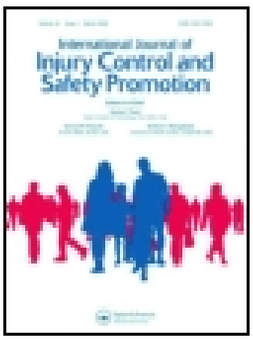

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ORIGINAL PAPER

Fire and flame related events with multiple occupational injury fatalities in the United States, 1980–1995

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Abstract

The National Traumatic Occupational Fatalities surveillance system recorded 1587 fire and flame related occupational fatalities among the civilian workforce in the United States between 1980 and 1995. Of these fatalities, 433 resulted from 127 incidents that involved two or more victims. For purposes of this study, these victims were categorized into one of three cause-of-death classifications: burns, inhalation or other traumatic injury. The classification 'Burns' accounted for 232 or just over one-half of the fatalities and an additional 172 cases were coded as inhalation. Other traumatic injury was named as the cause of death for another 23 fatalities or five percent of the multiple victims. The cause of death for the remaining six fatalities could not be determined from the death certificates. This study revealed the similarities and disparities of the demographic and employment characteristics associated with these three cause-of-death classifications.

Keywords: Fatal injuries; occupational trauma; fires; burns; inhalation.

Introduction

A fire department responded to a fire in the United States every 16 seconds during 1995.[1] These fires resulted in over 4500 civilian deaths and nearly 26,000 civilian injuries. The National Safety Council estimated that direct property damage from U.S. fires exceeded $8 billion, of which nearly one-third was workplace damage. During 1995, the National Traumatic Occupational Fatalities (NTOF) surveillance system maintained by the National Institute for Occupational Safety and Health (NIOSH) identified 69 occupational fatalities resulting from fire and flame related events. Property damage, lost wages, and other direct expenses for these fatalities cost society over $55 million.[2]

These losses are even more alarming considering that a major destructive fire can break out in a U.S. workplace at any moment. As an example, one of the most devastating fires recorded in modern U.S. history was the 1911 fire that destroyed the Triangle Shirtwaist Factory in New York City and killed 150 working women and young girls.[3] More recently, the 1991 workplace fire at Imperial Foods Processing Plant in Hamlet, North Carolina claimed 25 lives. Both of these fires might have been prevented if safety precautions such as accessible fire exits and properly functioning extinguishing systems had been present.[3,4] To further illustrate the continued risk of fatality, six fire fighters lost their lives in 1999 while fighting a fire at an abandoned warehouse in Worcester, Massachusetts.

Because of tragic events such as these, fire-related injuries and deaths have long been a research topic, but traditional emphasis has been on treatment rather than prevention efforts, or focused primarily on burns in the general population while neglecting those that are work-related.[5] Prior research has described the demographic and employment characteristics of the decedents, and identified circumstances of occupational fire and flame related fatal injury for events involving both single and multiple victims.[6] This prior work discovered that patterns within multiple victim events were not markedly different from single victim events for those variables analyzed. The analysis suggested that conducting

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similar studies using other variables, particularly the nature of injury, might reveal differences that would be helpful in identifying prevention efforts.

Adding to prior research, this study examined fire and flame related events as recorded in NTOF from 1980 to 1995 involving multiple occupational injury fatalities, focusing on the nature of injury. To identify common risk factors, and to generate hypotheses for future research, this study investigated the magnitude of the problem, the nature of injury, and worker characteristics. This study also presents demographic and employment characteristics of multiple-victim fatalities within each of three nature-of-injury classifications: burns, inhalation, and other traumatic injury.

Materials and methods

Data on occupational injury deaths used in this analysis were taken from the NTOF surveillance system for the years 1980 through 1995. This census maintained by NIOSH collects death certificates from the vital statistics reporting units in the 50 States, New York City, and the District of Columbia on an annual basis. This system consists of all U.S. death certificates with a positive response to the 'Injury at Work' box. These records are collected for workers 16 years of age or older for whom an external cause of death was an injury according to the International Classification of Diseases, 9th Edition (ICD-9), codes E800-E999.[7] The data for this study are for the civilian workforce.

The limitations of death certificates used to ascertain work-related fatality information have been described elsewhere.[8–12] Most relevant to this study is a lack of specificity in employment information on the death certificate.[8,9] A further limitation for part of the study period is the absence of national guidelines for completion of the 'Injury at Work' item on the death certificate at the time of data collection.[9,10] Operational guidelines for the determination of work injuries were implemented nationwide in 1993. Despite these limitations, death certificates have been shown to identify, on average, 80% of work-related fatalities nationally.[9,11] Therefore, counts presented in this paper should be considered the minimum number of fire and flame-related fatalities that occurred during the study period.

Cases were selected from NTOF only if the identified external cause of death was 'Accidents Caused by Fire and Flames,' ICD-9 codes E890-E899. This major category includes asphyxia or poisoning due to conflagration or ignition, burning by fire, and secondary fires resulting from explosions. Conflagrations in private dwellings, buildings, or structures; forest, grass, or brush fires; and fires caused by ignition of clothing or highly flammable material are included in these E-codes. However, fire in or on operating machinery (E919), fire in or on non-stationary transport vehicles (E800–848), and arson (E968 and E958) are excluded. In addition, these codes do not account for accidents caused by explosive material, which includes flash burns and other injuries resulting from explosion of explosive material (E923) or injuries incurred from fires where it was not known if the fire was intentional or accidental (E988).

Employment information was coded from the 'usual' industry and occupation entries on the death certificate. Certain occupations or industries may be under-represented due to this collection definition. For example, an automobile mechanic who volunteers as a firefighter should be classified as a mechanic regardless of the task being performed at the time of death. The 1987 Standard Industrial Classification (SIC) system was used to group industry into 11 division-level categories.[13] Occupation was categorized into 11 major divisions according to the 1980 and 1990 Bureau of the Census Occupational Classification System.[14]

For this investigation, a multiple-victim event was defined as a single incident involving two or more fatalities. Death certificates from the same state were subset by the victim's date of injury. An event was considered as a multiple-victim event if these certificates displayed the identical date of injury, hour of incident, and, when identified, firm name or address. The remaining certificates within this subset were evaluated based on all available information to ascertain if it was a multiple-victim event.

The multiple-victim event fatalities were classified into one of three nature-of-injury categories. 'Burns' was assigned if any of the narrative sections of the death certificate described the injury or condition using the word 'burn.' 'Burns' was also assigned if the narrative sections contained the terms 'charred,' 'incinerated,' 'conflagration,' 'thermal injury,' '2nd or 3rd degree' or 'tissue damage.' For the remaining cases, inhalation was chosen if the words 'smoke inhalation,' 'inhalation of super heated air/gas' or a combination of 'asphyxia' and 'smoke' appeared in any of the narrative sections. The category 'Other traumatic injury' included those cases that could not be categorized as burn or inhalation and for which the narrative sections included specific terms such as 'traumatic,' 'blast injury,' 'crushed' or 'traumatic injuries.' The unknown category was used only when no information was available concerning the injury or condition.

Average annual employment data used to calculate occupational fatality rates were obtained from Employment and Earnings, a publication of the Bureau of Labor Statistics.[15] Employment data from Employment and Earnings are based on the Current Population Survey (CPS), a monthly household survey of the civilian non-institutional population aged 16 years and older conducted by the Bureau of the Census.

Results

Multiple victims

During the 16-year period from 1980 to 1995, 1,587 workers lost their lives in incidents caused by fire and flames (Fig. 1). Of these, just over 25%, or 433, of the victims were involved in an incident with two or more fatalities. The proportion of

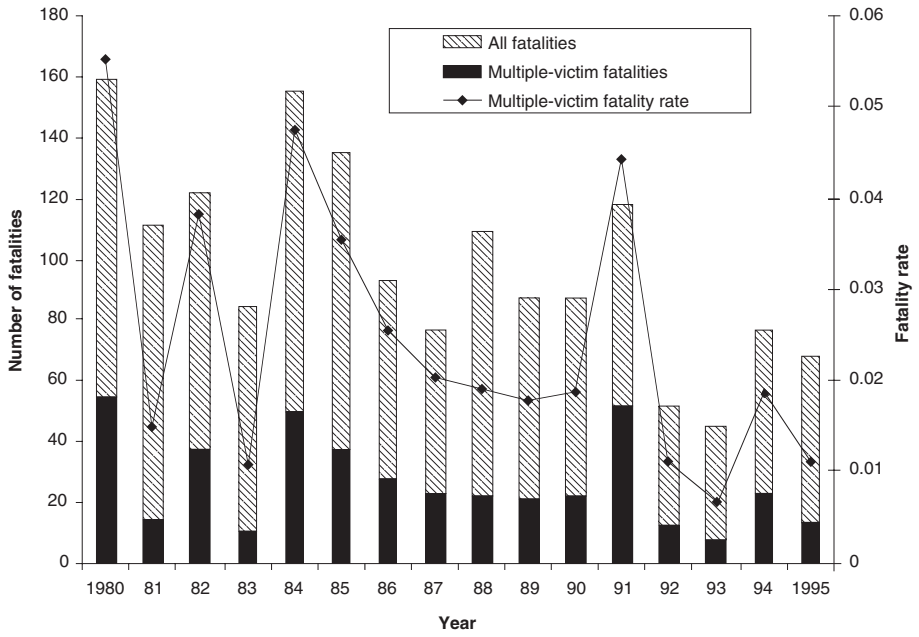

Figure 1. Number and rate of occupational fatalities due to fire and flames by year, 1980–1995.

all fire and flame related fatalities that were involved in multiple-victim events varied by year, ranging from a high of 44% in 1991 to a low of 13% in 1983. The number of fatalities per 100,000 workers also varied by year; the highest multiple-victim fatality rate was seen in 1980 and the lowest in 1993.

Incident characteristics

Ten percent of all occupational incidents caused by fire and flames involved two or more fatalities. Specifically, 127 incidents accounted for 433 fatalities. The average number of fatalities per incident was three, with a range of 2–26 fatalities in a single incident. Nearly 40% of multiple-victim incidents occurred in five states: California, Illinois, Louisiana, Pennsylvania, and Texas. By contrast, no multiple-victim event occurred in 16 states over the study period. Of the 127 incidents, 12.5% took five or more lives and six of these events involved 10 or more fatalities each. These six events took the lives of 102 victims in five states: Colorado, Illinois, Nevada, North Carolina and Utah.

Not all victims within a multiple-victim incident are categorized with the same nature of injury. Fifteen of the 127 incidents had a combination of burns and inhalation victims and another four incidents had victims categorized as burns and other traumatic injury. However, 70 or just over one-half of the incidents involved only burns victims, accounting for 203 fatalities. Fifteen of those burns victims were in a single multiple-victim event. An additional 31 incidents with 137 fatalities involved only inhalation victims. Three of these incidents accounted for nearly half, or 65, of the inhalation fatalities. There were five incidents with 11 fatalities, all categorized as 'Other traumatic injury.'

Similarly, not all victims within a multiple-victim incident are of the same sex or race. The decedents in 100 incidents were all male while only seven incidents consisted of all female victims. Two-thirds of the incidents involved only white victims while just over 5% of the incidents involved all black victims. Incidents with all hispanic victims accounted for 3% of all multiple-victim incidents.

Because there are many occupations within the same work environment and NTOF captures the usual occupation rather than the occupation at the time of death, a single incident could involve numerous occupations. Similarly, each incident does not necessarily have decedents from the same industry division. For example, a fire in a manufacturing facility could be responsible for the deaths of the machine operators working in the manufacturing industry, as well as sales workers from the wholesale-trade industry conducting business at that facility. Therefore, analysis by industry and occupation within these multiple-victim incidents was not conducted.

Fatality characteristics

Eighty-five percent or 362 of the multiple-victim-incident fatalities were males (Table 1). This frequency is just over five times as high as the number of female victims. However, the fatality rate for males was only four times as high as the fatality rate for females.

The highest number of fatalities occurred within the 25 to 34 year-old age group, accounting for just over one-third of all multiple-victim fatalities. This age group also experienced the highest fatality rate, nearly three-and-one-half times as high as the rate for the age group with the lowest fatality rate, victims under 19 years of age. The under-19

age group and the over-65 age group had the smallest number of fatalities, each having just over 2% of all multiple-victim fatalities.

Of the 433 multiple-victim fatalities, 338 or 78% were white and 62 or 14% were black. However, the fatality rate demonstrates a different risk pattern, with the rate for blacks being one-and-one-half times as high as the rate for whites.

Six states: California, Colorado, Illinois, Louisiana, North Carolina, and Utah, accounted for almost one-half of the fire-related multiple deaths during the study period. When fatality rates were examined, the highest rates per 100,000 workers were found in Colorado, Louisiana, Nevada, and Utah.

For approximately two-thirds of the multiple-victim event fatalities, E891 (Fires in buildings other than private dwellings) was listed as the external cause of death. Fires not in a building or structure (E892), such as forest or grass fires, accounted for the second largest number of multiple-victim incident deaths with 62 fatalities or 14% of the total.

Nearly 40% of the 433 fatalities resulting from a multiple-victim fire were employed in the manufacturing industry; this is over three-and-one-half times as high as any other single industry division (Table 2). Each of four industry divisions: public administration, mining, services, and construction, accounted for approximately 10% of multiple-victim fatalities. The mining industry experienced the highest fatality rate per 100,000 workers, a rate nearly six times as high as any other industry division.

One-fourth or 112 of the 433 multiple-victim fatalities listed precision production, craft, and repair as the usual occupation of the victim (Table 3). Only three other occupation groups: service; machine operators, assemblers, and inspectors; and handlers, equipment cleaners, helpers, and laborers each contributed over 10% of the total number of multiple-victim event fatalities. The highest multiple-victim fatality rate was experienced by those usually employed in a handlers, equipment cleaners, helpers, and laborers occupation. This rate was approximately 20 times as high as the lowest rate, which was experienced by those in administrative support, including clerical occupations.

The nature of injury for the majority of multiple-victim fatalities was classified as either burns or inhalation. The classification 'Burns' accounted for 232 or just over one-half of the fatalities, while an additional 172 cases were coded as inhalation. 'Other traumatic injury' was named as the nature of injury for another 23 fatalities or 5% of the multiple victims. The nature of injury for the remaining six fatalities could not be determined from the death certificate.

Table 1. Number of occupational multiple-victim fatalities due to fire and flames for nature of injury by sex, 1980–1995.

Sex	Total	Burns	Inhalation	Other traumatic injury
Total	433	232	172	23
Male	362	211	126	23
Female	71	21	46	0

Note: Because of unknown categories, the data may not sum to the totals.

Burns

As previously defined in this paper, the nature of injury was classified as 'Burns' if the death certificate described the injury using the word 'burn,' 'charred,' 'incinerated,' 'conflagration,' 'thermal injury,' '2nd or 3rd degree' or 'tissue damage.'

Table 2. Number of occupational multiple-victim fatalities due to fire and flames for nature of injury by industry division, 1980–1995.

Industry	Total	Burns	Inhalation	Other traumatic injury
All industries	433	232	172	23
Agriculture, forestry & fishing	18	5	12	–
Mining	43	15	28	0
Construction	39	30	9	0
Manufacturing	169	105	50	13
Transportation, communication, and other public utilities	25	11	8	–
Wholesale trade	13	9	4	0
Retail trade	17	8	9	0
Finance, insurance & real estate	3	0	3	0
Services	40	16	24	0
Public administration	47	23	19	5

The dashes indicate fewer than 3 fatalities.
Note: Because of unknown categories, the data may not sum to the totals.

Table 3. Number of occupational multiple-victim fatalities due to fire and flames for nature of injury by occupational group, 1980–1995.

Occupation	Total	Burns	Inhalation	Other traumatic injury
All occupations	433	232	172	23
Executive, administrative & managerial	32	10	16	4
Professional specialty	16	7	7	–
Technicians & related support	10	9	(1)	0
Sales	16	8	8	0
Clerical	11	8	–	0
Service	66	26	35	5
Farming, forestry & fishing	13	3	9	–
Precision production, craft & repair	112	69	41	–
Machine operators, assemblers & inspectors	58	27	25	5
Transportation & material moving	31	20	9	–
Handlers, equipment cleaners, helpers and laborers	55	36	17	–

The dashes indicate fewer than 3 fatalities.
Note: Because of unknown categories, the data may not sum to the totals.

Just over 90% of the 232 burns victims were male. When the male multiple victims were classified by nature of injury, 211 of 362 were burns (Table 1). Of the multiple victims who were female, 30%, or 21 of 71, were classified as 'Burns.'

Just over three-fourths of the fatalities categorized as 'Burns' were white and an additional 15% were black. The fatality rate for blacks with the nature of injury classified as 'Burns' was nearly twice as high as the rate for white burns victims. Distributing multiple fatalities by race revealed that 60% of the black victims died from burns. Similarly, of all white multiple victims, just over 50% died from burns (Fig. 2).

Just over-half of the 25–34 year-old age group was categorized as 'Burns.' Victims in the categories of less than 19 and over 65 years of age together accounted for less than 5% of the burns victims. Within the less than 19 and the 55–64 year-old multiple victims age groups, the majority, or 70% in each age group, were classified as 'Burns' (Fig. 3).

One-third or 79 of the 232 burns victims occurred in three states: California, Illinois, and Louisiana. In California, nearly 95% of the 31 multiple victims were categorized as 'Burns.' The District of Columbia, Louisiana, Nevada, and Utah had the highest fatality rates for cases involving victims classified as 'Burns.'

Fires in buildings other than private dwellings were identified as the external cause of death for 148 (64%) of 232 fatalities classified as 'Burns' (Fig. 4). No other external cause category accounted for more than 10% of the burns fatalities. Of those fatalities reporting the external cause as highly inflammable materials, nearly all or just over 90% were classified as 'Burns.'

Of the victims classified as 'Burns,' nearly 70% were usually employed in manufacturing, construction, or public administration, with 45% in the manufacturing industry alone (Table 2). By contrast, there were no burns victims within the finance, insurance, and real estate industry. The mining industry, while accounting for only 6% of the victims, experienced the highest fatality rate for burns. This rate was nearly four times as high as in the industry division with the next highest rate, public administration. Over 75% of all victims employed within construction and 60% of all victims employed within manufacturing were classified as 'Burns.'

Five of the 11 occupation groups accounted for over three-fourths of the burns victims (Table 3). Of these five occupation groups, precision, production, craft, and repair occupations accounted for the largest proportion or 30% of these fatalities. The highest fatality rate, experienced by those usually employed in handlers, equipment cleaners, helpers, and laborers occupations, was one-and-one-half times as high as the occupation group with the next highest rate. Of the multiple victims usually employed in technicians and related support occupations, 90% were classified as 'Burns.' By contrast, victims usually employed in the farming, forestry, and fishing occupations had less than one-fourth categorized as 'Burns.'

Inhalation

Inhalation was selected as the nature of injury when the selection criteria for 'Burns' were not met and 'smoke inhalation,' 'inhalation of super heated air/gas' or a combination of 'asphyxia' and 'smoke' was listed on the death certificate.

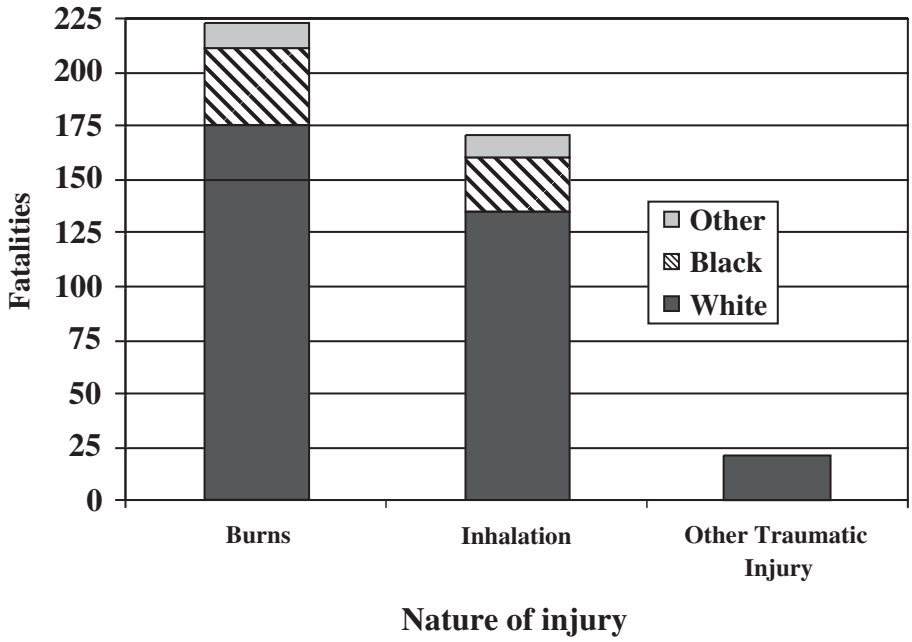

Figure 2. Number and distribution of occupational multiple-victim fatalities due to fire and flames for nature of injury by race, 1980–1995.

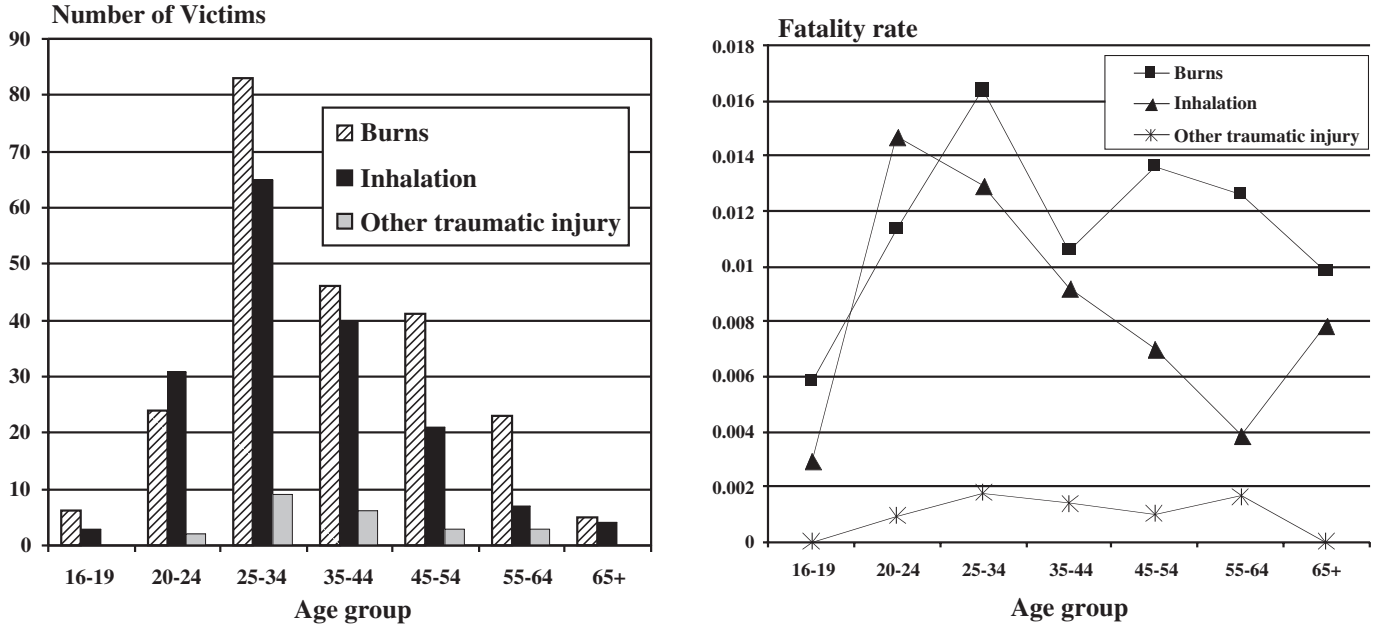

Figure 3. Number and rate of occupational multiple-victim fatalities due to fire and flames for nature of injury by age group, 1980–1995.

Of the 172 multiple-victim fatalities classified as due to inhalation, 73% were male and 27% were female (Table 1). In addition to having the highest frequency of victims, the fatality rate for males was more than double the fatality rate for females. Of the male multiple victims, the nature of injury was determined to be inhalation in 35%, while inhalation accounted for 65% of female multiple-victim fatalities.

Multiple-victim fatalities with the nature of injury coded as inhalation exhibited the same pattern as those classified as 'Burns': just over 75% white and 15% black (Fig. 2). When the nature of injury was inhalation, the black fatality rate was one-and-one-half times as high as the white fatality rate. Distributing multiple fatalities by race revealed that 40% of the black victims died from inhalation as did 40% of all white multiple victims.

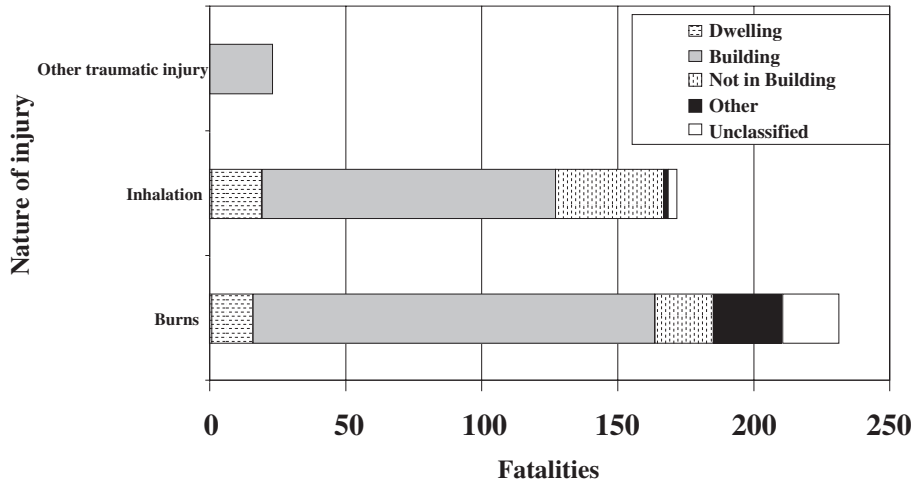

Figure 4. Number and distribution of occupational multiple-victim fatalities due to fire and flames for nature of injury by external cause of death, 1980–1995.

Sixty percent of the fatalities classified as inhalation were found in the age groups between 25 and 44 years old, with 40% within the 25–34 years-old category (Fig. 3). Victims in the less than 19 and over 65 years-old age groups together accounted for fewer than 5% of the inhalation victims. The distribution of age groups by nature of injury ranged from 53% of the victims classified as inhalation in the 20–24 years-old age group to 21% inhalation in the 55–64 years-old age group.

Only 30 states had fatalities for which the nature of injury was classified as inhalation. Colorado, North Carolina, and Utah accounted for 75, or just over 40%, of these victims. The number of fatalities from each of these states was nearly three times as high as any other state with inhalation victims. Of these 75 fatalities, Colorado had a single incident with 14 victims; North Carolina a single incident with 25 victims; and Utah a single incident with 26 victims. The highest rate for inhalation victims was found in Utah, where the fatality rate was nearly two-and-one-half times as high as in any other state. Not only did these three states account for the largest proportion of the multiple-victim inhalation fatalities, but the majority of multiple-victim fatalities within each state were also categorized as inhalation.

The external cause of death for nearly two-thirds of the victims classified as inhalation was fires in buildings other than private dwellings. Of the multiple-victim fatalities who died as a result of fires in buildings other than private dwellings, approximately one-third were categorized as inhalation. Conversely, the majority or 65% of the fatalities caused by fire that was not in a building or structure were inhalation victims (Fig. 4).

Manufacturing accounted for the largest number of inhalation fatalities, 30% of the 172 victims (Table 2). With 28 victims, mining accounted for the second largest number of inhalation fatalities. Mining also experienced the highest fatality rate for inhalation, with rates approaching 100 times as high as in the industry division with the lowest fatality rate. Two-thirds of those usually employed in the mining industry were categorized as inhalation fatalities. Although the number of victims usually employed in the fire, insurance, and real estate industry was small, all were classified with inhalation as the nature of injury.

Again, a small number of occupation groups accounted for a large proportion of the fatalities; 60% of the fatalities classified as inhalation were usually employed in only three of the 11 occupation groups (Table 3). Those usually employed in precision, production, craft, and repair occupations alone accounted for nearly one-fourth of these fatalities. As has been seen earlier, those usually employed in handlers, equipment cleaners, helpers, and laborers occupations experienced the highest fatality rate. The nature of injury was determined to be inhalation for 70% of the victims with the usual occupation of farming, forestry, and fishing.

Other traumatic injury

The category ‘Other traumatic injury’ included those cases that could not be categorized as ‘Burns’ or inhalation and for which the death certificate narratives included specific terms such as ‘traumatic,’ ‘blast injury,’ ‘traumatic injury’ or ‘electrocution.’ There were few fatalities in this category, 23 in total, so that generalizations should be made with caution. Additionally, the variability within many of the characteristics is considerably less than for the other two types of injury. For example, all of the ‘Other traumatic injury’ fatalities were victims of fires in buildings other than private dwellings (Fig. 4).

All victims categorized as ‘Other traumatic injury’ were male and 6% of the male multiple victims died from other traumatic injuries (Table 1). Similarly, nearly all, 21 of 23, of the ‘Other traumatic injury’ victims were white; two were

not classified (Fig. 2). Of all white multiple victims, just over 5% died from 'Other traumatic injuries.'

The pattern for age remains consistent with the other types of injury; the 25–34 years-old age group accounted for 40% of the 'Other traumatic injury' fatalities. However, there were no victims under age 19 or over age 65 (Fig. 3).

Nearly one-fourth of the 23 multiple victims that were categorized as 'Other traumatic injury' fatalities occurred in a single incident in Louisiana. Only eight other states reported fatalities from 'Other traumatic injury' during the study period. Although Delaware had only a single incident with victims of 'Other traumatic injury,' it experienced the highest rate for this category, three times as high as the next highest state. Of the multiple-victim fatalities occurring in Delaware, three-fourths were classified as 'Other traumatic injuries'.

Again, manufacturing accounted for the largest proportion of fatalities, well over half of the 'Other traumatic injury' deaths (Table 2). The remaining victims from this category were employed in three other industry divisions. The public administration industry experienced the highest rates for 'Other traumatic injury,' unlike any other type of injury.

The top two occupation groups, service and machine operators, assemblers, and inspectors, each accounted for just over 20% of the fatalities. The usual occupations for the remaining fatalities were found in six of the 11 occupation groups. Unlike the other types of injury, executive, administrative, and managerial occupations accounted for a sizable proportion of fatalities, 17% of the victims usually being employed in this category. Victims of 'Other traumatic injuries' accounted for less than 15% of the multiple-victim fatalities in each occupation group. The highest fatality rate was found in machine operators, assemblers, and inspectors, a rate one-and-a-half times that of handlers, equipment cleaners, helpers, and laborers, which experienced the next highest fatality rate.

Discussion

The results of this descriptive study further the understanding of occupational fire and flame related deaths by examining the nature of the injury associated with multiple-victim events. This analysis focused on the demographic and employment characteristics of the decedents as well as on the circumstances surrounding the event.

During the 16-year period studied, 433 workers lost their lives in 127 multiple-victim fire and flame related incidents. While the number of multiple fatalities varied substantially by year, the overall trend was declining. The mean number of multiple-victim fatalities was 34 for the first five years, 27 for the second five years, and 22 for the final six years of the study period. Furthermore, this declining pattern was displayed in all three types of injury. The mean number of burns deaths declined from 20 in the first five years to 11 in the last six; inhalation deaths declined from 12 to 11, and 'Other traumatic injury' deaths declined from three to one.

The fatality rate for multiple victims displayed the same yearly fluctuations and declining pattern as the number of fatalities; with a rate in the first five years that was nearly twice the rate in the final six years. The most dramatic decline was in the fatality rate for 'Other traumatic injury,' which was nearly three times as high in the first period as in the last. Burns was just over twice as high and inhalation was about one-and-a-quarter times as high.

The overall decline in fire and flame related fatalities can be attributed, in part, to the increased public focus on fire safety. As an example, in 1974 the United States Fire Administration (USFA) and its National Fire Academy were established to reduce life and economic losses due to fire. 'Since that time, through data collection, public education, research and training efforts, USFA has helped reduce fire deaths by at least half.[16]' More specifically, Demling attributes the decline in burns fatalities to improvements in medical treatment, multi-disciplinary research, and improved resuscitation techniques.[5] However, explanations for the decline in the other nature-of-injury categories are not as well documented in research and the parameters of this study were not sufficient to determine causal factors of their decline.

Based on the modal frequencies of each variable, a typical decedent of a multiple-victim incident was a white male between the ages of 25 and 34 who usually worked in a precision, production, craft and repair occupation and in the manufacturing industry. Victims of burns and inhalation had an identical profile. However, the profile for a victim of 'Other traumatic injury' differed slightly in that the usual occupation was among the service, machine operators, assemblers, and inspectors groups.

The nature of the work performed and the work processes within manufacturing industries contribute to their higher number of fire and flame fatalities.[17] These industries tend to have more conditions that may be hazardous, such as flammable materials, scrap wood and metal chips, oily rags, and other potential ignition sources.[1] Many of the precision, production, craft and repair occupations may also tend to work with more hazardous substances because they normally work in the manufacturing industry. Furthermore, manufacturing industries and precision, production, craft and repair occupations are male-dominated sectors, with 70 and 90 percent of the workforce being male, respectively.[6]

The profile based on the fatality rate differs based on a compilation of the highest rates across various categories. The typical decedent of a multiple-victim incident was a black male between the ages of 25 and 34 who usually worked as a handler, equipment cleaner, helper and laborer and in the mining industry. Decedents from burns and inhalation paralleled this profile, with the exception that the typical age for the inhalation classification was younger, between 20 and 24. Differing greatly from the general profile of a multiple-victim decedent, victims of an 'Other traumatic injury' were usually white males between the ages of 25 and 34 who

worked as a handler, equipment cleaner, helper and laborer and in the public administration industry.

Limited means of egress, extended travel distances required to reach safety, and dimly lighted exit routes may help explain the higher risk of those employed in the mining industry. Escape can also be hindered by poor visibility caused by dense smoke and associated poor air quality resulting in breathing difficulties.[18] The 1984 Wilberg mine fire near Salt Lake City, Utah, one of the six incidents in this study that had over 10 fatalities each, illustrates these points at the expense of 27 miners' lives.* The worst U.S. mine disaster in a decade occurred when a faulty air compressor was allowed to run unattended in a non-fireproofed area. Furthermore, investigation revealed that the mine was operating with an outdated firefighting and evacuation plan, with no fire suppression devices, and the longwall section was operating while a tunnel running off the tailgate of the longwall machine was blocked to human travel by a cave-in.[19]

During the 16-year period of this study, similarities among the victims of all three nature of injury classifications became apparent. The mean ages of workers for the three classifications were clustered as follows: burns 37 years, inhalation 35 years, and other traumatic injuries 38 years. This information, coupled with the age group data from the frequency and rate analysis, leads to the conclusion that age was not a determining factor in the nature of injury suffered.

Descriptions within all three types of injury indicated that fires in buildings other than private dwellings were the predominant external cause of death for multiple-victim incidents. This suggests that prevention of these deaths starts with more attention to building safety plans and practices as outlined in the employee emergency plans and fire prevention plans of 29 CfR 1910.38. According to Cravens,[3] 'when a fire occurs, the biggest single need . . . is the ability to respond quickly and confine the fire to manageable limits before it reaches the disaster stage,' reinforcing the need for fire and emergency plans.

Analysis of the incidents with the largest number of fatalities, those that resulted in 10 or more fatalities, further supports these conclusions. The 1982 NFPA investigation report[20] describes the contributing factors to the 1980 MGM Grand Hotel fire in Las Vegas, Nevada; these factors are also common among the largest multiple-victim fatality fires. Factors cited in the report include: no evidence that the building fire alarm system sounded; no sprinkler system in the affected area of the hotel; the ventilation system did not automatically shut down, which would have curtailed the spread of flames and smoke; evacuation was hampered by delayed notification of the occupants of the building; initial attempts by employees to extinguish the fire before notifying the fire department were unsuccessful; and there was an apparent lack of knowledge concerning exit strategies. Inoperable doors, such as doors bolted shut from the outside, and inadequate exits, such as a loading dock exit blocked by a tractor-trailer truck, were the chief causal factors of the loss of 25 lives in the 1991 workplace fire at the Imperial Foods Processing Plant in Hamlet, North Carolina.[21] The loss of life might have been prevented if safety precautions such as an emergency evacuation plan and properly functioning extinguishing systems had been present.[3,4] While not inside a building, a massive forest fire in Colorado claimed another 14 lives when smoke jumpers were enclosed by walls of fire and flame with no clear means of escape. Together, these three fire events claimed 49 lives, over 10% of all the multiple-victim event fatalities.

An explosion at a natural gas company in Garfield County, Colorado and an explosion at an oil refinery in Will County, Illinois are the remaining large multiple-victim fatality incidents. These two incidents accounted for 27 or just over 5% of the multiple-victim fatalities. Given the similarity in the incidents, one would expect the natures of the injuries to be similar if not identical. However, the fatalities at the oil refinery explosion were all classified as burns victims, while the natural gas company explosion did not involve any burns fatalities. To determine why this is the case, additional investigation into the circumstances of fire and flame related incidents accompanied by explosion is necessary.

The distribution of the external cause of death among burns, inhalation, and 'Other traumatic injury' points to the need for further refinement of study methods and sources to more accurately identify the circumstances surrounding these deaths. For example, the external cause of death for over 17% of 'Other traumatic injury' deaths was burning caused by conflagration. Similarly, burns victims were classified with an external cause of death of 'Other accidents resulting from conflagration such as collapse of or fall from burning building or structure.' These examples point to possible ambiguities present on the death certificates and lead to questions of their effectiveness as the sole source of information for research of this type. A formal investigation of the incident, conducted by agencies such as the Occupational Safety and Health Administration (OSHA), NIOSH, and NFPA, can provide specific details of the circumstances of the fatalities that will assist in formulating appropriate prevention recommendations.

Summary

This study examined multiple-victim workplace fatalities and the natures of the injuries that resulted in those deaths. Unfortunately, this approach did not yield more specific recommendations than those of OSHA and NFPA as outlined in prior work.[4,6,21] Further research, examining the detection and suppression systems employed, source of ignition, and type of work processes associated with the firm may enhance prevention and remediation recommendations. Consideration

* Only 26 Wilberg Mine fatalities were captured in the NTOF system. This may be due to the limitations associated with death certificates used to ascertain work-related fatality information.

should also be given to the use of different data sources, such as the NIOSH Fire Fighter Fatality Investigation and Prevention Program, the Federal Emergency Management National Fire Incident Reporting System, and the NFPA annual survey of fire incidents.

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