mechanism of injury observed among females aged 10–19 years. Animal-related trauma constituted approximately 70% of the head injuries experienced by this subgroup, and virtually all these injuries involved horses. The adequacy of supervision of children who are handling large animals is an important issue, especially when younger children are involved. Animals and their behavior are unpredictable, and this too contributes to the occurrence of injury events. A common feature of many recreational injuries is the inadequacy of protection to the head when the victim falls or is thrown from a moving height.

5.2.2. Prevention

Three aspects of the above pattern of injury have implications for prevention. First, it is important that young children have supervision that is appropriate to their activities. By definition, adequate child supervision requires the responsible guardian to be close, attentive, and able to provide continuous monitoring of child activities (Morrongiello et al., 2008). Second, there have been recent efforts to develop age-appropriate guidelines for the involvement of children in farm work (Lee and Marlenga, 1999) and a need for analogous child guidelines for recreational activities on farms has been suggested (Pickett et al., 2005). Third, innovative strategies are required to improve rates of helmet use associated with horse riding and other recreational farm activities. Improvements in the design and safety features of helmets may also be required. While helmet use is an obvious prevention strategy, adherence to such measures is likely to be minimal in situations that involve voluntary compliance with best practices.

5.3. Vulnerable group 3—head injuries to older male farm operators

5.3.1. Interpretation of pattern

The final vulnerable group identified in our analysis was men over the age of 60 years, and the most common causes of head injury observed were related to tractors, agricultural machinery, and blunt animal trauma. Although these represent divergent types of injury, what is common between them is that they illustrate the physical vulnerability of aging men who continue to work in a hazardous physical environment well beyond the typical age of retirement. Past reports have also implicated older machinery and farm husbandry practices as risk factors in this age group (Voaklander et al., 1999).

5.3.2. Prevention

Prevention of major head injury among older farm operators represents an obvious challenge given the diversity of hazards involved. No one strategy would be expected to impact upon a substantial majority of injury events. However, older farmers remain vulnerable due to the physical demands of their occupation and the interaction of these demands with declines in developmental function, including failing eyesight and hearing, impaired strength and slowed reaction times. Older farmers are especially at risk when they work with equipment without modern safeguards and in isolated circumstances. A rational and universal strategy towards the prevention of injury in this vulnerable subpopulation does not exist and is sorely needed. Similar to recent efforts to create evidence-based work guidelines for child workers on farms (Lee and Marlenga, 1999), work guidelines could be developed that consider developmental declines in physical function. Organizations such as *AgrAbility* (Meyer and Fetsch, 2006) have pioneered the development of standards for safe work practices among disabled farmers. Conceptually, the same process could take place in order to assist older farmers.

6. Strengths and limitations

Strengths and limitations of this analysis warrant recognition. The analysis is of value in that it profiles the occurrence of serious head injuries in the agricultural sector. This is one of the first such analyses of its kind, and our identification of and focus on vulnerable subgroups within the farm population is an original approach. Second, the analysis represents a unique application of national injury surveillance data that includes information on causes and consequences of acute head injuries on farms. Third, as part of the data collection protocol, the coding of all key variables describing the external causes of head injury were scrutinized for accuracy, and standard cleaning algorithms were applied.

With respect to limitations, although our study examined a large case series we were restricted to available data sources for patients admitted to Canadian hospitals. Information describing the nature and anatomical site of injury is not compiled routinely as part of existing mortality registries (Pickett et al., 1999). Some of our observations were also based upon administrative records collected for other purposes. Thus, details surrounding the descriptions of injury events varied by institution, and the quality of information supplied was dependent upon the vigilance of individual medical records technicians.

7. Conclusion

Through these analyses we profiled the occurrence of hospitalized head injuries sustained by agricultural populations that is unique to the occupational health and safety literature. We identified three vulnerable subgroups of farm people and offered analyses and insights surrounding the prevention of head injuries in these vulnerable groups. Given that head injuries are a leading cause of permanent disability, their prevention is paramount. Thus, there is a need for innovative interventions that focus on the specific injury patterns discussed, as well as evaluations of these same interventions. There is also a need for ongoing surveillance of these sentinel patterns of injury identified as priorities in this current analysis.

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