Summarization of Injury and Fatality Factors Involving Children and Youth in Grain Storage and Handling Incidents

S. F. Issa, W. E. Field, K. E. Hamm, Y.-H. Cheng, M. J. Roberts, S. M. Riedel

ABSTRACT. *This article summarizes data gathered on 246 documented cases of children and youth under the age of 21 involved in grain storage and handling incidents in agricultural workplaces from 1964 to 2013 in the U.S. that have been entered into the Purdue Agricultural Confined Space Incident Database. The database is the result of ongoing efforts to collect and file information on documented injuries, fatalities, and entrapments in all forms of agricultural confined spaces. While the frequency of injuries and fatalities involving children and youth in agriculture has decreased in recent years, incidents related to agricultural confined spaces, especially grain storage and handling facilities, have remained largely unchanged during the same period. Approximately 21% of all documented incidents involved children and youth (age 20 and younger), and more than 77% of all documented incidents were fatal, suggesting an under-reporting of non-fatal incidents. Findings indicate that the majority of youth incidents occurred at OSHA exempt agricultural worksites. The states reporting the most incidents were Indiana, Iowa, Nebraska, Illinois, and Minnesota. Grain transport vehicles represented a significant portion of incidents involving children under the age of 16. The overwhelming majority of victims were male, and most incidents (50%) occurred in June, October, and November. Recommendations include developing intervention strategies that target OSHA exempt farms, feedlots, and seed processing facilities; preparing engineering design and best practice standards that reduce the exposure of children and youth to agricultural confined spaces; and developing gender-specific safety resources that incorporate gender-sensitive strategies to communicate safety information to the population of young males with the greatest risk of exposure to the hazards of agricultural confined spaces.*

Keywords. *Children, Confined spaces, Engulfment, Grain entrapment, Youth.*

The hazards associated with confined spaces in production agriculture have historically been and continue to be significant causes of work-related injuries and fatalities (Beaver, 2005; Riedel and Field, 2013; Issa et al., 2014). Because there is no comprehensive or mandatory reporting system that collects data on agricultural confined-space incidents, it has been difficult to make evidence-based recommendations concerning

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the best strategies to reduce the frequency and severity of these incidents. This research gap is especially apparent with respect to incidents involving children and youth under the age of 21, who account for approximately one fifth of all documented incidents (Riedel and Field, 2013). (In this article, the terms "children" and "youth" refer to persons 1 to 20 years old. No cases were documented prior to the age of 1.)

Since 1978, Purdue University's Agricultural Safety and Health Program (PUASHP) has been documenting grain entrapment cases throughout the U.S. In total, 1028 fatal and non-fatal grain entrapment cases have been documented and entered into a national agricultural confined spaces incident database, with the earliest case dating back to 1964. The summary of cases occurring in 2010 included 59 incidents, the highest annual number of documented incidents recorded in the database (due to continued surveillance efforts, the number of originally documented cases in 2010 increased from 51 to 59), and noted the disproportionately high rate of incidents involving children and youth overall (Riedel and Field, 2011). In 2013, the number of incidents dropped to 33, of which no incidents involved a child or youth (Issa et al., 2014).

Due to increased workplace safety and health compliance efforts by the Occupational Safety and Health Administration (OSHA), targeted activities conducted by land grant institutions, and recent high-profile cases, such as the incident in Mount Carroll, Illinois, involving several young workers and intense media exposure, there has been a push for a more aggressive approach to address the problem of confined spaces in agriculture and the effect on children and youth in particular. While the historical data attest to the infrequency of these incidents relative to other causes of injuries to children and youth, public pressure and rising expectations have called for more robust workplace safety and health standards and greater emphasis on evidence-based solutions to reduce the occurrence of these incidents. However, a review of the public record indicates there has been little published literature that specifically addresses the problem of child and youth injuries and fatalities associated with agricultural confined spaces, especially with respect to grain storage and handling facilities. This article attempts to address this void by summarizing the data contained in the Purdue Agricultural Confined Space Incident Database (PACSID) that relate to incidents involving children and youth exposed to grain storage and handling facilities.

Literature Review

Workplace hazards and injuries are generally addressed by a mixture of safety education, best practices, engineering standards, and workplace safety and health regulations. For example, the problem of tractor overturns, the leading cause of farm-related fatalities, has led to a broad-based response involving more aggressive data collection, development of educational programs, drafting of new engineering standards (including the recommendation to install rollover protective structures), and attempts to regulate the age of operators. These efforts have begun to have an effect on the frequency and severity of this type of incident. This section summarizes prior efforts to address the problem of youth-related injuries and fatalities in agricultural confined spaces.

Education

Some of the earliest documented efforts to raise awareness of the risks to children and youth from exposure to grain storage and handling facilities were Extension publications and fliers that included specific warnings concerning the risks to children exposed to free-

flowing grain (McKenzie, 1969). In 1969, McKenzie released an educational slide presentation on the hazards of flowing grain and addressed the risks to children. The resource was revised in 1978 and distributed nationally (Field and McKenzie, 1978). This was followed by an Extension outreach project conducted by PUASHP in conjunction with the *Indiana Prairie Farmer* magazine, Brock Manufacturing, Meridian Insurance Company, and the Indiana Rural Safety and Health Council. This effort involved the placement of 15,000 to 18,000 flowing grain warning decals on grain storage and transport vehicles throughout Indiana during the mid-1980s. This effort also resulted in the development of a grain handling safety curriculum that was distributed to all (1250) secondary agricultural education teachers in Indiana, Ohio, Michigan, and Kentucky. Aherin and Schultz (1981), at the University of Minnesota, produced an educational module that included a slide set with a script. The module was distributed extensively throughout the U.S. and Canada. A portion of the materials focused on entrapment issues related to youth in bins and gravity wagons. Similarly, Schwab et al. (1997) produced a curriculum that teaches grain safety (particularly grain entrapments) through science and math lessons that targets secondary students.

Later efforts include those conducted by Farm Safety 4 Just Kids, an organization that was founded after Keith Adams, the founder's son, suffocated in a grain transport vehicle (GTV) (Adams, 1997). The organization developed safety decals for installation on GTVs and related educational resources for distribution throughout North America. The organization recommended that GTVs be retrofitted with childproof guards and that warnings be installed on all grain storage structures (Adams, 1997). These efforts led to wide distribution of educational material on the danger of grain entrapments for children and youth. A review of current farm safety curricula targeting children and youth found that nearly all contain a component on agricultural confined spaces (Tormoehlen and Field, 2004).

The National Institute for Occupational Safety and Health (NIOSH), part of the U.S. Centers for Disease Control and Prevention, has awarded grants to fund research with the intent of elucidating causative factors and finding solutions to reduce the frequency of agricultural injuries. This included support of the National Children's Center for Rural and Agricultural Health and Safety, which published the North American Guidelines for Children's Agricultural Tasks (NAGCAT). The NAGCAT are recommended guidelines for farm families to follow voluntarily in deciding which jobs should be assigned to their children and at what age (MCRF, 2013). These guidelines include specific recommendations concerning exposure to agricultural confined spaces.

With support from OSHA Susan Harwood Training Grants, at least two curriculum projects are in process to develop training materials for young and beginning workers in the grain industry (Field et al., 2014; Rylatt et al., 2014). In addition, a position statement for youth working in the grain industry has been developed (Rylatt and Salzwedel, 2014).

However, questions have been raised regarding whether educational materials and raising awareness in general are enough to prevent youth injuries. Zentner et al. (2005) discussed how farm parents generally acknowledged that more dangers are involved in farming than in other occupations but did not translate that perceived danger into a higher risk of injury or the need to take precautions with youth involved in agriculture. In particular, the study findings revealed that perceived dangers did not result in a high number of farm parents adhering to NAGCAT recommendations and suggested that voluntary guidelines may be insufficient to change the perception of hazards among farm families. Similarly, in a study of 334 farm-related childhood incidents, Morrongiello et al. (2008) found that adult supervision, defined with characteristics of attention, proximity, and continuity, did not

lower but actually increased the rate of injury or fatality among youth. These findings suggest that education and awareness alone might not be sufficient in addressing agricultural incidents in grain bins and GTVs, and other strategies might be needed.

Regulations

Currently, two sets of regulations cover some aspects of youth employment in agricultural operations involving confined spaces. The first set is the Agricultural Hazardous Occupations Order (AgHOs), which was written in 1968 as part of the Fair Labor Standards Act of 1938. Under the provisions of the AgHOs, persons younger than 16 cannot be employed in agricultural production where they would be assigned to enter agricultural confined spaces, including vertical silos, bunk silos, manure pits, and environmental controlled fruit storage areas. Once a youth reaches the age of 16, there are no restrictions concerning farm-related employment under the provisions of the Fair Labor Standards Act. In all other occupations declared by the Secretary of Labor to be particularly hazardous, workers are required to be at least 18 prior to employment (29 CFR 570.2: Minimum age standards). However, the minimum age requirement exempts the employment by a parent of his own child. As noted above, accessing certain spaces on farms has been found to be particularly hazardous.

The second set of relevant regulations is under the provisions of the current OSHA workplace safety and health standards (29 CFR 1910.146: Permit-required confined spaces, and 29 CFR 1910.272: Grain handling facilities) that require workers to be at least 18 years old before being assigned to work in a permit-required confined space, including certain grain storage structures (OSHA, 1993, 2002). In commercial grain operations not exempt from the OSHA standards, the OSHA standards have been interpreted such that it is unacceptable to allow workers younger than 18 to access clearly defined confined spaces as well as grain storage bins, silos, or tanks that may not, for political reasons, be defined as confined spaces.

Due to political pressures when these regulations were being drafted and the cost of implementation, the AgHOs do not apply to the children of farm owners, who are exempt from compliance. In addition, the OSHA regulations do not generally apply to exempt facilities, such as farms, feedlots, and seed processing operations. This means that a farmer can employ a youth at 16 years of age to help empty residual grain from a bin while commercial grain storage facilities can only hire those older than 18. This also means that no current state or federal regulations prohibit those younger than 18 from working inside an agricultural confined space, including a grain storage facility, as long as it is owned by the worker's parent or guardian. It is important to note that there is some confusion over the current interpretation of the agricultural workplace exemption language found in 29 CFR 1910.146 and 29 CFR 1910.272. Also of note, while federal funds cannot be used to carry out compliance or enforcement efforts on exempt agricultural workplaces (due to a funding restriction placed by the U.S. Congress on the Department of Labor's authorization language), some states provide non-federal sources of funding to enforce the standards on some exempt farms. In some cases, the actions of both the parents and employers of underage workers injured while performing particularly hazardous tasks have been adequate justification for pursuit of child neglect or abuse claims or raised as evidence in civil litigation.

The lack of regulations for farm children younger than 16 and for farm employees between the ages of 16 and 18 may contribute to the overall higher injury rates for young

workers. Marlenga et al. (2007) looked at 286 cases of child and youth injury in agriculture and found that 33% involved youth age 15 and younger performing tasks that were prohibited by the AgHOs, and 36% involved youth ages 16 and 17. In their conclusion, the researchers advised that removing the exemption for farms and farm children could "prevent one-third of work-related injuries sustained by children." Although not stated, it was assumed some of the cases analyzed in that study involved grain storage and handling facilities. In addition, exempt youth accounted for the largest proportion of children and youth who were fatally injured inside these spaces (Riedel and Field, 2013).

Although various sources have recommended expanding the regulatory reach of the AgHOs to enhance the protection of children and youth employed in agriculture, little has been accomplished to update the regulations. Efforts in 2011 to strengthen the AgHOs would have significantly reduced access to confined spaces in agriculture for those younger than 18, and initial consideration was given to raising the minimum age for such employment to 21. However, those proposed rule changes were met with substantial resistance from the agricultural community and were eventually withdrawn by the U.S. Department of Labor. Finally, it is interesting to note that the AgHOs do not specifically mention grain bins that are not designed as oxygen limiting. This exclusion is most likely due to the limited use of grain storage bins, the infrequency of incidents in the mid-1960s when the rules were drafted, and the lack of subsequent revisions.

Engineering Standards

A review of current applicable engineering standards that target children and youth found none that addresses the safety of this workforce in and around agricultural confined spaces. Recommendations were found that encouraged making external ladders on some confined spaces inaccessible to children and ensuring that openings or access points are adequately covered. Even the long-standing recommendation to provide appropriate warnings regarding children on grain storage and handling facilities, including GTVs, has not made its way into engineering standards. Currently, ASABE is developing an engineering standard for steel grain storage bins. One of the motivations behind the standard is to reduce access to the structure, thereby reducing the frequency of entrapment.

High-Profile Cases

Case studies involving children and youth fatally or severely injured while working in grain storage and handling facilities are common in the literature. The following examples occurred at both commercial facilities and OSHA exempt family farms.

Case 1

In 1999, a 15-year-old boy, who had taken an agricultural safety class (AgHOs certification) two years previously at the age of 13 and was certified to begin farm employment when he turned 14, entered a grain bin on his family's farm to clear the door and install a sweep auger while two farmer relatives were loading corn. Between trips to town, the older family members lost track of the boy and realized that neither had seen him since he had entered the bin. They located the boy fully engulfed inside the bin and were able to extricate him from the grain, call emergency responders, and administer CPR. They were not successful in reviving the boy. Despite the safety class, background, family history, and supervision, he had become entrapped beneath flowing grain and died of suffocation (CDC, 2000).

Case 2

In May 2009, a 17-year-old male was assigned to enter a steel storage bin to help unload grain at a commercial grain operation in Haswell, Colorado. While removing residual grain, he became engulfed in the flow and was fatally crushed. OSHA's investigation into the youth's death revealed he was among several teenage workers who were exposed to the same hazards at the operation but had not been trained properly or made aware of an emergency action plan (U.S. Attorney's Office, 2011).

Case 3

In July 2010, in Mount Carroll, Illinois, four youth, ages 14, 14, 19, and 20, were sent into a grain bin to remove crusted residual out-of-condition grain from the walls while the unloading auger was running. This practice, known as "walking down the grain," is illegal under federal law. As the crust was broken up, the grain began to flow and within seconds entrapped three of the workers. Two became completely engulfed and suffocated, while the third was rescued after nearly six hours of effort. The operation was charged with 12 willful and 12 serious violations of OSHA regulations (USDOL, 2011).

Case 4

In August 2011, a 17-year-old male became entangled in a grain auger inside a flat-bottom storage structure that was being emptied at a commercial operation in Kremlin, Oklahoma. A co-worker, also 17, tried to assist the entrapped youth and became entangled in the same auger. Emergency responders had to extricate both workers from the inadequately guarded auger, and each remained in critical condition for days (Stein, 2011). Both teenagers suffered leg amputations, among other injuries (Monforton, 2012).

Case 5

In March 2012, an Indiana fourth-grader died of asphyxiation after a ten-foot pile of cornmeal collapsed on top of him. The boy was playing on his parent's farm and had embedded himself in the pile of cornmeal when it suddenly collapsed around him and suffocated him.

Methods

Data Collection

Data were collected in a variety of ways, including online searches, subscription to news clipping services, NIOSH Fatality Assessment and Control Evaluation (FACE) reports, media reports, police reports, state summaries of farm-related fatalities, first-hand interviews, litigation documents, and prior research reports. Relevant cases collected during the course of this study, but not previously recorded or summarized, were also entered. Voluntarily reported case data were also obtained by members of the PUASHP staff through personal communication at various gatherings, such as professional safety meetings and conferences (e.g., ASABE and ISASH), National FFA conventions, trade shows (e.g., National Farm Machinery Show and Farm Progress Show), and county extension meetings. Information was also gathered from other parties interested in agricultural health and safety (i.e., Great Plains Center for Agricultural Health, land grant universities, and state departments of health) to cross-reference data in the PACSID. Two independent third parties were also employed to conduct a comparable search for cases reported during selected periods for comparison with previously documented cases.

There is no claim that the PACSID is comprehensive, as noted by the number of previously unidentified cases that were documented during the course of the study. In addition, the data clearly suggest that non-fatal incidents and certain types of agricultural confined space incidents, such as those involving tower silos, are severely under-reported.

Data Management

Since 1978, PUASHP has managed a database in an ongoing effort to collect and file information on documented injuries, fatalities, and entrapments in all forms of agricultural confined spaces. The primary focus of the early data collection effort was incidents involving flowing agricultural materials (FAM), primarily grain. The effort evolved from stacks of 5×7 index cards to several computer-based data management systems. The data were eventually entered into the Farm Accident Data Coding Sheet Classification System developed by Purschwitz (1989) and later incorporated the work of Kelley and Field (1996), Kingman et al. (2001), Beaver (2005), Roberts et al. (2011), and Riedel and Field (2013) and became the PACSID. At the time of this article's preparation, the PACSID contained information on 1654 cases (some incidents have multiple victims) from 1964 to the present, the majority of which involve grain storage, manure storage, or GTVs. The earliest recorded case actually occurred in 1956, and two other cases occurred before 1964. However, starting in 1964, incidents were reported every year.

The database uses Microsoft Access to categorize and allow query of all forms of documented agricultural confined space incidents. The database was modified in 2010-2011 with support from an OSHA Susan Harwood Training Grant to include a broader spectrum of incidents involving agricultural confined spaces, including entrapments, engulfments, asphyxiations, entanglements, falls, and electrocutions. If required, earlier entries were recoded as more data became available for assigning a category or type of confined space incident. In cases where there were coding difficulties, a panel of subject matter experts assisted in interpreting the data. In many cases, efforts were made to corroborate case information by using more than one source, including local emergency first responders and law enforcement agencies. Cases based on hearsay that could not be confirmed with an external source were not included in the database.

Riedel and Field (2013) summarized the confined space cases included in the PACSID from 1964 to 2010 to estimate the frequency, severity, and primary causative factors of injuries, fatalities, and entrapments in all forms of agricultural confined spaces. Data on additional incidents occurring in 2011-2013, along with earlier incidents not previously documented, were added to the database, forming the database used for this article. This article specifically summarizes data gathered on the 246 documented cases of youth age 20 and younger involved in grain entrapment or engulfment cases that have been entered into the database. These cases represent approximately 15% of all confined space cases documented in the database.

Data Analysis

Several key parameters in the PACSID data used in this analysis are age, gender, state, month, year, farm type, fatality vs. non-fatality, and agent of injury. Based on the presentation of the data, incidents for each age are shown separately, categorized into five-year increments, ten-year increments, or into youth (ages 1-20) and adult (ages 21-90) categories. The upper threshold age of 20 was selected to understand the grain entrapment risks as youth transition into adult workers. In other words, the study attempted to focus on young and beginning workers in order to develop a new evidence-based safety curriculum.

The OSHA exemption status was based on the farm type listed in the PACSID. If the site was a grain elevator, commercial facility, or non-farm facility, then the exemption status was identified as OSHA non-exempt. If the incident occurred at a farm (ranch, cash grain farm, etc.), then the exemption status was identified as OSHA exempt. All remaining cases were given an exemption status of unknown. The category of the incident (GTV or bin/silo) was based on the "agent of injury" input parameter. Regression analysis was conducted for the 1-20 and 21-90 age groups to determine grain entrapment trends. The regression curve was based on year (independent) and number of incidents (dependent).

Results

Summary of All Agricultural Confined Space Incidents

The PACSID currently contains data on 1654 cases involving individuals who were injured or killed due to an exposure with an agricultural confined space. A summary of these incidents has been reported by Riedel and Field (2013) and Issa et al. (2014). Currently, there are 352 cases involving youth age 20 and younger. Of these 352 cases, 246 (70%) involved grain entrapment or engulfment.

Role of Age, Status, and Gender in Grain-Related Incident Distribution

In the last 48 years (1964-2013), 1028 grain entrapment and engulfment cases were documented and recorded in the PACSID. Of these, 703 cases, approximately 70% of all reported cases, resulted in a fatality. These cases are nearly equally distributed across age groups (1-80 years old), with the exception of incidents involving the 11-20 age group, which accounted for almost 18% with an 80% fatality rate (fig. 1). The 51-60 and 41-50 age groups have the second and third largest numbers of incidents, respectively. The percentage of fatal versus non-fatal incidents for each age group ranges from 60% to 80%. The 11-20 and 21-30 age groups have the highest fatality rates (80%), while the 81-90 age group has the lowest (60%). Focusing on the 1-20 age group, the 10-14 age range, which corresponds to school grades three to eight, experienced the largest number of incidents (fig. 2). Looking at a three-year rolling average, the largest percentage of fatal to non-fatal occurred in the 15-17 (90%) and 16-18 (91%) age groups. For 160 cases, the exact age of the person was unknown; these cases represent 34 fatalities and 126 non-fatalities.

With regard to current OSHA regulations, 297 of all documented cases occurred at OSHA non-exempt facilities, 335 cases occurred at OSHA exempt facilities, and the remaining cases (396) had unknown exemption status (it is believed that the majority of the unknown cases occurred at OSHA exempt operations). The majority (77% of cases) of incidents at OSHA non-exempt facilities occurred to individuals between ages 21 and 60, while the majority (70% of cases) of exempt facility incidents occurred to individuals between ages 1 and 20 and between ages 51 and 80 (fig. 3). OSHA exempt cases represent incidents that occurred on farms and feedlots. OSHA non-exempt facilities include commercial facilities and grain elevators. Cases with unknown exemption status were not included.

Cases with unknown exemption status were equally distributed across the age groups

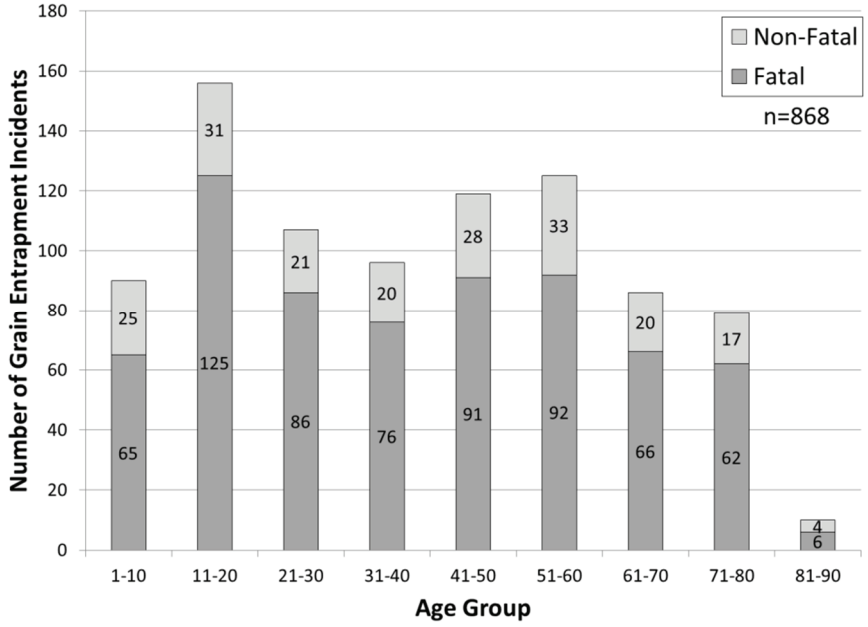

Figure 1. Age distribution of documented grain entrapments from 1964 to 2013. Only cases for which age is known are listed. The exact age of the person was unknown for an additional 160 cases, and these cases represent 34 fatalities and 126 non-fatalities.

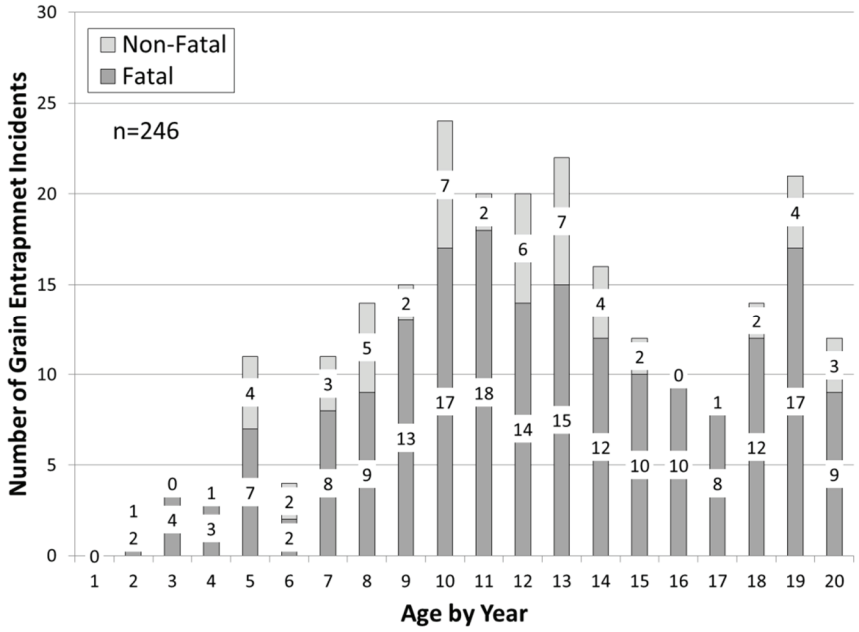

Figure 2. Age distribution of documented grain entrapments from 1964 to 2013 for ages 1 to 20.

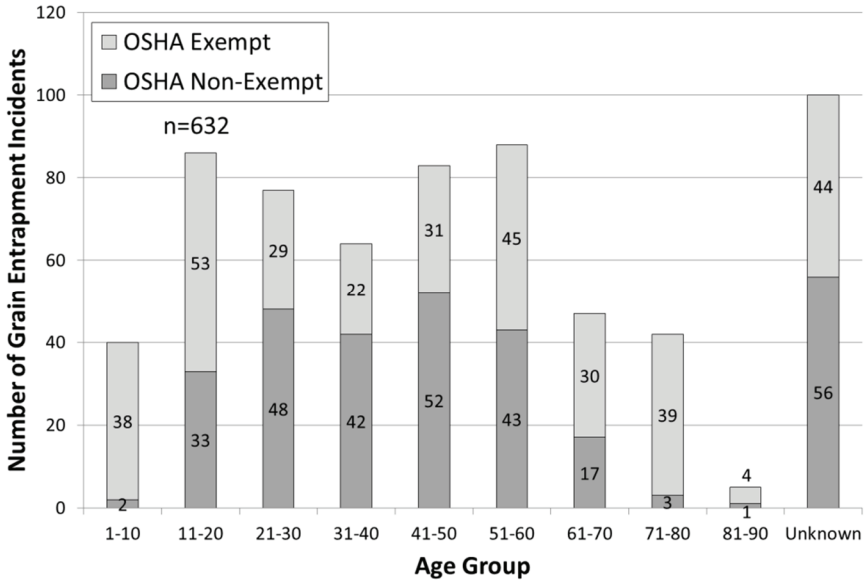

Figure 3. Age distribution of grain entrapments by exempt vs. non-exempt operation from 1964 to 2013.

and usually represented 30% to 50% (with a mean of 40%) of the cases for each particular age group (data not shown). A review of incidents for those between 1 to 20 years old (fig. 4) reveals that the majority of the cases (86%) for ages 2 to 16 occurred at exempt facilities, while the majority (65%) of the cases for ages 17 to 20 occurred at non-exempt facilities.

The vast majority of documented cases (986, or 96%) involved males. There were 29 reported cases involving females, and 13 cases where the gender was unknown. While the male incidents could be generally described as equally distributed, the female incident distribution was significantly higher in the first two age periods (fig. 5). More than 51% of the female incidents occurred to children younger than 15, compared to about 17% for the male incidents. Moreover, while overall female incidents account for only 3% of the total incidents, females represent approximately 11% for ages 1 to 10. Lastly, while 68% of all male incidents involved a fatality, only 62% of female cases resulted in fatality.

Role of Age Distribution in Type of Agent

Most entrapment cases occurred in grain bins or silos, accounting for a total of 794 (77%) cases. GTVs, including wagons, trucks, rail cars, and all other transport vehicles, accounted for 120 cases, and the remaining 114 cases involved entanglements in equipment or engulfment in open piles of grain or other grain storage locations. The majority of GTV entrapments involved children and young adults ages 1 to 20 (fig. 6). Kelley and Field (1996) found that the typical victim of a GTV entrapment was male and 11 years old. Similarly, in this study, the average age for these incidents was found to be approximately 17, in comparison to 42 for grain bin incidents. On the other hand, grain bin and silo incidents were spread over the age range and primarily occurred to ages 11 to 80 (fig. 7). Most of the GTV cases for ages above 20 occurred in rail cars and tractor trailers.

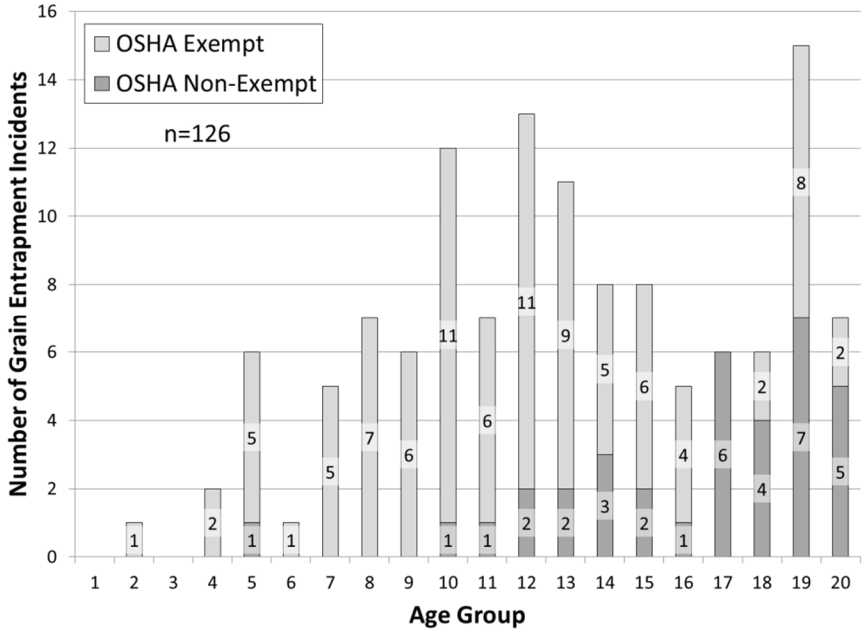

Figure 4. Age distribution of grain entrapments by exempt vs. non-exempt operation from 1964 to 2013 for ages 1 to 20.

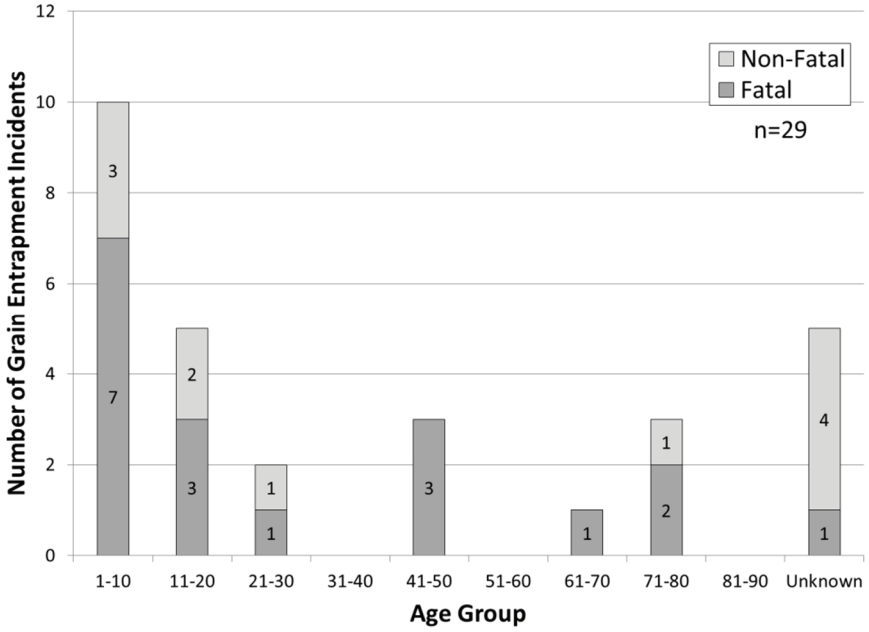

Figure 5. Age distribution of grain entrapments from 1964 to 2013 for females.

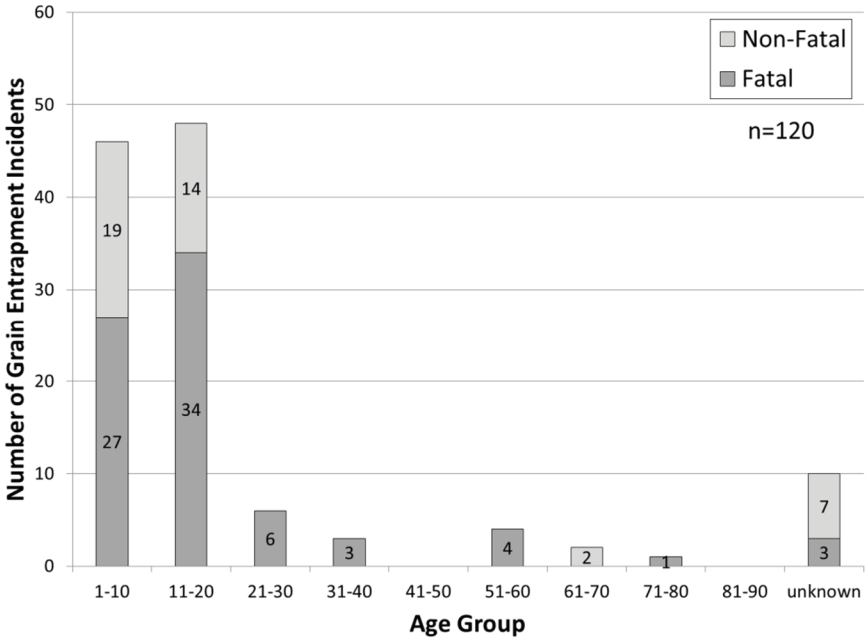

Figure 6. Age distribution of grain entrapments from 1964 to 2013 involving grain transport vehicles.

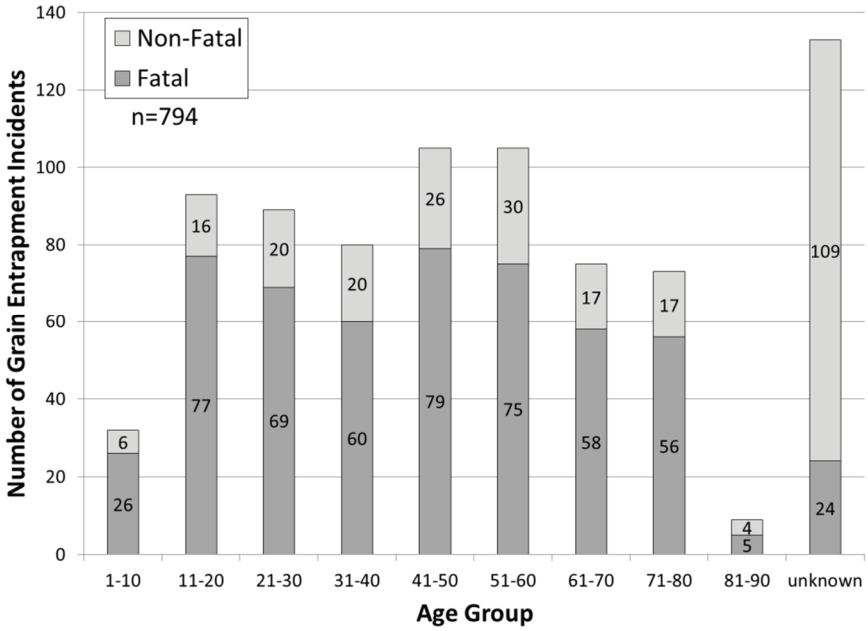

Figure 7. Age distribution of grain entrapments from 1964 to 2013 involving grain bins and silos.

For the youngest age group (1-10), GTVs represented the majority (51%) of the incidents. Within this age group, grain bins still played a major role in 36% of the incidents. In the 11-20 age group, GTVs still represented a major cause of death, with 31% of the fatalities; however, grain bins were involved in the majority (59%) of these incidents (fig. 8). In subsequent age groups, grain bins represented the vast majority of cases (86% to 90%), and GTVs made up a small minority of cases (0% to 3%). All other agents consistently represented about 10% of the cases regardless of the age group.

Age Distribution of Incidents over the Years

From 1964 to 1985, case numbers for children and young adults (ages 1 to 20) were not significantly different ($p = 0.46$) from adult case numbers (ages 21 to 90). Since then, adult case numbers have increased dramatically, while young adult cases have remained relatively consistent, decreasing slightly from their peak in the late 1980s (fig. 9). Reported cases for adults continued to increase when summarized using a five-year average. The five-year average was highest in 2010 and 2011 at 24.8 cases. Note that the five-year average does include cases for which age is unknown. In comparison, incidents involving children and young adults peaked in 1990, at 9.6 incidents per year, and then decreased to stabilize around 4 to 5 incidents per year.

While incidents involving children and young adults remained relatively flat compared to adults, there has been a significant change in the age makeup of this group. Focusing only on children and young adults (ages 1 to 20) in the first two decades of the data, a total of 87 youth cases, incidents involving those 1 to 10 years old, represented 43% (37) of the youth cases, and the 11-20 age group was involved in 57% (50) of youth cases. In the last 20 years, incidents involving the 1-10 age group represented 28% (23) of youth cases, while the 11-20 age group represented 72% (60) of youth cases (figs. 10 and 11).

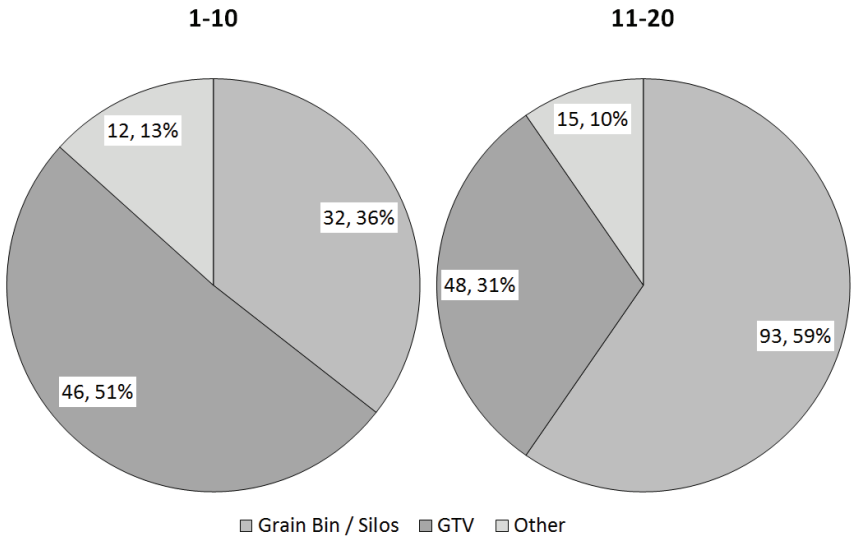

Figure 8. Distribution of grain entrapment incidents by age group. Numbers inside the pie charts represent the number of incidents and the percentage of distribution.

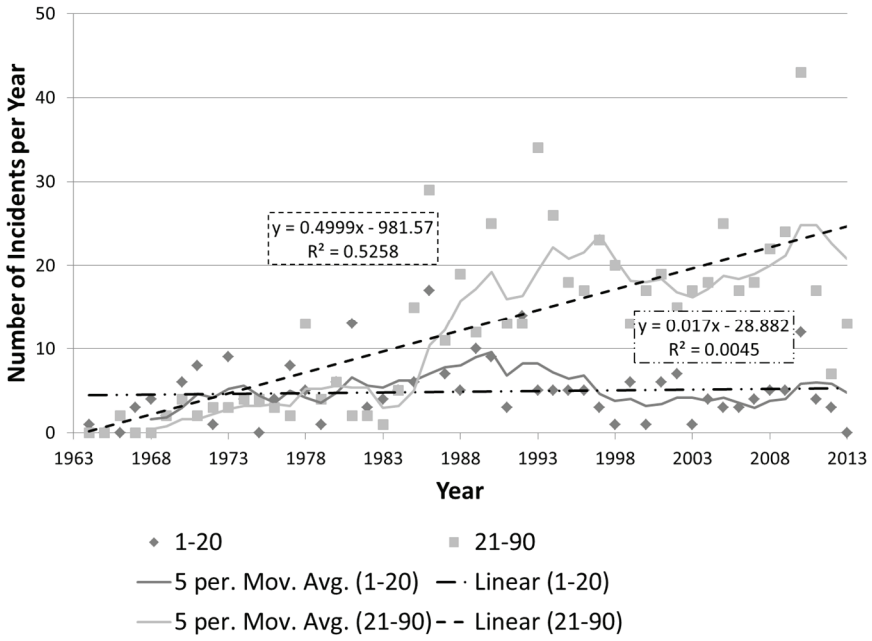

Figure 9. Distribution of grain entrapment incidents over the years by age group. The lines following each set of data points represent the five-year moving average.

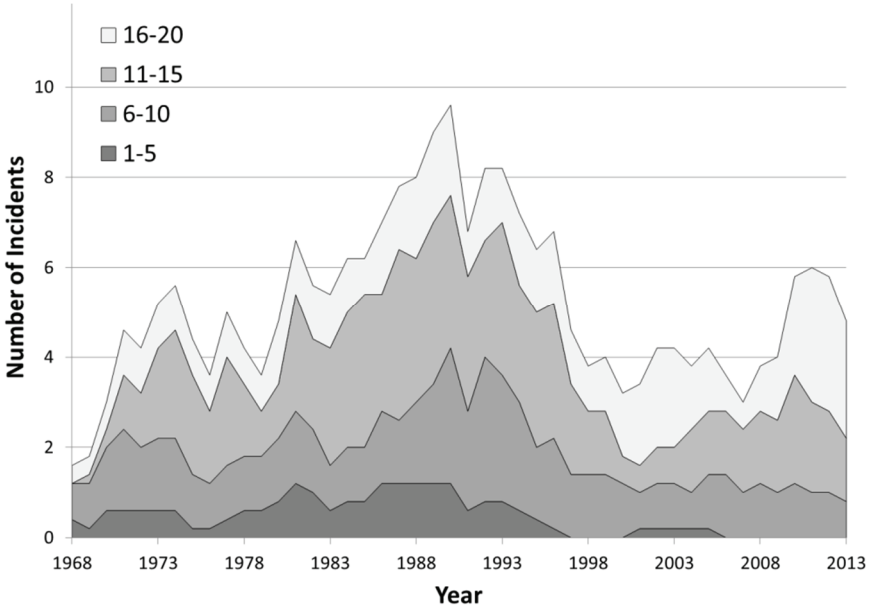

Figure 10. Distribution of grain entrapment incidents over the years by age group for ages 1 to 20. The filled area represents data for the 16-20 age group. The data points represent the five-year moving average of the actual data.

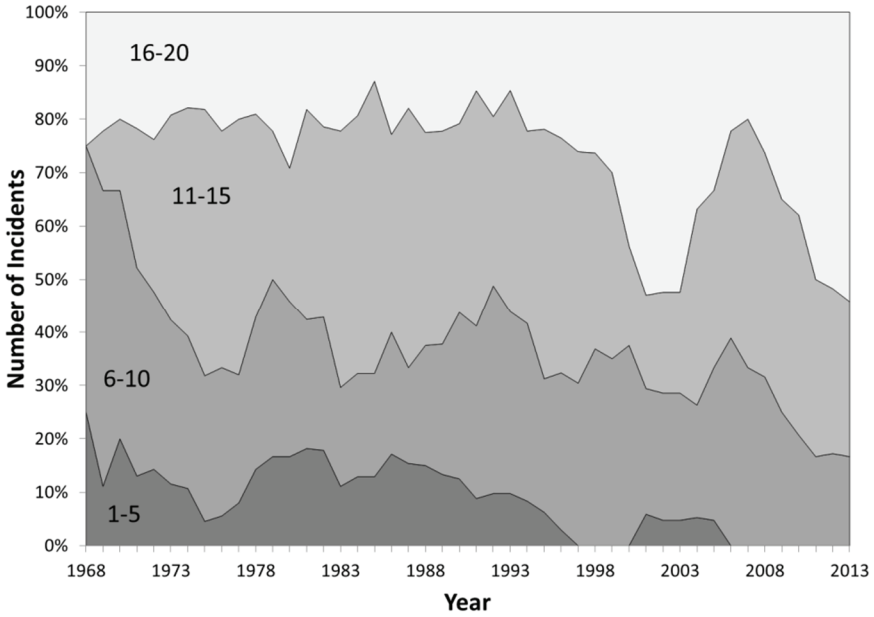

Figure 11. Distribution of grain entrapment incidents over the years by age group for ages 1 to 20. The filled area represents data for the 16-20 age group. The data points represent the five-year moving average of the actual data.

The drop was most significant for the 1-5 age group, which dropped from 13% (11) to 1% (1). The 1-5 age group experienced a significant ($p < 0.01$) decrease in incidents from 0.44 per year (first ten years) to 0.04 per year (last ten years). The 6-10 age group experienced an insignificant decrease from 1.3 to 1.06 incidents per year, and the 11-15 age group experienced an insignificant increase from 1.36 to 1.64 incidents per year. At the same time, the 16-20 age group increased in percentage of cases from 21% (17) to 41% (34). The 16-20 age group was the only age group to experience a significant ($p < 0.01$) increase in the number of cases from the initial documented years to recent years. For this age group, the five-year average for incidents per year increased from 0.8 (first ten years) to 1.7 (last ten years).

Age Distribution of Incidents over the Month and Geography

For the 1-20 age group, approximately 50% of all entrapment cases occurred in June, October, and November (117 of 246 cases; fig. 12). On the other hand, entrapment cases for adults occurred year round, with January, March, and October having the largest numbers of documented incidents. The geographic distribution of child and young adult cases was similar to the distribution of adult cases (fig. 13). One major difference was that the frequency of incidents involving youth was higher in Indiana compared to the adult group, which was more focused on the entire Corn Belt. A possible reason for this higher rate in Indiana is that PUASHP has been more aggressive in documenting both fatal and non-fatal incidents involving grain storage and handling over the past 30 years. This finding further supports the position that non-fatal incidents involving children and youth are significantly under-reported in the PACSID, especially in the Corn Belt.

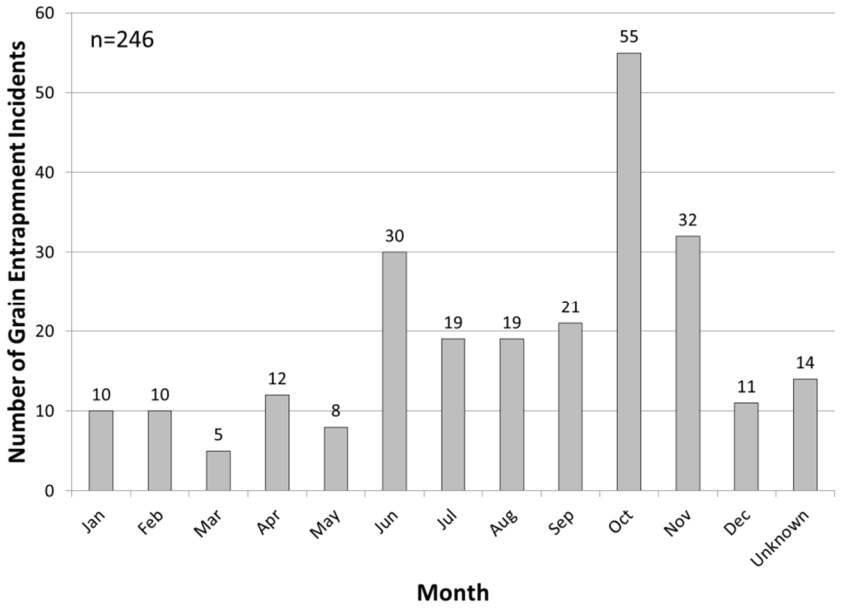

Figure 12. Total number of grain entrapment incidents by month from 1964 to 2013 for ages 1 to 20.

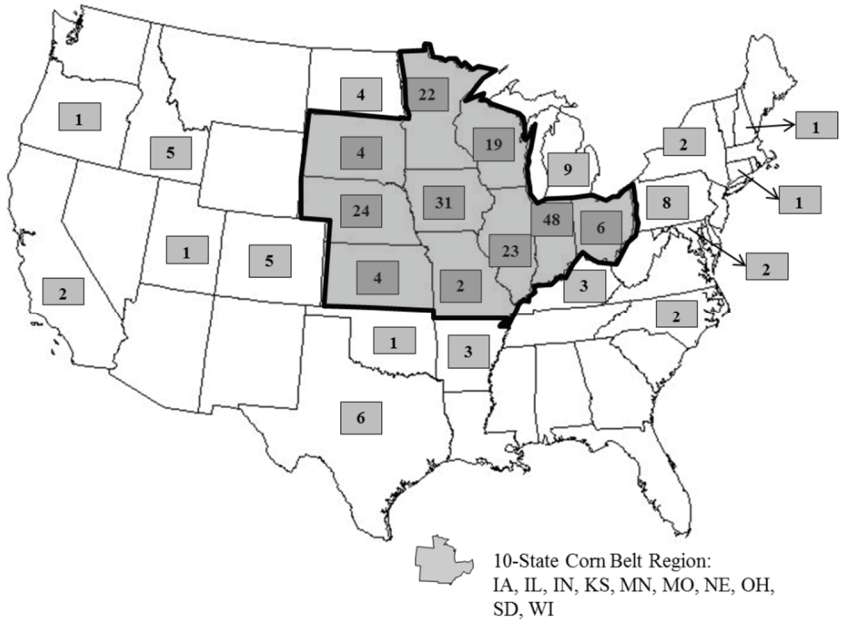

Figure 13. Geographic distribution of grain entrapment incidents (1964-2013) for ages 1 to 20.

Discussion

The growing awareness and safety campaigns regarding farm safety, and agricultural confined spaces in particular, do not yet appear to have impacted the number of adult incidents, since these incidents have continued to increase over time. Meanwhile, the number of incidents involving children and young adults has remained constant since the late 1990s (fig. 9), even though the number of bins on farms and the volume of grain in storage has continued to rise (USDA, 2014). There has also been a significant shift in the average age of youth involved in incidents; initially, ages 1 to 10 represented 40% to 60% of cases, while they now represent less than 20% of cases (fig. 11). For the older documented cases, those involving children represented about 50% to 60% of overall incident reports, but cases involving children now represent about 15% to 20% of overall incident reports. This shift is most likely due to increased awareness efforts that have targeted young farm children, as there was a large increase in total incidents occurring after 1985 but no corresponding increase of incidents involving children and youth. Furthermore, since cases involving youth are usually more visible, data collection for these incidents may reflect the number of cases more accurately. However, it is important to note that a lack of decrease in the overall number of youth cases is in sharp contrast to the study by Hendricks and Hendricks (2010), who found a significant decrease in the estimated number and rate of injuries for all youth living on farms. They also reported a decline in injury rates for non-farm youth in general (Hendricks and Hendricks, 2010).

Another contributing factor that may influence the frequency of incidents is the growth in the capacity of on-farm storage structures. While a 50,000 bushel bin was once considered large, it is now common to see bins of 100,000 to 300,000 bushel capacity installed on farms. These larger bins are more difficult to access and more likely to be off limits to younger family members.

Overall, incidents involving children and young adults under the age of 21 accounted for 24% of all grain entrapment cases documented in the database (fig. 1). A spike in the number of incidents by age was noted at age 10 and continued until age 14 (fig. 2), when there was an overall drop in the number of incidents. This corresponds to the time when young adults enter high school (ages 15 to 17) and may be due to the more significant social and academic pressures that high school places on their lives. However, the 15-18 age group had the highest fatality rate of any age group (90%).

One observation that appears especially relevant is the assignment of works tasks to youth that are suitable relative to an individual's size but less suitable with respect to an individual's experience and training. In numerous cases, younger workers were assigned to enter a confined space because they were more physically able to reach the access point or enter it. On most older bins, the access hatch on the roof is 61 cm (24 in.) in diameter. Based on recent participation in grain safety classes, this narrow size makes entry by many adults difficult or impossible due to their waist and shoulder dimensions, especially with bulky clothing. Consequently, the task of bin entry is assigned to a smaller, often younger, worker who can fit through the opening.

Related to this observation is the assignment of hazardous tasks inside grain storage structures based on seniority. Older, more experienced workers are more reluctant to perform in-bin tasks, which are then allocated to younger, less experienced workers.

Other general observations include:

- Incidents at OSHA exempt sites dominate until age 16.

- GTVs represent a significant portion of the incidents involving younger children.
- The frequency of incidents involving females is not significant (3%) but represents about 10% of youth ages 1 to 10.
- October and November are the months with the largest numbers of incidents involving persons age 20 and younger.

Gender Discrepancy

With males representing over 96% of all grain entrapment cases, while also representing 79% of all crop workers (NAWS, 2004), it became apparent that there is a need to address this gender discrepancy. Due to the extreme differences between gender involvements in agricultural confined spaces, consideration was given to potential causative factors. Research has described the tendency of girls to explore and evaluate risk through vision, while boys touch and retrieve (Vogel et al., 2003). Boys are more active and open to taking risks: "boys are more likely than girls to believe they will not get hurt when engaging in injury-risk behaviors, to rate the potential injury severity as low, and to attribute actual injury outcomes to bad luck as opposed to their own behaviors" (Morrongiello and Dawber, 1998). Societal and parental assumptions also affect injury rates. One study commented on the gender difference in task assignment, noting that higher rates of injury for girls related to animals, while higher rates of injury for boys related to machine operation (McCurdy and Carroll, 2000). Another study suggested that this trend of social role distribution of assignments between girls and boys is decreasing (Hendricks and Hendricks, 2010), which was not supported by this study.

The increase in the number of women engaged in agricultural production and related occupations reported in the 2007 Census of Agriculture and National FFA membership (USDA, 2009; FFA, 2012) has not affected the gender distribution of farm-related injuries and fatalities. Even though females are increasingly more involved in agriculture, there has not been a corresponding increase in entrapments, indicating that women are less likely to be in direct contact with grain storage and handling facilities regardless of age group. The need to develop more gender-specific safety resources for agricultural confined spaces appears justified.

Conclusions

Historically, there has been limited ability to evaluate the efficacy of evidence-based intervention initiatives related to incidents involving agricultural confined spaces, such as education, engineering, or regulation. Safety measures that usually work for other fields involving children may not be the best strategy within the farming ethos, especially on current OSHA exempt farms, feedlots, and seed processing operations.

We recommend a response strategy of continued safety education and promotion of best workplace practices to reduce the level of exposure that children and youth have to all agricultural confined spaces in order to decrease the high number of injuries and fatalities. More work should be done to teach children and parents about the dangers of playing or working around grain storage and handling facilities. Engineering standards and practices should enhance the safety of facilities and equipment that incorporate confined spaces, including an emphasis on access and egress points, warning labels, and a reduction of the need to enter a grain storage structure, especially to remove residual grain. Additional research is needed to explore the role that access opening dimensions have on the assignment

of younger workers to perform tasks inside grain storage structures. Finally, due to the overwhelming majority of confined space related incidents involving young males, gender-specific safety resources should be developed that use gender-sensitive strategies to communicate safety information to the high-risk population of males with potential exposure to agricultural confined spaces.

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