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Narrative text analysis of Kentucky tractor fatality reports☆

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Abstract

Narrative information in fatality investigation reports contains data elements not routinely analyzed with coded occupational injury surveillance data. A narrative text analysis of 69 Kentucky Fatality Assessment and Control Evaluation (FACE) agricultural tractor fatality reports from 1994 to 2004 was performed. The FACE reports were developed using the National Institute for Occupational Safety and Health, Division of Safety Research-recommended FACE report format that incorporates Haddon's matrix. Haddon's matrix separates the fatal incident into three event phases and is used to develop points of intervention based on human, organizational, and environmental factors. A multivariate logistic regression analysis for association between identified exposure variables and the outcomes of interest was undertaken. The operation of a tractor with an attached bucket, muddy terrain, and being thrown from the tractor were independent risk factors for being declared "dead at the scene". A tractor rollover and operation of a tractor on a slope were independent risk factors for being "crushed" by a tractor. Narrative text analysis of FACE fatality investigation reports is a valuable tool for the identification of additional factors contributing to tractor fatalities that can inform farm safety training, identify new areas for agricultural interventions, and support the development of new agricultural engineering strategies.

Keywords: Tractor; Overturn; Fatality reports; Narrative; Text analysis

1. Introduction

In 2005, the agriculture industry and related occupations had the highest worker fatality rates of all private industries (32.5 worker fatalities per 100,000 agricultural industry workers and 73.1 farmer fatalities per 100,000 workers, respectively) in the US (Bureau of Labor Statistics, 2005). In comparison, the occupational fatality rate for the Kentucky agricultural, forestry, and fishing industry was 44% higher than the national rate (46 deaths per 100,000 workers) and over three times higher for farming occupations (243.9 deaths per 100,000 workers) in 2005 (Kentucky Fatality Assessment and Control Evaluation (FACE) Program data). Fatal agricultural injuries were the leading cause of all worker deaths (22%) in Kentucky from 1994 to 2005 and the majority were due to agricultural machinery. Farm tractors were involved in 48% ($n = 167$) of the fatalities. Previous studies have shown that tractor rollovers are associated with the victim being crushed by the tractor (Centers for Disease Control and Prevention (CDC), 1993; Goodman et al., 1985; Hansen, 1986; Reynolds and Groves, 2000). Also, many agricultural workers die on the scene as a result of being crushed (Meiers and Baerg, 2001).

The Kentucky FACE program conducts surveillance of all work-related deaths and performs on-site investigations of worker deaths involving machinery, highway work zones, youths, and immigrant workers, as recommended by the National Institute for Occupational Safety and Health (NIOSH). In addition, Kentucky conducts on-site investigations of agricultural occupational fatalities and self-employed worker deaths because of the high fatality rates in these industries and occupations. Information from surveillance data and on-site investigations is used to produce fatality reports, newsletters, and hazard alerts for dissemination to employers in similar industries and occupations for injury prevention purposes.

Fatality investigations include information on the circumstances involved in the pre-event, event, and post-event phases of the fatal incident, based on Haddon's matrix[2]. Haddon (1969) developed this framework to examine the contribution of the

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host, the agent, the physical environment, and the social–cultural environment at each phase of an injury incident. The elements of a FACE investigation include the identification of contributing factors such as the initiating action, worker factors, work environment factors, pre-event activities, activities during the fatal event, and post-event activities. Since 1994, Kentucky FACE program personnel have completed and distributed 127 fatality reports, 69 of which involved tractors.

Basic surveillance data is encoded for every occupational fatality case and entered in the FACE database. However, complete information on the circumstances of the occupational fatality is only available in the narrative investigation reports, and they contain no coded variables. Comprehensive information that includes both basic coded data as well as narrative data provides a more complete evaluation of the injury event (Jones and Lyons, 2003; Lincoln et al., 2004; Lipscomb et al., 2004).

This study had two objectives: (1) to characterize and quantify investigative report text data elements beyond what is contained in FACE surveillance data and (2) to identify new risk factors for being declared "dead at the scene" or being "crushed" in a tractor fatality, in contrast with tractor fatalities where the victim was not declared "dead at the scene" or was not "crushed", respectively, using investigative narrative text reports. FACE surveillance data indicate that 49% of all tractor-related fatalities involve a tractor overturn. We, therefore, hypothesized that most of the victims in the tractor fatality reports involving tractor overturns without a rollover protective structure (ROPS) would have been crushed and died at the scene and would not have been transported to the hospital alive to receive medical treatment.

2. Materials and methods

2.1. Report development

When the FACE evaluator receives initial notification of a worker death, basic information is obtained: victim name, type of fatality, time and location of incident, name, address, employer contact and phone number, name(s) of witness(s), and a short synopsis of the incident.

Following the confirmation of a reported fatal injury as work-related, a site investigation is initiated if the worker death occurred in the agricultural industry or in the other NIOSH-priority target areas. The goal of FACE site investigations is to produce narrative reports that thoroughly describe organizational, behavioral, and environmental factors that contributed to a specific occupational fatality. Analyses of these factors in the pre-event, event, and post-event phases lead to recommendations for prevention of future similar-nature incidents (Higgins et al., 2001).

Next, the FACE evaluator contacts the county coroner and the site visit is scheduled. The evaluator conducts interviews with emergency medical services (EMS) personnel, witnesses, coworkers, family members, personnel managers, human resource directors, safety officers, state police, manufacturers, and others. Field notes and digital pictures are taken. Names and phone numbers are collected from all those interviewed in case follow-up information is needed. Multiple source documents such as Occupational Safety and Health Administration (OSHA), medical examiner, toxicology, and police reports are examined, and manufacturers, distributors, engineers, organizations, associations, and governmental agencies are consulted to develop recommendations for prevention. These recommendations are aimed at increasing knowledge, changing work practices, and changing behaviors and attitudes of employers and employees. A draft report is written that includes the organizational, behavioral, and environmental factors that contributed to the fatal incident using the NIOSH Division of Safety Research (DSR)-recommended FACE report format.

2.2. Study sample

The study sample included all occupational farm fatality reports where a tractor was involved ($n = 69$) produced by the FACE program from 1994 to 2004 inclusive. Three other tractor reports were not included in the analysis because they were partial reports (interviews could not be completed with all witnesses, family, or company representatives), and did not contain all of the required elements according to the NIOSH-recommended FACE report format outline.

2.3. Narrative text analysis

The principal categories for narrative text analysis were established based on customized coding developed to elucidate the circumstances related to farm tractor fatalities:

1. Conditions surrounding the fatal incident: (a) environmental factors, (b) human factors, (c) mechanical factors, (d) equipment type, (e) location, (f) farm production type, (g) weather, (h) work experience, (i) pre-existing health condition, and (j) decedent's employment classification.
2. Pre-event activities: (a) initiating action.
3. Activities during event: (a) injury event (due to energy source or agent) and (b) outcome.
4. Post-event activities: (a) medical response, (b) cause of death, and (c) intervention.

A narrative text search was performed with NVivo version 2.0 (QSR International, Dorcaster, Vic., Australia), a software program that analyses detailed text. Codes based on the predetermined categories listed above were created in NVivo to guide the text search. Each narrative text variable or string was then searched and coded in accordance with the established categories. Frequencies of each code were determined for each narrative text variable. Different forms of the narrative text phrase were searched for each variable. For example, the acronym "ROPS" was first searched. Then each report was scanned for the use of the acronym "ROPS" in the context of the report. Examples of text phrases containing the acronym "ROPS" were "no ROPS" and "lack of ROPS". Only the absence of a ROPS was recorded for the ROPS variable.

2.4. Statistical analysis

Frequencies and percentages were calculated for all coded data. A bivariate analysis was performed to identify exposure variables associated with being either "crushed" or declared "dead at the scene". The significance of the association was determined based on the calculated OR and 95% CI using the Mantel–Haenszel method (Stokes et al., 2000). The variables with a significant association of either being "crushed" or being declared "dead at scene" were included in multivariate logistic regression analyses modeling the probability for the corresponding outcomes. The final logistic regression models were built with SAS® proc logistic with step-wise selection. The significant risk factors were reported with their odds ratios and corresponding 95% Wald confidence limits. The Hosmer–Lemeshow goodness-of-fit test was used to assess the model fit.

3. Results

3.1. Worker and worker environment conditions

Lack of tractor maintenance was identified as a human factor in 10% of the agricultural tractor fatality reports and inexperience was mentioned in 9% of the reports (Table 1). Pre-existing health conditions were rarely cited: only four reports mentioned a heart condition, only two reports mentioned diabetes, and only one report mentioned the victim as being overweight. Only 19% of the fatality reports described the victim as being a "full-time" farmer: 23% were described as being "retired" and 22% were described as "part-time" farmers. The mean age of the victims was 52 ± 15 years (data not shown), ranging from 16 to 86 years.

Frequencies for work environment factors contributing to agricultural tractor fatalities are shown in Table 2. Almost half of the fatally injured persons were not wearing seat belts when the fatal incidents occurred and over half of the tractors were not equipped with a ROPS. One-quarter of all the tractors had a rotary mower attached. Environmental factors such as operating the tractor at dusk, on eroded terrain or with poor visibility were infrequent. As might be expected, warm weather was mentioned in 23% of the reports; muddy terrain, rainy, wet, and sunny weather were each mentioned in 17% each of the reports. Cattle were raised on the 36% of the farms and tobacco on 32% of the farms. Over half of all incidents occurred on a slope, hill, gulley, ravine, or embankment.

Table 1
Worker factors identified in tractor fatality reports ($n = 69$), 1994–2004

Worker factors	Text phrase	No. of reports coded (%)
(A) Human	Lack of "maintenance"	7 (10)
	"Lack of safety training", "no safety training"	6 (9)
	Loose-fitting "clothing"	4 (6)
(B) Work experience	"No experience", "novice", "unfamiliar" (with equipment or task), "no formal training"	6 (9)
	"Experienced"	4 (6)
	Experienced "close call" or "previous incident"	4 (6)
(C) Pre-existing health condition	"Heart" condition	4 (6)
	"Diabetes"	2 (3)
	"Depression"	2 (3)
	"Overweight"	1 (1)
(D) Employment classification	"Retired"	16 (23)
	"Part-time"	15 (22)
	"Full-time"	13 (19)

3.2. Pre-event, event, and post-event activities

Regarding pre-event factors, almost one-quarter of the victims were mowing when the fatal incident occurred (Table 3). Seventeen percent of pre-event actions by the victims were described as "tractor began to slide". The most frequent (54%) fatal injury event cited was an overturn or rollover and 12%

Table 2
Work environment factors identified in tractor fatality reports ($n = 69$), 1994–2004

Work environment factors	Text phrase	No. of reports coded (%)
(A) Mechanical factors	No "seat belt"	34 (49)
	Faulty "brakes"	9 (13)
	Faulty "clutch"	6 (9)
(B) Environmental factors	Lack of "visibility"	3 (4)
	Operating equipment at "dusk"	2 (3)
	Operated tractor on "eroded" terrain	2 (3)
(C) Tractor equipment	Lack of "ROPS"	36 (52)
	"Bush hog", rotary mower"	17 (25)
	Lack of "counterweights", counterweight"	14 (20)
	"Bucket", "front-end loader", "loader"	9 (13)
	"Trailer" or "wagon"	9 (13)
	"Auger" or "plow"	5 (7)
(D) Incident location	"Embankment", ravine", "gulley", "hill", "slope"	38 (55)
	Paved "road", "black top", "asphalt", "public highway"	8 (12)
	"Gravel" road, "dirt" road	7 (10)
(E) Type of farm	"Cattle"	25 (36)
	"Tobacco"	22 (32)
	"Hay"	14 (20)
	"Corn"	6 (9)
(F) Weather	"Warm"	16 (23)
	"Sun", "sunny"	12 (17)
	"Muddy", "rain", "slick", "wet"	12 (17)
	"Dry"	9 (13)
	"Cool"	6 (9)

Table 3
Activities identified in tractor fatality reports ($n = 69$), 1994–2004

Text phrase	No. of reports coded (%)
Pre-event activities	
(A) Initiating action	
"Mowing" "mow"	16 (23)
"Slid", "sliding", "slide"	12 (17)
"Reversing", "backed up", "backward"	9 (13)
"Baling", "baled"	5 (7)
"Braking", "braked"	2 (3)
Activities during event	
(A) Injury event	
"Flipped", "overturn" "rollover", "roll over"	37 (54)
"Fall", "fell"	8 (12)
"Entangled", "entangle"	7 (10)
"Jumped", "jump"	4 (6)
(B) Outcome	
"Pinned", "pinning", "trapped"	19 (28)
"Thrown", "threw", "throw"	12 (17)
Post-event activities	
(A) Emergency medical response	
"Coroner"	51 (74)
"Emergency medical services (EMS)"	44 (64)
"Police", "sheriff", "deputy"	30 (43)
"Rescue"	14 (20)
"Fire department (Fire)"	11 (16)
(B) Medical intervention	
"Dead at the scene"	19 (28)
"CPR"	4 (6)
(C) Cause of death	
"Crushing", "asphyxiation"	22 (32)
"Head", "skull"	14 (20)
"Drown", "drowned"	1 (1)

of the victims jumped from the tractor. The fatal injury was caused by being pinned by the tractor for 28% of the cases and being thrown from the tractor in 17% of the cases. When post-event activity search terms were tabulated, the coroner was called to the scene in three-quarters of the fatal incidents and emergency medical services in a little over one-half of the fatal incidents. Twenty-eight percent of the victims were declared "dead at the scene". When the cause of death was examined for each victim in the reports, almost one-third of the victims died of crushing injuries and one-fifth of the victims died of head injuries.

3.3. Statistical analyses

Univariate and multivariate logistic regressions were performed on the risk factors identified in the narrative data to analyze the potential risk factors for either being declared "dead at the scene" or being "crushed" by the tractor. The significant univariate-independent variables included in the "crushed" multivariate analysis were lack of tractor maintenance, lack of tractor brakes or clutch, lack of seat belt, the lack of a rollover protective structure (ROPS), lack of tractor counterweights, overturning the tractor, and driving in a sloped location. The presence of a bucket on the tractor, muddy weather, and being thrown from the tractor were the significant univariate variables included in the "dead at the scene" multivariate analysis. All but one of the deaths was male. Age was not significant and was dropped from the final models.

Table 4
Univariate and multivariate logistic regression analysis of potential factors for being declared "dead at the scene" ($n = 69$)

Risk factor	No. of reports	Odds ratio	95% CI
Univariate analysis			
(A) Tractor equipment			
Bucket	9	7.2	1.6–32.9
None	60	1.0	
(B) Weather			
Muddy	12	5.3	1.4–19.5
Other	57	1.0	
(C) Outcome			
Thrown	12	5.3	1.4–19.5
Other	57	1.0	

Risk factor	Odds ratio	95% CI	*p*-Value
Multivariate analysis			
(A) Tractor equipment			
Bucket	9.1	1.7–51.1	0.01
No equipment	1.0		
(B) Weather			
Muddy	5.8	1.3–26.5	0.02
Other	1.0		
(C) Outcome			
Thrown	8.7	2.0–38.8	0.00
Other	1.0		

3.3.1. "Dead at the scene" injury outcome

Three variables were found to be associated with the "dead at the scene" injury outcome and were included in the forward stepwise selection logistic regression model: operation of a tractor with a bucket, muddy terrain, and being thrown from the tractor. The crude and adjusted odds ratios for a "dead at the scene" outcome in the final model are shown in Table 4. There was no interaction between the predictor variables in this model; therefore, the contribution of each variable was independent of the others. Tractor drivers who were operating a tractor with an attached bucket were 9.1 times as likely as those with no attached equipment to be declared "dead at the scene". When being thrown from the tractor was examined as a contributing factor, the odds of incurring a "dead at the scene" outcome were increased 8.7 times. Muddy terrain increased the likelihood of being "dead at the scene" 5.8 times.

No significant interactions were found. The generalized R^2 proposed by Cox and Snell was 0.3. The model correctly classified 80% of the cases (area under ROC = 0.8) (Hosmer and Lemeshow, 2000). The Hosmer–Lemeshow goodness-of-fit test gave a p-value of 0.7 indicating satisfactory model fit.

3.3.2. Fatal "crushed" injury outcome

Seven contributing factors were significantly associated with a fatal "crushed" injury outcome (Table 5) in the initial uni-

Table 5
Univariate logistic regression analysis of potential factors for being "crushed" ($n = 69$)

Risk factor	No. of reports	Odds ratio	95% CI
Univariate analysis			
Human factor			
(A) Lack of maintenance	7	6.6	1.2–37.4
Other	62	1.0	
Mechanical factor			
(A) Lack of brakes/clutch	12	6.1	1.6–23.5
Other	57	1.0	
(B) Lack of seat belt	34	6.0	1.9–19.2
Other	35	1.0	
Tractor equipment			
(A) Lack of ROPS	36	11.2	2.9–43.3
Other	33	1.0	
(B) Lack of counterweights	14	5.8	1.7–20.5
Other	55	1.0	
Injury event			
(A) Overturn (rollover)	36	19.4	4.0–93.5
Other	33	1.0	
Incident location			
(A) Embankment/slope/gulley	38	16.1	3.4–77.3
Other	31	1.0	

Risk factor	Odds ratio	95% CI	p-Value
Multivariate analysis			
(A) Incident location			
Embankment/slope/gulley	6.2	1.1–34.6	0.04
Other	1.0		
(B) Injury event			
Rollover	8.8	1.6–48.0	0.01
Other	1.0		

variate analysis. These included the lack of tractor maintenance, the lack of brakes, or a clutch as well as the lack of a seat belt on the tractor, the lack of an attached ROPS, the lack of tractor counterweights for tractor balance, overturning the tractor, and operating the tractor on an embankment or a slope. These variables were included in the final forward step-wise selection regression analysis model. Only two factors were determined to be significantly associated with a fatal "crushed" outcome in the multivariate logistic regression analysis. Overturning/rolling over of the tractor increased the likelihood of being "crushed" by the tractor by 8.8 times. Also, tractor drivers who operated the tractor on a slope were more likely than those on level ground to suffer a fatal "crushing" injury (OR = 8.4, 95% CI = 1.6–48.0). The model had a generalized R^2 of 0.3, area under ROC = .8, and a Hosmer–Lemeshow goodness-of-fit p-value of 0.4.

4. Discussion

While a number of studies have analyzed narrative text from various datasets to identify factors contributing to occupational injuries, few have analyzed comprehensive narrative-based injury fatality reports. The present study identified and quantified the narrative-based injury elements contributing to tractor fatalities based on the FACE standardized format of a fatal injury report that incorporates Haddon's matrix. Employers, co-workers, family, and similar industry employers were interviewed and consulted for the development of the final investigative report. Each interviewee was asked about the pre-event, event, and post-event activities. The FACE evaluator determined how the host, the agent, the physical environment, and the social–cultural environment contributed to each phase of the tractor-related fatality.

Farm injuries have been analyzed using logistic regression models in a number of regional telephone surveillance studies that examined primarily pre-event risk factors. Among New York farmers, the risk factors significantly associated with farm injuries were older age, joint trouble and hearing loss, working long hours, being the farm owner/operator and operating a farm with larger gross sales (Hwang et al., 2001). In the upper Midwest, the number of hours worked, operating an auger, growing field crops and male gender were found to increase the risk of farm machine-related injuries in a study that did not include tractors (Gerberich et al., 1998). In central Wisconsin, the number of hours worked, non-resident worker status, and cattle-raising increased the risk of machine-related injuries, including those related to tractors (Layde et al., 1995). In previous studies examining only tractor-specific injuries, mounting and dismounting the tractor (Lee et al., 1996), gender, age and a previous injury history (Carlson et al., 2005), and the lack of a ROPS and seat belt (Kelsey et al., 1996; Browning et al., 1995) were the factors most frequently associated with an increased risk for an injury.

We found that a tractor rollover and operating a tractor on a slope increased the odds of being crushed by the tractor by factors of 8.8 and 6.2, respectively. It has been estimated that nationally, half of tractors are not equipped with a ROPS; in Kentucky, only 29% of tractors have ROPS and half of all farming deaths are due to tractor rollovers (Cole, 2003). Part of the reason for the high number of rollovers may be the steep, hilly terrain in the eastern half of Kentucky (Browning et al., 1995). Additionally, buckets (front-end loaders) attached to the tractor increased the odds of being declared "dead at the scene" by a factor of 9.1. Front-end loaders are used on farms to transport feed, manure, dirt, and other materials. When a heavy load is raised too high, the tractor's center of gravity and stability are altered, increasing the risk of rollovers.

In a study of Georgia farm tractor fatalities using death certificates, 75% of the fatalities were due to tractor rollovers (Goodman et al., 1985). The authors determined that 82.6% of the victims died from a crushing injury. In our study using narrative text analysis from FACE reports, 32% of the victims were described as having crushing injuries. The difference between these percentages may be due to variation in reporting of a "crushing injury" by coroners in different states. In our study, coroners were on the scene in 74% of the cases, whereas the Georgia study does not report whether coroners determined the cause of death listed on the death certificate.

Beef cattle and tobacco, which are the predominant Kentucky agricultural products, were also the most common products raised on the farms where the tractor fatalities occurred in our study. In a previous study of older Kentuckian farmers

(Browning et al., 1998), farms that raised beef cattle either alone or in combination with tobacco were at a significantly higher risk for farm injury. We did not find an elevated risk of being crushed or being declared dead at the scene associated with the type of farm. Browning et al. (1998) also found an elevated risk of injury for full-time farmers compared to part-time farmers. In our fatality reports, 22% of decedents were part-time farmers, whereas part-time workers accounted for 49% of the farmers interviewed in Browning's study. We examined only fatal tractor injuries whereas Browning et al. (1998) examined nonfatal farming injuries in older farmers.

Narrative text coding and analysis using keywords has been shown to be a sensitive and specific method for classifying injury information (Jones and Lyons, 2003; Wellman et al., 2004; Williamson et al., 2001). Using the FACE surveillance dataset alone, the frequency of all tractor-related fatalities involving a tractor overturn was determined to be 49%. Using the text analysis approach on the investigative reports, we determined that 54% of the tractor fatalities involved a tractor overturn. This is a good indication that our narrative search by keywords and text strings has a high degree of sensitivity.

Narrative text coding based on the Haddon matrix and the hazard scenario frameworks has been shown to provide a comprehensive analysis of the factors contributing to injuries in specific worker populations (Lincoln et al., 2004; Lipscomb et al., 2004; Bondy et al., 2005; Lombardi et al., 2005). Bondy et al. (2005) suggested that the use of narrative analysis of reports based on Haddon's matrix provided more comprehensive information on the human, organizational, and environmental factors contributing to worker injuries. Bondy et al. (2005) thought that detailed interview reports like the ones analyzed in this study would provide many data elements with few missing data variables.

FACE fatality investigation reports consist of an examination of the geographic location of the fatality, as well as interviews of witnesses, family, employers, coroners, and others. These added resources provide a more comprehensive analysis of the pre-event, event, and post-event phases of the fatality and targeted recommendations for the prevention of fatalities of a similar nature than coroner or police reports alone. For example, coroner reports may not include information on the type of terrain or the use of a bucket. Both of these elements were identified as risk factors for being declared dead at the scene through our narrative text analysis of the FACE fatality investigation report.

Coded surveillance data alone may not provide sufficient information for the development of workplace interventions. Narrative text provides supplemental information on additional unknown risk factors (Lincoln et al., 2004). For example, operating a tractor with an attached bucket increases the odds of a fatal tractor incident in which the victim is declared "dead at the scene". There was no coding of tractor attachments within the FACE dataset that would have alerted FACE personnel to a problem with buckets on tractors. Additionally, muddy conditions contributed to being declared "dead at the scene". There is no coded variable within the FACE dataset for the condition of terrain or weather on the day of the fatal incident. With these newly identified risk factors, coded data variables for tractor attachments and weather can now be added to the FACE dataset for tracking. Narrative information, therefore, enriches the coded surveillance dataset. Additionally, the results of this study identify risk factors that need to be investigated further and emphasized in education interventions.

Limitations of the study include the author's identification of text strings and keywords used to analyze the text. It is possible that other risk factors may not have been discovered with the narrative text analysis. However, performing a word search on every single word (excluding articles such as "the" and "a") within the text of all the reports is not feasible within a reasonable time frame. Another limitation of this study is the possible lack of specificity of the text data (Lombardi et al., 2005). The coding of specific words might be lost due to misspelling, truncation, or fragmentation. Finally, the small sample size in this study means that important scenarios could have been missed by the researchers because certain factors did not have the statistical power to achieve significance.

5. Conclusions

This study contributes to the body of evidence regarding tractor fatalities by using FACE reports that include Haddon matrix variables to identify additional risk factors for being either declared "dead at the scene" or being "crushed" by a tractor. This narrative text analysis supports the need for continued development of both engineering and educational interventions for the prevention of farm injuries.

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